Piperaceae Crops-Technologies and Future Perspectives

iisr

INDIAN INSTITUTE OF SPICES RESEARCH

(Indian Council of Agricultural Research)

Calicut - 673012, Kerala

Compilation of Lead Papers & Extended Summaries
National Seminar on Piperaceae - Harnessing Agro-technologies for Accelerated Production of Economically Important *Piper* Species

Organised by
Indian Institute of Spices Research, Calicut
National Research Centre for Medicinal and Aromatic Plants, Anand

In collaboration with
Directorate of Arecanut and Spices Development, Calicut

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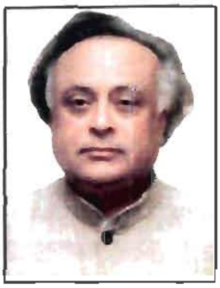
जयराम रमेश
JAIRAM RAMESH



वाणिज्य एवं विद्युत राज्य मंत्री
भारत सरकार
नई दिल्ली
MINISTER OF STATE FOR COMMERCE & POWER
GOVERNMENT OF INDIA
NEW DELHI

24th October, 2008

MESSAGE

Agriculture remains the backbone of the economy of our country. The majority of India's population lives in about 600,000 small villages and are engaged primarily in agriculture and related activities. Agriculture sector has been accorded highest priority in various policy announcements of Government of India as also of State Governments. The country has laudable achievements in terms of attaining self-sufficiency in food production, having surplus for export, which is marked by Green Revolution, White Revolution, Blue Revolution, Yellow Revolution and now Golden Revolution. The country achieved growth rates in agriculture during VIII, IX and X plan periods of 4.69%, 2.06% and 3.97% respectively. Agriculture contributes 11% to the export basket of the country.

Spices are important commercial crops widely grown in diverse agro-climatic conditions of the country. Today, India produces over 4 Million Tonnes of about 63 spices in different varieties - Major Spices, Seed Spices, Tree Spices, Exotic Spices and Herbal Spices valued at US $ 10 billion and they contribute 6% to the total agriculture export. During the year 2007-08 alone, India exported around 4.5 lakh MTs of spices valued at US $ 1.1 billion. The global spice community has been showing a greater trust in India's quality and competitiveness. In tune with the international food safety standards, more and more Indian farmers are turning to organic spice cultivation. National Standards have also been developed for organic produce. As a part of promoting the exports of spices and spice products, the Government has started regional-crop-specific Spices Parks across the country. Some of the Indian spices have been given Geographical Indication tags too, which will provide further impetus to the growth of this industry. The global spices industry is poised for a major leap in 21st century due to emerging advances in fortified and functional consumer food industry.

I am happy to note that Indian Institute of Spices Research, Kozhikode is organizing the *National Seminar on Piperaceae* with a theme of *"Harnessing Agro-Technologies for Accelerated Production of Economically Important Piper Species"* during 21-22 November, 2008 at Kozhikode. The survival of the Indian pepper economy depends on how we are able to withstand competitions from other producing countries and further to increase its productivity and improve quality. I am hopeful that the deliberations during the Seminar will lead to evolving fruitful results for formulating future course of action.

I wish the Seminar all the success.

(Jairam Ramesh)

प्रो. वी. एल. चोपड़ा
PROF. V.L. CHOPRA

सदस्य
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योजना भवन
नई दिल्ली - ११० ००१
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MESSAGE

The pepper family 'Piperaceae' is commercially important because it hosts two economically very important species of *Piper* namely *P. nigrum*, *P. betle* which are very much part of our life in India. This family includes many other economically important plants like betel, long peppers etc. Considerable research efforts have been put by IISR, NRCMAP, AICRP Spices, AICRP Betelvine, SAUs, NGOs, Spice Boar, DASD and Private entrepreneurs to tackle problems in production and utilization of black pepper and betel in India.

Sixteen black pepper and five betelvine varieties and several production and protection technologies have been evolved for large scale adoption. The development and extension agencies of ICAR, SAUs and line departments and other Ministries jointly should transfer these technologies for increased production and export.

The germplasm available at various institutions has to be registered and utilized for developing new varieties for better quality and yield with the help of conventional and modern biological tools.

It is a pleasure to note that National Seminar on Piperaceae is intending to address all these issues and formulate the future plan of action.

I wish the seminar a great success.

(V.L. CHOPRA)

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MESSAGE

I am happy to know that a National Seminar on Piperaceae with a theme of **"Harnessing Agro- Technologies for Accelerated Production of Economically Important *Piper* Species"** is being organized by Indian Institute of Spices Research and Directorate of Arecanut and Spices Development, Calicut during 21-22 November, 2008.

Black pepper, a 'King of Spices' has large share in domestic and international trade. Recognizing the importance of black pepper, a focused research attention has been provided at Indian Institute of Spices Research and through the All India Coordinated Research Project. The efforts in this direction have resulted in the development of new cultivars and region specific technologies. Besides generating technologies to improve the quality and productivity of black pepper we need to address issues of its processing and value addition aimed to consolidate our position as chief exporter and also to improve the farmers' income. It is hoped that the National Seminar will deliberate on the emerging issues and firm up strategies for their adoption.

I wish the Seminar a grand success.

(Mangala Rai)

Date : 7th November, 2008
New Delhi

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MESSAGE

I am immensely pleased to know that Indian Institute of Spices Research, Calicut, Kerala is organizing a National Seminar on Piperaceae during 21-22 November, 2008.

The family *Piperaceae,* the most archaic of pan-tropical flowering plants has provided important species for commercial production. Several *Piper* spp. From India, South Asia and Africa are of economic importance since they are used as spices and traditional medicines. Black pepper and betelvine are most important, which are cultivated widely. Focused attention provided has resulted in development of new cultivars and technologies. But there are many new challenges which require to be addressed utilizing science and technologies. I am sure, the conference will deliberate upon the issues to develop new direction of research on these crops.

I wish the Seminar a grand success and compliment the organizers for their efforts.

(H.P. Singh)

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BHUBANESWAR - 751003, ORISSA

Prof. D.P. Ray
Vice-Chancellor

October 15, 2008

MESSAGE

Spices and medicinal and aromatic plants are our strengths. Piperaceae crops like black pepper, betel and long pepper are the best suited to different cropping systems. There may be a yield plateau in traditional areas of cultivation of these crops. It is worth to explore the areas having similar ecological niche to introduce these crops for augmenting our yield and production through modern tools like GIS.

Black pepper is a rain fed crop; however, to save this perennial crop occasionally it is essential to adopt modern methods of irrigation practices to sustain its growth and yield from monsoon aberrations. There is a spread of virus through vegetative method of propagation of planting material and quality standards have to be established for these crops to assure quality materials.

I am sure this National Seminar being organized at the Indian Institute of Spices Research, Calicut with a focus on harnessing agro-technologies for accelerated production of economically important *Piper* species will vividly deliberate upon such issues and sort out useful recommendations to get over the problems confronting black pepper and betel vine production and marketing in India.

I wish the seminar all success.

(D. P. Ray)

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October 15, 2008

MESSAGE

Planned investment in horticulture in the last three plan period has been rewarding in terms of increased production, productivity, availability and export of horticultural produce, which has fuelled growth and private investment in this sector. Of late, horticulture has emerged as one of the options for diversification of Indian agriculture leading to improvement of nutritional security, creation of employment opportunity and enhancement of farm income.

The national goal of achieving 4 per cent growth rate in agriculture can only be achieved through the contribution in horticulture sector. The horticultural sector has grown at 6 per cent during the last plan period. The production and productivity of horticultural crops, especially spices, have increased many fold. Black pepper and betel, as horticultural crops, have been grown in India since time immemorial. There is demand for these crops in both domestic and international markets.

The National Seminar on *Piperaceae* being organized at Indian Institute of Spices Research, Calicut during 21st - 22nd November, 2008 is intended to deliberate on crop improvement, production, protection, processing and value addition of these crops. The seminar will provide a platform for farmer's interface wherein farmers and scientists will share their experience and wisdom on various issues. It is expected that the deliberations will provide a road map for further accelerated growth of the spice and betel industry of our country.

I wish the seminar and its organizers all success.

(S.K. Pattanayak)

CONTENTS

Black pepper – Research for future

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India was one of the leading producers, exporters and consumers of black pepper till nineties when Vietnam became the largest producer. In India, the area under pepper during the crop year 2005-06 crossed the 2.6 lakh ha mark with a production of 92.9 thousand tons. There is an increasing production trend in the past decade with increased productivity with year 2005-06 recording a highest productivity of 357 kg/ha. Even though the area under pepper has slightly reduced after 1998-1999, the production and productivity has increased substantially in further years up to 2006. But the productivity got reduced to 281 kg/ha during 2006-07 and the area has also come down to 2.46 lakh ha, primarily due to the price decline. Major cropped area is in India (2.25 lakh ha), Indonesia (1.88 lakh ha), Brazil (50,000 ha), Vietnam (48,800 ha) and Malaysia (13,000 ha) with a production of 62, 30, 39, 90 and 16.5 thousand tonnes in 2004, respectively (table 1).

Table 1. Production of black pepper, country wise (2000-2004)

Country	2000	2001	2002	2003	2004
Brazil	29,000	41,000	43,000	47,000	39,000
India	58,000	79,000	80,000	65,000	62,000
Indonesia	34,000	24,000	25,000	45,000	30,000
Malaysia	21,500	24,300	21,600	17,800	16,500
Sri Lanka	10,676	7,841	12,600	12,660	12,820
Vietnam	45,000	56,000	75,000	80,500	90,000
Thailand	6,535	8,820	9,960	9,500	9,500
Madagascar	1,500	3,375	2,500	2,500	2,500
Others	2,000	2,500	3,000	3,500	4,659
Total	208,211	246,836	272,660	283,460	266,979

(Source: www.ipcnet.org)

In view of the high density planting and more intensive cultivation, productivity of pepper in Thailand is the highest (3400 kg ha^{-1}) followed by Vietnam (1700 kg ha^{-1}). In India, the average productivity of pepper/vine is highest (around one kg) in Karnataka and lowest (around 0.6 kg) in Kerala. The estimated yield/vine in the tea estates is 3.3 kg. Since there is a vast difference between the recorded yield and present level of national productivity, there is enough potential to increase productivity in the country by filling the yield gaps. But, the productivity in India in terms of the yield/vine is comparable to any other pepper producing country in the world. Studies carried out by the Centre for Development Studies indicated that the average population of vines/ha is around 300 with only two thirds of the vines in bearing condition. As against this, the production system in other countries except that of Sri Lanka (to a lesser extent in Indonesia) is monocrop with population ranging from 1800 to 2200/ha. The productivity per vine in these conditions will be same as that of India.

Research on black pepper is carried out in India at Indian Institute of Spices Research (IISR), Calicut besides Andhra Pradesh Agricultural University (APAU, Chinthapally), Kerala Agricultural University (KAU, Panniyur and Ambalavayal), Tamil Nadu Agricultural University (TNAU, Yercaud), Konkan Krishi Vidyapeeth (KKV, Dapoli), Bidhan Chandra Krishi Viswa Vidyalaya (BCKV, Pundibari) and University of Agricultural Sciences (UAS, Sirsi). The production system in India is highly sustainable and is mostly an intercrop and a homestead crop. The statistics of yield is relatively difficult to compute on account of this factor. Another factor that needs to be considered is that majority of the vines in households supply the requirement for the family and only the surplus reach the market. Besides, the consumption of pepper within the country has risen from 35,000 tons in 2000 to 66,200 tons in 2006 showing 75% increase in per capita consumption of pepper (table 2). During the X plan period from 2001 there is an increase of 6.8% in area with a marginal reduction in the production and productivity rates.

Table 2. Trend in consumption of pepper in India

Year	Consumption (t)	Per capita consumption (g)	Increase in consumption %
2000	35,000	35	16.60
2001	50,624	49	44.60
2002	52,000	50	2.70
2003	58,000	55	11.50
2004	60,000	56	3.50
2005	63,000	58	5.00*
2006	66,200	60	5.00*

(Source: www.ipcnet.org) * estimated value

The best way to increase the area and productivity is to go in for large scale cultivation in non traditional areas in North East India. This would be an ideal crop to be grown along with shade trees in tea estates. If atleast 40 to 50 shade trees/ha is planted with black pepper in about three lakhs of hectares in the NE states and in North Bengal, we would be able to meet the international rcquirement without any additional burden on the land. GIS studies carried out at IISR amply indicated the suitability of NE states for black pepper. The pattern of growth in production is indicated in table 3. Eventhough, all states showed an area led growth during the present decade, only Tamil Nadu showed increase in productivity.

Table 3. Pattern of growth in black pepper production (1980-81 to 2004-05)

Pattern of growth	Period	Pepper producing states
Area led growth (ACGR in area expansion is more)	P – I: (1980-81 to 1989-90)	Kerala, Karnataka, Tamil Nadu, Others & All India
	P – II: (1990-91 to 1999-2000)	Karnataka, Tamil Nadu
	P – III: (2000-01 to 2004-05)	Kerala, Karnataka, Others & All India
	Overall: (1980-81 to 2004-05)	Kerala, Karnataka, Tamil Nadu, Others & All India
Productivity led growth (ACGR in productivity is more)	P – I: (1980-81 to 1989-90)	None
	P – II: (1990-91 to 1999-2000)	Kerala, Others, All India
	P – III: (2000-01 to 2004-05)	Tamil Nadu
	Overall: (1980-81 to 2004-05)	None

With the prevailing export and consumption pattcrn, the demand for black pepper in the national and international market will grow tremendously. The projections on black pepper demand showed that a need for 12% growth rate in production in each forth coming five year plans to achieve a production target of 1.28 lakh tonnes in 2025 (table 4). The goal in the coming years will be a cumulative 60% increase in production and productivity to reach this herculean task.

Table 4. Future demand of black pepper production and productivity

Year	Total demand (t)	Qty. to be produced (t)	Area under the crop (ha)	Targeted productivity (t/ha)
2006-07	81287	82882	233520	0.355
2011-12	91375	92658	233520	0.397
2016-17	102701	103733	233520	0.444
2021-22	114531	115362	233520	0.494
2026-27	127902	128570	233520	0.551

Nowadays the pressure on land is very high and in future it will become worse making area expansion under the crop an impossible effort. Hence achieving the production target without increase in the area is possible only by increasing the productivity per unit area to 550 kg/ha from the present value of 281 kg/ha. The increase in productivity can be made possible by popularizing the high yielding improved varieties, replacing the old senile and unproductive plantations with improved cultivars/varieties and popularizing adoption of latest technologies in crop management practices.

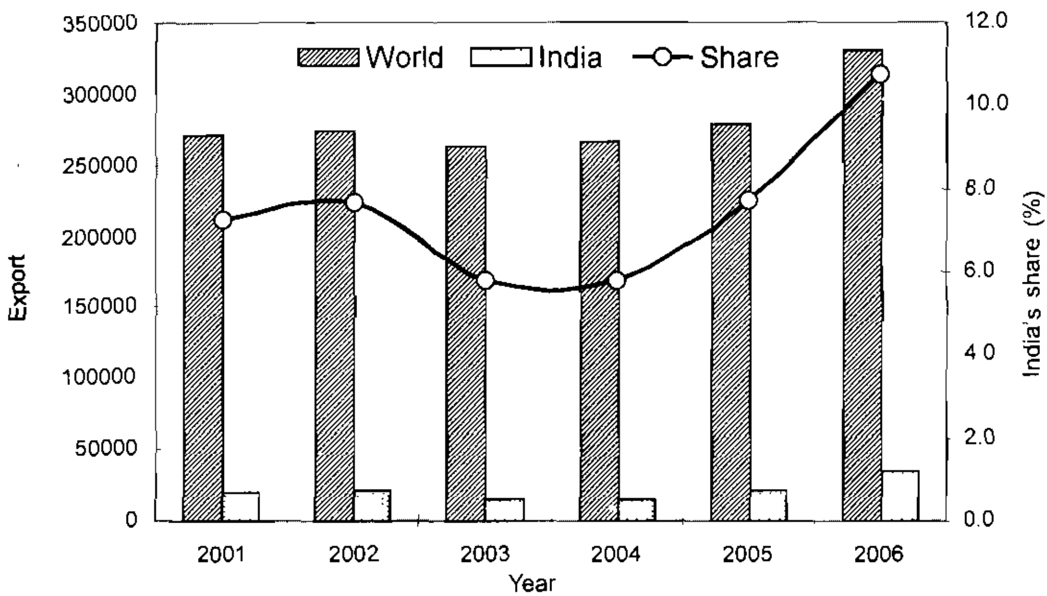
As black pepper is a perennial crop and starts its full potential yield from third year after planting, the following projections are considered (table 5) for maintaining the production and productivity of the crop with reference to the performance during past five years. Since the newly planted and replanted areas will come to an economic yield from third year after planting, the productivity needs to be increased by 25, 9.5 and 8% in the next coming five year plans.

Table 5. Projection of black pepper production with replanting programme

	2007-08	2010-11	2015-16
Black pepper			
Area ('000 ha)	246	246	246
Production ('000 t)	69	92.66	103.73
Productivity (kg/ha)	355	377	422
With the projected replanting @ 10% area			
Net yielding area (ha)	221400	196800	172200
Projected production (t)	82880	92660	103730
Hence productivity (kg/ha)	374	470	602

(Considering the newly planted/ replanted area with full yield during third year onwards)

India's share in black pepper export was only 7% in 2004 as compared to about 80% of Indonesia (Fig. 1). Value addition plays an important role in the export of black pepper. White pepper constituted 16.9% of total export of pepper, whereas India's contribution to white pepper production and export was in miniscule (Fig. 2)



Source: International Trade Centre (ITC), Geneva

Fig. 1. World black pepper export (tonnes) and India's share in the same

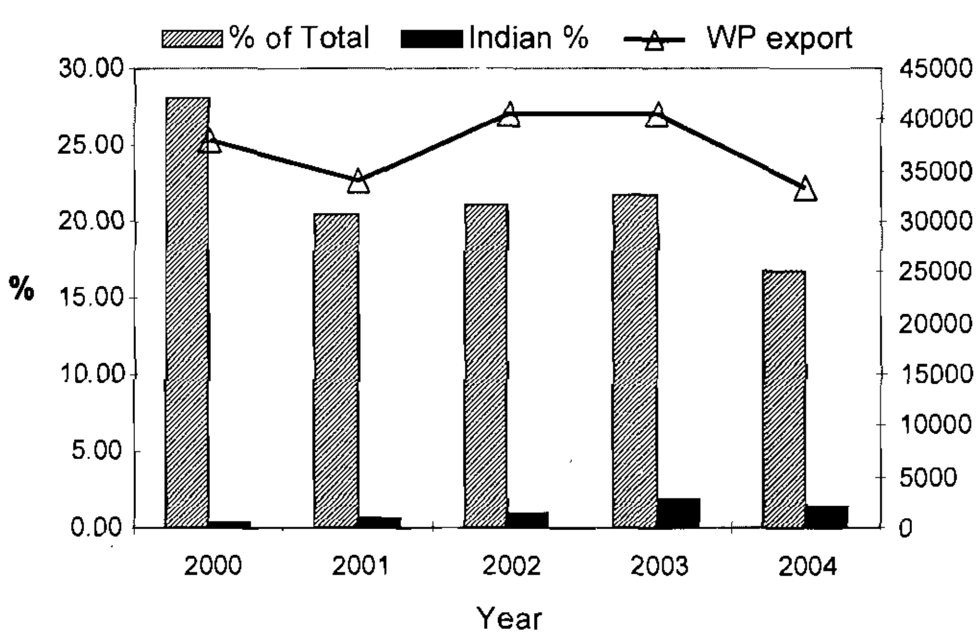


Fig. 2. World white pepper production and India's share in the same

Organic pepper has also established its market share better than other pepper products like dehydrated green pepper, pepper in brine, freeze-dried pepper or frozen pepper. There is a market for organic pepper presently in most developed countries including Germany, Netherlands, France, U.K., Switzerland, Denmark, Italy, U.S.A, Canada, Japan and Australia. Other developed countries in European Union and some developing countries are likely to source organic pepper in coming years. It is relevant to mention here that there is no domestic market now in India for organic pepper. There is demand for both black and white organic pepper. Organic green pepper in brine has also been imported by Germany. There are demands for organic pepper oil and oleoresin, but information is lacking whether these products have been supplied. By and large, organic black pepper is the most widely marketed product.

A well-articulated vision is critical in order to provide guidelines for decision making and to avoid compromising long-term strategic needs and responsibilities in the face of immediate, external pressures. The following are some the major issues identified and strategies to bring India back to the forefront in spices production and research.

	Issues	Strategies
1.	Non-availability of genes characterized for desirable traits such as yield and quality, disease, pest and drought tolerance for pyramiding in a single cultivar	• Breeding varieties for resistance/tolerance to pollu, *Phytophthora* foot rot, nematodes, viruses and drought by using conventional and biotechnological approaches
2	Lack of quality certification standards for producing disease free planting material	• Developing certification standards, production of disease free quality planting materials of HYVs and its distribution though extension agencies
3.	Crop loss by pest and diseases and emergence of new pest and diseases	• Development of integrated pest and disease management practices for increasing the productivity
4.	Pesticide residues in produce	• Development and popularization of Good Agricultural Practices (GAP) for spices
5.	Non-availability of methods to control post harvest losses and aflatoxin contaminations	• Developing suitable on-farm processing techniques • Developing storage and packaging system to suit HACCP norms • Post-harvest processing technologies for adding value, and minimizing storage loss

6.	Poor adaptability of management practices by farmers	• Development of cost effective agricultural practices • Dissemination of technologies to the farmers
7.	Lack of organic farming technology package for spice based cropping system	• Development of technology package for conservation and organic farming
8.	Market fluctuation influenced technology adoption	• Development of recipes and systems for value addition to enhance the consumption of spices at domestic and international levels. • Development of market intelligence support to tap the export market
9.	WTO implications	• Genetic finger printing of germplasm and patenting technologies and traded pepper for GI appellatiary purpose

Technology assets and projected future needs to achieve development goals

Research areas	Current technology assets	Projected technology needs
Biodiversity conservation and utilization	• *In vivo* conservation • *In vitro* conservation • Cryo preservation of germplasm	• High-throughput genotyping of germplasm collection • Variety identification/ fingerprinting for tracking in exchange
Genetic improvement of crops	• Improved breeding clones as potential varieties • Some source of resistance in *Piper colubrinum* against major diseases	• Frontier science technology for gene discovery for resistance and yield traits, and better utilization of gene banks • Gene technology to engineer resistance to *Phytophthora*, nematodes and pollu & mealy bug and abiotic stresses • Targeted metabolite production in engineered crop • Physiological traits and quality modification by genetic engineering • *Genomics for host–pathogen/pest* interactions

Crop management	• Nucleus planting materials for use by farmers • Diagnostic technologies for viruses • Low input or ecologically based nutrient, pest and pathogen management technologies • Production systems & analysis (environment, markets) relevant to our situations • Technology transfer methodologies (manuals, CDs, training courses)	• Soil less or organic planting materials and farming technologies • Effective diagnostic tools for pests and pathogen (detection strips, DNA or peptide chips) • Tools and methods for understanding problems in targeted systems and decision-making tools for technology deployment and policy decisions • Geospatial tools for ex-ante impact assessment and enhanced natural resource management • Internet-mediated technology diffusion (distance learning, helpdesks, video conferences)
Post-harvest utilization	• Efficient storage methods for long term storage • Post-harvest processing technologies (white pepper, pepper in brine *etc.*)	• Post-harvest processing technologies for adding value, minimizing loss, and stabilizing prices • Low input storage technologies for zero contamination • Methodological approaches to product development and marketing of small farmers' produce

Conclusion and future thrust

The vision should be for a strategic plan to tackle the potential to impact development, specific research needs and opportunities exist in target areas and how the research should be done, *i.e.*, the articulation of conceptual, or theoretical, frameworks within which to conduct the research as well as how to organize ourselves to create and capture synergies that increase our research and development impact. Hence, major thrusts in future research programmes should be oriented towards the following focused approaches for increasing productivity of black pepper.

- Conservation of genetic resources and bar-coding of genotypes
- Increasing productivity of spices - to raise the production levels to the targeted 6.0 kg / vine by 2025 using improved varieties with high yield, quality traits and disease/ pest resistance

- Increasing productivity of spices through quality planting material production and crop management - to raise the production levels to the targeted levels using quality planting materials, replanting and rejuvenation of old gardens, good agricultural practices, INM and organic farming.

- Increasing productivity of spices – to raise the production levels through IDM/ IPM

- Chemo profiling and identification of new flavour compounds, bio active principles for patenting – to identify superior varieties with excellent flavour, identifying newer compounds

- New market oriented technologies for value addition, processing, product development – to increase the acceptability, demand and value of pepper and new markets

- Development of data bases, prediction models, production strategies and market intelligence – use of GIS & bioinformatics tools in pepper cultivation, marketing and trade.

Role of AICRPS in shaping black pepper research in India

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All India Coordinated Research Project on Spices
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The All India Coordinated Research Project on Spices (AICRPS) is located in Kerala with its head quarters at Indian Institute of Spices Research, Calicut, The research programmes of AICRPS are coordinated through a network of its 19 regular coordinating centers spread over 14 states in 15 Agricultural Universities. During the XI plan additional 8 Co-opting and 7 Voluntary centers are proposed in different agro-ecological regions of the country covering 22 states. The AICRPS is the largest network in spices research in the country which was originally initiated as a combined project of spices and cashew under the name All India Coordinated Spices & Cashew Improvement Project (AICSCIP) during 1971 (IV Plan) with its headquarters at CPCRI, Kasaragod. In order to intensify spices research and development AICSCIP was bifurcated into two separate projects one each for spices and cashew nut and the present AICRPS came into existence in 1986.

The All India Coordinated Research Project on Spices conducts and coordinates research on 12 major spices *viz*, black pepper (*Piper nigrum*); cardamom (*Elettaria cardamomum*); large cardamom (*Amomum subulatum*); ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*); clove (*Syzygium aromaticum*); nutmeg (*Myristica fragrans*); coriander (*Coriandrum sativum*); cumin (*Cuminum cyminum*); fennel (*Foeniculum vulgare*); fenugreek (*Trigonella foenum-graecum*) with specific mandates and with a proposed budget of Rs. 1400 lakh for the XI Plan and a sanctioned staff strength of 83 in various categories.

Mandate and objectives of AICRP on spices

- Evolving high yielding, high quality varieties suitable for various agro-ecological situations, and that are tolerant / resistant to pests and diseases.
- Standardizing agro-techniques for different agro-climatic conditions.
- Evolving measures for management of major pests and diseases.
- Working as an interface between State Agricultural Universities (SAUs) and Indian Council of Agricultural Research (ICAR).

Black pepper

To overcome the production constraints in pepper, various research and extension efforts are in progress. The research on black pepper is mainly being carried out in Kerala. The Indian Institute of Spices

Research (IISR), State Agricultural Universities (SAUs) of Kerala, Karnataka and Tamil Nadu, All India Coordinated Research Project on Spices (AICRPS), Spices Board, Directorate of Arecanut and Spices Development, Department of Agriculture of different states are engaged in research/development/ extension activities.

Black pepper research centers under AICRPS

The research on black pepper is mainly carried out by the 8 AICRP centres based in SAUs (table 1) in 6 states of India. The centers are also distributed in various states of the country to fulfill the mandates of the project. The pepper centers are located in Kerala, Karnataka,, Andhra Pradesh, Tamil Nadu, West Bengal and Maharashtra. The centers of AICRPS are so established to cater to the needs of different farming systems. AICRPS has centers in the traditional and non-traditional areas of black pepper. Black pepper can be grown as a pure crop (on live or non-living standards) or as an intercrop. Among the traditional areas, black pepper is grown as a pure crop in parts of Kerala and the Panniyur and Pampadumpara centres cater to the needs of this area. The centres at Sirsi and Mudigere in Karnataka caters to the needs inter cropping in coffee and arecanut. Dapoli, Chintapalli, and Yercaud centers are situated in nontraditional areas and are involved in evolving high yielding, high quality varieties and technologies suitable for various agro-ecological situations. Black pepper is reported to grow from sea level up to 3000 ft MSL. The centers are so located to evaluate the performance of black pepper grown at various elevations.

Table 1. Black pepper research through AICRPS centres

S.No	Centre/University	State	Agro climatic region
1.	Panniyur (KAU)	Kerala	West coast plains & Ghat region
2.	Sirsi (UAS-D)	Karnataka	"
3.	Pampadumpara (KAU)	Kerala	"
4.	Mudigere (UAS-B)	Karnataka	"
5.	Chintapalli (APAU)	Andhra Pradesh	Southern plateau & hill region
6.	Yercaud (TNAU)	Tamil Nadu	East coast plain & hill region
7.	Pundibari (BCKVV)	West Bengal	Lower Gangetic plain
8.	Dapoli (KKV)	Maharashtra	Western Plateau & hill region

Pepper Research Station, Panniyur was started in 1952 under the erstwhile Madras Agriculture Department, later in 1956 it was brought under the Kerala State Department of Agriculture in 1972. With the establishment of Kerala Agricultural University, it became one of its constituent research stations. Since then, research on crop improvement, crop management and crop protection aspects of black pepper are carried out in this station. The station is unique among all the agricultural research stations in India because it is the only station solely devoted to research on black pepper. This is an important coordinating centre of the AICRP on spices of the ICAR with nine sanctioned posts including scientific and technical.

Potential of black pepper

In India, black pepper cultivation is mainly confined to the states of Kerala, Karnataka and Tamil Nadu. Kerala is the major producer followed by Karnataka and Tamil Nadu. Pepper is a traditional crop of Kerala, cultivated in almost all the homesteads. It is mainly cultivated on a plantation scale in districts of Idukki, Wynad and Cannanore. In Karnataka, main cultivated areas are confined to districts of Dakshina Kannada, Uttara Kannda, Kodagu, Hassan, Shimoga and Chikmagalur areas; cultivation is mainly as inter crop in arecanut and coffee estates. The cultivation in Tamil Nadu is steadily increasing in areas like Vellimalai, Meghmalai, Yelagiri, Kolli and Shevroy hills besides the traditional areas in the Nilgiris, Anamalis as well as in Thirunelveli and Kanyakumari districts.

The average pepper productivity in India is one of the lowest in the world (281 kg/ha). India has enough potential to increase production if the observed productivity gap in the country is filled through proper planning. However, some of the factors that contribute to low productivity in black pepper are adopting traditional cultivars/land races, cultivating in the same piece of land over the years, non-adoption of improved package of practices, devastating diseases such as *Phytophthora* foot rot, lack of high quality improved varieties available for cultivation *etc.*

Productivity of pepper needs to be increased from the present level of 300 kg/ha to at least to the minimum level of 1000 kg/ha. This target can only be achieved by popularizing high yielding varieties/ hybrids together with adoption of an improved production technology and expanding areas to non traditional areas. Several production technologies have been standardized for increasing productivity, including management of major diseases and pests. Production technologies developed in the research centres have been demonstrated, but adoption level of such technologies by growers is still very low.

Research in black pepper

The AICRPS has contributed enormously in developing several improved varieties, technologies for increasing the production and productivity and control measures against major diseases and pests of black pepper in the country.

Present research activities are mainly focused on germplasm collection, conservation, evaluation, crop improvement programme for evolving high yielding varieties coupled with quality/tolerance/resistance to pests and diseases and drought, developing crop protection techniques and production technologies for improvement of black pepper.

Conservation of genetic resources

Collection and conservation of genetic resources of black pepper is a high priority. Systematic surveys of the various pepper growing areas of the different states (Kerala, Karnataka, Tamil Nadu, Andhra Pradesh) and the Western Ghats forests and part of the North East region sub Himalayan regions of India were conducted to collect the variability of black pepper and *Piper* species.

The pepper research centres hold a considerable number of germplasm collections from Kerala, Tamil Nadu, Karnataka, Andhra Pradesh as well as from Western ghats region. The related taxa being maintained besides *P. nigrum* include *P. argyrophyllum*, *P. attenuatum*, *P. barberi*, *P. betle*, *P. mullesua*, *P. galeatum*, *P. longum*, *P. hymenophyllum*, *P. sugandhi* and *P. trichostachyon*.

The germplasm collected are conserved at various locations. A total of 550 accessions of germplasm have been collected, evaluated, maintained and conserved at various centres of AICRPS (table 2).

Table 2. Germplasm holding of black pepper at AICRPS centres

Centre	Indigenous		Exotic	Total
	Cultivated	Wild and related sp.		
Panniyur	144	22	3	169
Sirsi	110	6	1	117
Chintapalli	56	-	-	56
Yercaud	116	8	-	124
Pundibari	11	-	-	11
Dapoli	66	-	-	66
Dholi	7	-	-	7
Total	510	36	4	550

Improved varieties

Systematic research efforts in the last three decades resulted in the release of superior lines through hybridization/open pollination/clonal selection from the popular cultivars. They are suitable for a variety of growing situations and areas. Seven improved varieties were released including two hybrids (table 3) at Panniyur station. Among the pepper varieties, Panniyur-1 and Panniyur-3 are hybrids having bold berries. Panniyur-2 and Panniyur-5 grow well in mixed cropping system. The yield of Panniyur -5 is stable even under drought. Panniyur - 7 is a steady and stable yielder and the unique feature of this variety in its tolerance to drought and its good performance under adverse climatic conditions.

Table 3. The improved varieties of black pepper and their quality attributes (Pepper Research Station,KAU, Panniyur)

Name / Year of release	Pedigree	Yield, kg/ ha (dry)	Potential Yield (kg/ha)	Oleoresin (%)	Piperine (%)	E.oil (%)
Panniyur-1 (1971)	Uthirankotta x Cheriyakaniyakadan	1242	8800	11.8	5.3	3.5
Panniyur-2 (1989)	Open pollinated progeny of Balankotta	2570	3313	10.9	6.6	3.1
Panniyur-3 (1989)	Uthirankotta x Cheriyakaniyakadan	1953	3269	12.7	5.2	3.1
Panniyur-4 (1989)	Clonal selection from Kuthiravally	1277	2443	9.2	4.4	2.1
Panniyur-5 (1993)	Open pollinated progeny of Perumkodi	1826	4487	12.3	5.5	3.8
Panniyur-6 (1999)	Clonal selection from Karimunda	2127	3359	8.3	4.9	1.3
Panniyur-7 (1999)	Open pollinated seedling progeny of Kalluvally	1410	2770	10.6	5.6	1.5

Promising varieties in pipeline

The accession, Karimunda 1 (PRS-20), Sullia (PRS-49) and Taliparamba IV are some of the promising accessions identified by PRS, Panniyur centre. They have a potential yield up to 5000 kg/ha. A few promising cultures identified in the hybridization studies are Cul.-5232, Cul.-5308, Cul.-5403 and Cul.-5834.

Intervarietal hybridization

Intervarietal hybridization in black pepper is carried out to evolve black pepper varieties with high yield, pest and disease resistance and other durable traits. Progenies obtained through hybridization are primarily screened for vegetative characters. These are later evaluated for berry, spike and yield characters and tolerance to pest and diseases. The promising lines are advanced to CVT at different locations. Among the intervarietal hybrids P6 x P 5 is found to be promising with green berry yield of 3.540 kg/vine.

Interspecific hybridization

Interspecific hybridization of black pepper with *P. colubrinum* (tolerant to *Phytophthora* foot rot) were attempted at Panniyur station and a partly fertile interspecific hybrid having partial resistance to the dreaded disease *Phytophthora* foot rot was developed through hybridizing *Piper nigrum* with the wild species *Piper colubrinnum*. Hybridity of interspecific progenies was established through morphology, anatomy, cytology, and molecular studies.

Identification of varieties suitable for various agro ecology regions

Trials are on at various AICRPS centers at Panniyur, Chintapalli, Dapoli, Sirsi, Pundibari, Pampadumpara, Ambalavayal and Yercaud in three different CVTs. The promising cultivars along with the released varieties are evaluated at different locations (plains and high elevation) to identify suitable varieties for various locations and cropping systems.

Studies conducted by Dapoli centre recommended Panniyur-1 for cultivation in Konkan region of Maharastra. Panniyur - 1 and Kottanadan have been identified as suitable varieties for cultivation at Chintapalli area of Andhra Pradesh. Panniyur –1 was also identified as a good variety for inter cropping in coffee plantations. Panniyur-3 performed well with maximum mean yield of 12.0 kg of green berry/ vine (3.6 kg dry berry/vine) and 100 berry weight of 12.4 grams in Yercaud.

Nutrient management

Studies carried out at AICRPS centres also recommended the fertilizer schedule (g / vine / year) for major areas depending upon soil nutrient status and location, which is given below.

NPK @ 50:50:200	Panniyur and similar regions. The P dose may be either increased to 100g/ vine/year or decreased to 25 g/vine/year depending on P status of soil.
NPK @ 100:40:140	In medium fertile soil.
NPK @ 200:80:280	In arecanut and pepper mixed cropping system for heavy rainfall Sirsi region of Karnataka.
NPK @ 150:60:210	For Karnataka under irrigation.
NPK @ 50:50:150	Optimum dosc under rainfed conditions of Andhra Pradesh.
NPK @ 100:60:160	For Chintapalli area of Andhra Pradesh in two splits (July & September)
NPK @ 140:55:270	For laterite soils of Kerala where soil N and K are poor.
NPK @ 50:50:150	Panniyur region of Kerala.

Application of 1/3 of the above dose is recommended for the first year and 2/3 during the second year and full dose from third year onwards. Fertilizers are best applied in two splits, first half in May-June with the receipt of rains and 2nd half in August -September after cessation of heavy rainfall. Application of micro nutrients-zinc, boron and molybdenum @ 5,2 and 1kg/ha in soil in September increased the yield and quality of pepper.

Effect of *Azospirillum* on black pepper yield

Experiments were carried out in farmer's field with existing black pepper vines at *Panniyur, Sirsi and Yercaud* during 2000-01 to 2004-05 to study the role of *Azospirillum* on the yield of black pepper and to develop an appropriate package of nutritional requirement to improve the productivity in mixed cropping. Application of *Azospirillum* @ 50 g along with recommended 100% inorganic N, P and K with 10 kg FYM per vine recorded higher fresh berry yield (6.83 kg) compared to recommended dose of fertilizers (RDF) (6.12 kg). This was followed by the vines supplied with *Azospirillum* @ 50 g along with recommended 75% nitrogen and 10 kg FYM per vine (6.57 kg). It has also resulted in obtaining maximum cost benefit ratio of 1:3.29. Applying 50 g of *Azospirillum* + 10 kg FYM per vine was highly effective in increasing the spike yield (5.03 kg/vine), of black pepper at Panniyur centre. Application of inorganic N 75% + *Azospirillum* (50g) + 10 kg FYM was found to be best treatment at Yercaud with 8.4 kg and 2.6 kg of green and dry berries. This was closely followed by application of inorganic N 50% + *Azospirillum* (50g) + 10 kg FYM (8.0 and 2.6 kg by green and dry berries respectively).

Effect of P- solubilizers (Phosphobacteria) on black pepper yield

Application of Phosphobacteria @ 50 g along with recommended 100% inorganic P and 10 kg FYM / vine recorded maximum fresh berry yield) compared to other treatments at Sirsi and Panniyur with a C:B ratio of 1:3.3. Where as inorganic N 75% + phosphobacteria 50g + 10kg FYM was ideal for increasing the yield in Yercaud.

Development of organic package for pepper based cropping systems

Technology to produce organic pepper has been standardized. Vermicompost enhanced the growth of black pepper in nursery. Combined application of *Azospirillum,* Phosphobacteria and VAM increased the growth of black pepper cuttings in nursery. Application of biocontrol agent *Trichoderma* against *Phytophthora* foot rot was advocated. Trials at Panniyur (KAU), Ambalavayal (KAU), Sirsi (UAS-D) revealed maximum yield per vine with the application of biofertilizers (*Azospirillum* @ 50 g/ phosphobacteria @ 50 g) + FYM 10 kg along with recommended dose of NPK. In the organic farming studies at Panniyur FYM 10 kg + *Azospirillum* 50 g + wood ash 2 kg was superior (6.489 kg/ vine) and was on par with recommended dose of fertilizer (5.434 kg/vine).

Irrigation and water management

Pepper is grown as a rainfed crop in majority of areas and seldom irrigated. However, for initial two years pot watering or drip irrigation is essential for proper growth and development of vines. Studies conducted at Panniyur showed that irrigation at IW/CPE ratio of 0.25 from November-December to the end of March and with holding irrigation thereafter till monsoon (June), increased pepper yield by about 90% for both Panniyur and Karimunda varieties. Depth of irrigation recorded is 10 mm (100 liter of water/irrigation at an interval of 8-10 days). Water is applied in basins taken around the vine at a radius of 75 cm and mulching at the base with dry leaves helps to maintain soil moisture. Drip irrigation trail conducted at Panniyur revealed non significant difference between levels of irrigation and varieties.

Drip irrigation @ 2 litres / vine / day contributed towards more spike number, green berry yield and spike length when irrigated during summer months.

Propagation

Grafting of *P. nigrum* (laterals, runners, topshoots) on *P. colubrinum* root stock (resistant to *Phytophthora* foot rot) was standardized and the pepper grafts are being evaluated.

Disease management

Black pepper is affected by several diseases in nursery and plantation caused by fungi, bacteria and virus. Major pepper diseases are *Phytophthora* foot rot (quick wilt), slow decline (slow wilt) anthracnose stunted diseases *etc.* Pepper is infected by several species of insects damaging various parts of vine such as root, shoot, leaves, spike and berries. Depending up on the severity and extent of damage, pollu beetle, top shoot borer, leaf gall thrips, scale insects and mealy bugs are considered as major pests.

Although many pests and diseases affect the pepper plantation, *Phytophthora* foot rot caused by *Phytophthora capsici* is the most serious. Attempts were made to develop suitable management strategies through cultural, chemical, biological and integrated approach. Correlation studies of foot rot disease and weather parameters at Panniyur Station showed that the disease incidence more or less followed the annual rainfall pattern. Intensity of the disease incidence was maximum (39% vines) in July where weather parameters like rainfall, number of rainy days and relative humidity were the highest. Increase in the amount of rainfall, number of rainy days and relative humidity was conducive for the increase in the incidence of the disease. Based on this relationship, a multiple linear regression equation had been developed at Panniyur using all weather variables for predicting the disease incidence.

The current foot rot management technologies available in the packages of practices of Kerala Agricultural University and All India Coordinated Research Projects (AICRP) were compared with the local practices followed by farmers at *Panniyur, Sirsi, Pampadumpara* and *Mudigere* in both existing plantations and newly planted gardens. All the treatments were found to be significant in reducing the foot rot incidence. The disease index ranged from 3.1 in potassium phosphonate (0.3%) + *Trichoderma harzianum* (@50 gm/vine) treated vines to 10.1 on vines adopted by local practice of farmer. The plots treated with potassium phosphonate @ 0.3% and *Trichoderma harzianum* @ 50 gm vine^{-1} was found to be effective in managing foot rot incidence in black pepper followed by Bordeaux mixture 1% spray and COC 0.2 % drenched plots. The various diseases and their control measures standardized at various centers are given in tables 4, 5 & 6. A low cost technology for mass multiplication of biocontrol agent, *Trichoderma* sp. as for the management of *Phytophthora* foot rot has been developed.

Table 4. Nursery diseases/pest and management in black pepper

Disease / pest and causal organism	Management / Control measures
Leaf rot and blight (*Rhizoctonia solani)*	Removal of the affected cuttings/ spraying and drenching the cuttings with 0.2% copper oxychloride or bavistin (0.2%) or Bordeaux mixture (1%) at bimonthly intervals.
Basal wilt (*Sclerotium rolfsii Pythium* sp.)	Removal of the affected cuttings and spraying Bordeaux mixture (1%) and drenching the cuttings with 0.2% copper oxychloride at monthly intervals.
Phytophthora foot rot (*Phytophthora capsici* F. *piperi*	Dip the cuttings in culture suspension of *T. harzianum* & *T. viride*. Fortnightly application of 1.0% Bordeaux mixture, or Captafol (1.0 %), solarization of nursery soil mixture (3.3 k lux) fortified with VAM @ 100 cc/kg and *Trichoderma* @ 1 g/kg soil.
Root knots (*Meloidogyne incognita*) Root necrosis & rot (*Radopholus similis*)	Add phorate @ 1.0 g per bag. VAM incorporation in nursery mixture / fumigation with methyl bromide @ 500 g/ton of nursery soil mixture under polythene cover for 24-48 hours –5-15 days before planting of the cuttings.
Scale insects (*Lepidosaphes piperis*)	Spray monocrotophos 0.05% or dimethoate 0.1%
Leaf gall thirps (*Liothrips karnyi)*	Apply carbofuran 3 G or Phorate 10 G @ 3 g a.i/vine during June-July and September-October, spraying 0.05% monocrotophos or dimethoate on tender flushes.
Top shoot borer (*Cydia hemidoxa*)	Spray monocrotophos 0.05% on tender terminal shoots

Assessment of technologies

The technologies developed by the centres are tested in front line demonstrations (FLDs) for which a specific budget is allocated to each centre and are passed on to extension agencies of various states. The centres are also involved in the multiplication and distribution of nucleus planting material of improved varieties developed by them.

Demonstration of two technologies developed in black pepper are in operation at Panniyur Center *viz.*

- Demonstration of improved high yielding varieties of pepper, Panniyur 6 and Panniyur 7
- Demonstration for multiplication of planting materials of black pepper.

Table 5. Important disease of black pepper and their management

Disease and causal agent	Management /control
Phytophthora foot rot caused by soil borne fungus *Phytophthora capsici*	Adopt phytosanitory measures, cultural practices, chemical and biocontrol measures.Provide adequate drainage, grow grass cover, avoid trialing of runner shoots on the ground, careful farm operations without injuring the underground parts of the vine. Improve the microclimate by shade regulation, lopping off the branches of live standards to ensure better light penetration and to reduce humidity. Phytosanitation : Remove the affected vines along with the root system and burn to check the inoculum build up. Drench the spot with 0.2% copper oxychloride or 1% Bordeaux mixture @ 5-10 l/vine. Gap filling. Spraying Bordeaux mixture (BM) (1.0%), recommended cultural practices and drenching copper oxychloride (0.2%) twice during June & September. Apply *T. harzianum* (50 g/vine) mixed with 1kg neem cake followed by Akomin 0.2% (potassium phosphanate) spray in first week of June @ 3l / vine and drench @ 5l / vine twice during the season (before onset of monsoon and during second week of August) in addition to cultural practices.
Slow decline (Slow wilt) Nematodes: *Radopholus similis, Meloidogyne incognita* Fungi : *Rhizoctonia* sp., *Fusarium* sp., *Pythium* sp.	Application of carbofuran 3G or phorate 10 G (30 g/vine) plus Bordeaux mixture spraying and copper oxychloride (0.2%) drenching plus soil application of neem cake @ 2 kg/vine. Drench basin with 1% copper oxychloride @ 5-10 l/ vine 2-3 times during monsoon season.
Black berry (Pollu) disease (*Anthracnose*) *Colletotrichum gloeosporoides* (appears towards the end of monsoon)	Spray Bordeaux mixture (1.0%) or Captofol (1%) once before flowering starts (July) and at berries formation stage (August). A combination spray of quinalphos 0.1% and Zyneb 0.2% once in June and again in September to control pollu fungus and pollu beetle. Application of a combination fungicide (carbendazim and Mancozeb 0.1%) or carbendazim 0.1% also is recommended.

Table 6. Important pests of black pepper and their management

Pests/Causal agent	Management/control
Pollu beetle (flea beetle) *(Longitarsus nigripennis)*	Spray endosulfan (0.05%) or quinalphos (0.025%) or dimethoate or monocrotophos (0.05%) twice at June-July (21-30 days after setting of berries) and September-October
Top shoot borer (*Cydia hemidoxa)*	Spray endosulfan (0.05%) when new shoots emerge
Leaf gall thrips (*Liothrips karyni)*	Spray monocrotophos or endosulfan or dimethoate (0.05%) or phosphamidon (0.03%)
Scale insects (*Lepidosaphes piperis)*	Spray two rounds of monocrotophos (0.05%) or dimethoate (0.05%) or quinalphos (0.05%) at 15 days interval, after harvest. Organic products neem oil / neem gold (0.5%) application four times at fortnightly interval is also effective
Mealy bug (*Pseudococcus vigatis)*	Drench monocrotophos (0.1%) or dimethoate (0.05%) or quinalphos (0.05%) at 15 days interval
Root knot and burrowing nematodes (*Meloidogyne incognita* and *Radopholus similis)*	Phorate 10G, carbofuran 3G, aldicarbe @ 3 g a.i./ vine twice a year, May -June and September-October and cover with a thin layer of soil

New initiatives

Demonstration plots of black pepper in North East

Demonstration plots of black pepper in arecanut gardens at Mohitnagar (West Bengal) and Kahikuchi (with released varieties namely Panniyur-1, Sreekara, IISR Shakthi, IISR Thevam and IISR Malabar Excel) has been initiated in collaboration with AICRP on Palms.

New centres for black pepper research

Among the eight co-opting centres and seven new voluntary centers approved under AICRPS during the XI plan, Bidhan Chandra Krishi Vishwa Vidhyalaya, Kalyani, West Bengal has been identified for carrying out research on black pepper, ginger and turmeric.

Evaluation of orthotropic shoots of black pepper

Black pepper is mainly propagated in the field using runner shoots. To produce bush pepper, lateral shoots are being used. Initiatives have been taken in AICRPS to evaluate and study the performance of orthotropic shoots of black pepper. Experiments on rooting of orthotropic shoots of black pepper are already standardized and field planting would be taken up to evaluate their performance.

Management of *Erythrina* gall wasp

Erythrina gall wasp has become a serious pest on *Erythrina*, a popular standard of black pepper. Severe gall wasp infestations may cause defoliation and death of the tree. Studies have been initiated to study the pest surveillance and the severity of the disease damage and their management. The studies would be conducted at Idukki and Wayanad by the Pampadumpara centre and in Chikmagalur and Coorg districts by Mudigere centre.

Success stories

The first black pepper hybrid variety Panniyur 1 released in 1971 is still performing well and is a favourite variety of the farmers and is being widely cultivated in pepper growing areas world wide.

Constraints

- Lack of sufficient quality planting materials
- Low productivity
- Inadequate post harvest infrastructure and storage facilities
- Non-availability of improved technology for organic cultivation
- Unorganized marketing system

Potential

- Scope for extention of area under non traditional areas
- To grow black pepper under irrigated condition
- Scope for production of organic black pepper in North Eastern states.
- To grow black pepper as an intercrop in oil palm plantation
- Bush pepper cultivation under protected conditions

Priority areas for the future

- Collection and conservation of germplasm including wild type and to strengthen breeding programme
- Conservation and optimal utilization of natural resources
- Emphasis on crop productivity per unit area
- Production of disease free planting material
- Developing cost effective post harvest handling and storage techniques
- Well-organized transfer of technology system supported with extension and sound seed production programmes
- Evolving suitable regulated marketing systems for internal and export markets by assembling processing, packaging, storage and trading facilities at one place
- Identification of potential trade centres in the country and setting up of market intelligence and information systems

Production and utilization of black pepper - a Brazilian experience

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Introduction of black pepper in Brazil and its utilization

Black pepper introduction in Brazil is related with the Portuguese colonization. During the 17th century black pepper was introduced in the State of Bahia, and then transported to the States of Paraiba, Maranhao and Pará. The commercial utilization of this crop (culture) started only in the 20th century, since 1933, when Japanese immigrants introduced the cultivar (cv.) 'Cingapura' (Kulching) in the State of Pará (Northern Region – Amazon). During the 1950's Brazil changed from a pepper importer country to become an exporter of this spicery (Albuquerque and Condurú 1971).

In the State of Espírito Santo (Southeast Region – Atlantic Forest), cv. 'Pimenta-da-terra' (lately registered as 'Espírito Santo BRA-272'), was initially introduced, however with low productivity. The crop started to expand since 1974, with the utilization of cv. 'Cingapura', originated from the State of Pará and Bahia. The cultivation of more than 180 hectares was made especially for Italian immigrant descendents. At the end of the 1980 decade, a new increase occurred, due to the increasing prices and bank credits through a financial stimuli to the blackpepper culture and availability of new cv. 'Bragantina', 'Guajarina' and 'Iacara' with high productivity (EMBRAPA 2008). Introduction of new cultivars in the 80's and 90's, as cv. 'Guajarina BR 353', 'Bragantina BR 124' and 'Iaçará-1', to partially substitute cv. 'Espírito Santo' (pimanta-da-terra) and 'Cingapura BR- 19', introduced since the 1970 decade, has contributed to the increment of the productivity in the State of Espírito Santo (Milanez *et al.*, 1987), from 1,300 kg ha^{-1} in 1981 to a productivity of 3,636 kg ha^{-1} in 2006 (Serrano *et al.* 2008).

In Brazil, black pepper is manly used for preparation of industrialized food (Bologna sausage, salami, sausage, ham, cold meat, *etc.*). However, significant quantities are trade in the form of berries or powdered pepper in small packs sold in super-markets and county markets. A small quantity is used in the fabrication of food tempers, in the pharmaceutical industry, in cosmetics and perfumes and as a natural insecticide.

Economic and social importance

World's pepper production during the last decade has been always more than 270 thousand tons (table 1), with approximately 85 % of black-pepper, 15 % of white-pepper and a small quantity of green pepper in pickles. The biggest world producer is Vietnam, followed by India and Brazil, with these last two countries being the biggest exporters (International Pepper Community 2008).

Table 1. World production, commercialized prices and Brazilian participation in the total production (modified from IPC 2008)

Year	Production (tons)		Brazilian participation	Mean price
	World	Brazil	(%)	per kg (US$)
1995	189,174	20,000	10.57	2.65
1996	191,771	25,700	13.40	3.00
1997	187,000	18,000	9.63	4.50
1998	205,034	17,000	8.29	5.20
1999	218,740	22,000	10.06	4.85
2000	254,210	30,000	11.80	3.40
2001	305,696	43,000	14.07	2.25
2002	441,312	45,000	10.20	1.56
2003	355,160	50,000	14.08	1.50
2004	294,159	45,000	15.30	1.48
2005	299,275	40,000	13.37	1.36
2006	289,230	44,500	15.39	2.04
2007	271,040	35,000	12.91	3.02
2008	262,900*	33,000*	12.55*	3.56**

(* estimated; ** until August)

In 2007, Brazil produced 35 thousand tons and exported 36 thousand tons (34 thousand tons of black pepper and 2 thousand tons of white-pepper), originated from 2007 production and from production stocks from preceding years. For the year of 2008 there is a production and export expectation of 33 thousand tons. The country's internal consumption is about 6 to 8 thousand tons per year (IPC 2008).

During the last few years Brazilian export has been always more than 30 thousand tons, representing about 0.5 % of the export in Brazilian agribusiness (Instituto Brasileiro de Geografia e Estatística – IBGE 2008).

Brazilian production during the actual decade was higher than during the 1990's decade. With the increase of world production in the beginning of the decade (2001 to 2005), there was also a decrease in prices in the international market (similar to the ones occurred during the end of the 1980's and beginning of 1990's), thus, consequently a reduction in Brazilian export occurred, with a little increase since 2006 (table 1).

Despite Brazil being one of the countries possessing the most advanced technology in the production process, the country has problems in the international market, due to its low quality standard, thus achieving lower prices compared to other exporting countries. The biggest importers of Brazilian pepper in 2007 were United States, Germany, Netherlands, Spain and France, with a volume of 11,797; 6,317; 2,188; 1,675 and 1,319 tons respectively (IPC 2008).

Major part of the pepper production (80 to 85 % of the total production) is by small farmers (family growers), with financial aid from the National Program of Strengthen of the Familiar Agriculture (PRONAF). These growers had prices of guarantee for their production (Program of Guarantee Prices for the Familiar Agriculture), established by the government at an actual value of US$ 1.00 / kg.

In social terms, pepper is considered a work absorbing culture, one each ton of harvested pepper corresponds to one job in the field. The culture of pepper generates income of more than 30 million dollars per year and about 120 thousand jobs during the cultivation season (EMBRAPA 2008). This fact has a social importance, once creating jobs in the county side it reduces rural exodus to bigger urban centers.

At present, Brazil has a cultivated area of over 30,000 hectare, with a mean productivity of 1,200 kg per hectare. The State of Pará (Northern Region) accounts for 83 % of the production, followed by the State of Espírito Santo (Southeastern Region), with 10 % of the production and the State of Bahia (Northeastern Region- Atlantic Forest), with 5 %, the rest of the country counts for the rest (2 %) of the production (IBGE 2008). Brazil has large favorable areas for pepper production and large areas with water limitation, thus showing a big potential to increase its production without the necessity of deforestation, as there are many agricultural areas without proper use or even degraded but able to be recovered.

In terms of external market, the biggest Brazilian pepper volume export occurred in 1991 with 47,553 tons. Later, production, as well as export reduced drastically, with the highest reduction in 1997, with only 10,000 tons. Studying pepper market Filgueiras (2002), concluded that this product offer was inelastic to price in Brazil. This result was expected, once the demand for the product behaves in irregular way to fluctuations in prices, ruled by the international market. The production of pepper occurs in cycles, as the average permanent cultures, once the grower's expected prices are above or under the price received by the selling product or paid by the acquired input, the prospect made with base on the grower's prices is unsatisfactory (Santana & Silva 1998).

With regard to the price of pepper paid to the grower, great oscillations are observed, especially because commercialization is still a great obstacle for growers. Because of the oligopsony market of pepper in Brazil characterized by the existence of a small number of buyers or even when more number of buyers exist, a small part of them are responsible for an expressive amount of buying in the market.

Pepper growers went through a serious price crisis between the years 2002 and 2006, when prices under US$ 1.00 / kg did not meet the costs of production. This fact occurred due to the great product offer in the international market, especially offered by Vietnam. From the second semester of 2006 and ahead, world stocks of the product decreased, as well as the Vietnamese production, which increased world price of pepper. In Brazil, some price peaks were observed in October 2006 (US$ 2.60 / kg), May of 2007 (US$ 3.90 / kg) and at the end of February 2008 (US$ 4.10 / kg).

The increasing pepper prices in the last two years are stimulating the traditional Brazilian pepper growers to invest and modernize their plantations, also motivating growers from the States of Acre, Amazonas, Amapa, Roraima, Rondônia, Tocantins (North Region), Minas Gerais (Southeast Region), Ceara and Paraíba (Northeast Region) to establish the plantation.

Crop management

Pepper requires hot and humid climate. In Brazil, most part of the plantations occurs in regions up to 200 m altitude and relative humidity arround 60 and 85 %. The two main producing regions of the country have their particularities: in the State of Pará plantations are located in areas with precipitation of almost 2,000 mm / year and mean temperatures between 26 and 28 °C; in Espírito Santo State pepper is cultivated in areas with precipitation of 1,200 mm / year and mean temperature of 23 °C. Irrigated plantations represent more than 80 % of the cultivated plots (micro-spray, drip-irrigation, conventional spray irrigation) (Serrano *et al.* 2006).

In general, the State of Espírito Santo uses more technology when compared to the State of Pará, with the consequent higher productivity (about 3,000 kg per hectare). This State also made better use of fertilization (including fertilization), use of horizontal driers, concreted drier floor, solar ovens or transparent plastic ovens for pepper drying (Fig.1) and mechanical driers besides machines for pre-cleaning, cleaning and classification of pepper. This fact is due to the useful employment of the structures used in *Coffea canephora* culture, as Espírito Santo State produces more than 10 millions bags of 60 kg/year of this product.

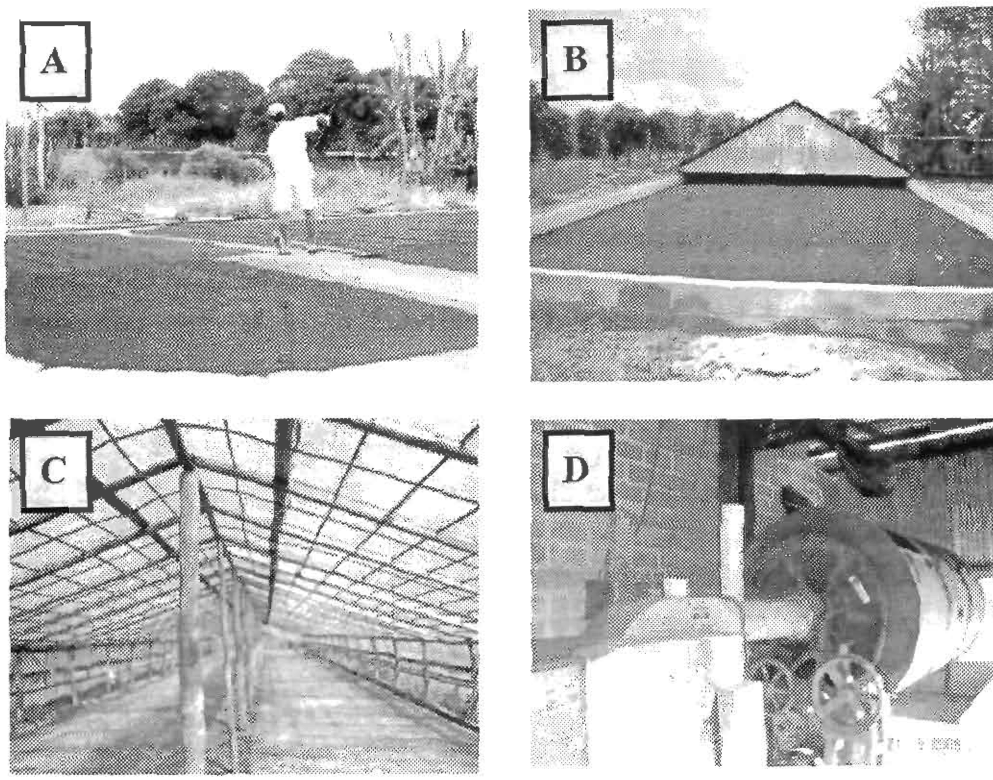

Fig.1. Black pepper drier systems
A – open concreted floor; B – concreted floor boat type; C – concreted floor with plastic cover and D – horizontal drier.

Cultivars 'Bragaantia BR-124', followed by 'Icara', 'Cingapura BR-019' and 'Guajarina BR-353' are at the moment the most planted in the country. In the State of Pará, for plantations in shaded conditions cultivars 'Apra' and 'Kuthiravally' are recommended. For industrial purposes (oleoresin and essential oil extraction) cv. 'Kottanadan' is recommended (Serrano *et al.* 2008).

Pepper plantings are asexually originated, from cuttings derived orthotropic branches of adult vine. Growers purchase planting material from plantations certified by the Agricultural Ministry. The common spacing used are in single or double row varying from 1,333 to 2,500 plants per hectare.

Economical success in permanent species plantation is directly dependent on the planting material quality, representing the most important input for the implementation of the culture, thus planting material must have a good genetic constitution, must be free of diseases, pests or physical/mechanical damages and low cost. The price of a pepper planting in the country is about US$ 0.75. The cost of plantation implementation in Espírito Santo State is of about US$ 7.50 when using cutting of high quality (US$ 5.00 per cutting unit). In the State of Pará the cost for implementation is lower, as the availability of cuttings is higher, with each unit commercialized at approximately US$ 1.20.

For cultivation of pepper under full sun conditions, the use of high resistant wood for stacking, for example wood sticks made of *Melanoxylon breuna* or even concreted stacking, is recommended. Sticks must have 3 m length with 10 to15 cm thickness. For shaded cultivation the use of live stacking is recommended with species such as *Azadiracta indica*, *Gliricidia sepium*, *Schizolobium parahiba* or *Erythrina fusca*. Shaded systems allows a reduction in implementation costs of about 21 % compared with wood stacking system, but productivity decreases due to competition for nutrients, water and light.

The nutritional diagnosis is performed through soil and foliar analysis, with sufficiency range or DRIS (Diagnosis and Recommendation Integrated System) commonly used for the foliar analysis, with specific norms existing for the State of Pará and Espírito Santo. For the production, 120 to 200 kg of N, 50 to 80 kg of P_2O_5 and 180 to 250 kg of K_2O per hectare per year are recommended.

Main difficulties of pepper plantations

One of the major difficulties is the high risk investment that this activity represents, as it has a high implantation and maintenance costs, fluctuation and uncertainty of future prices, necessity of irrigation (Espírito Santo State), problems with diseases and pests and even commercialization problems (traders keep main part of the profits leaving growers with a minimum final profit).

Absence of investments in research, related directly with the lack of studies and development of new techniques, processes and cultivars have been one major problem to surpass the problems in this activity, which lacks also professional and technical guidance to accomplish the correct activity management in the field and during post-harvest.

In Brazil the main disease is caused by the soil fungus *Fusarium solani* f. sp. *piperis* that spreads rapidly within the plots destroying in a short period of time big cultivated areas. This problem becomes even more serious especially due to the reduced genetic base, associated with favorable environmental conditions of temperature and humidity. Still, there is not an efficient disease control measure in Brazil, thus prevention management measures have been recommended, such as the implementation of the culture in distant areas from the diseases plantations, selection of cuttings from healthy and vigorous plants, treatment of planting material, sterilization of substrate for rooting and control nematodes in contaminated areas, avoiding wounding of roots and other plant parts, performed soil drainage in clay soils, the use of cover crops during dry season and use of organic manure, avoidance of re-use of stacking materials and transit of people and machinery from contaminated areas. Other important diseases caused by fungi (*Colletotricum gloeosporioides* and *Pellicularia koleroga*) can be more efficiently controlled.

Another problem is the presence of soil nematodes (genus *Meloidogyne*), with a difficult, expensive and inefficient control. The pepper mosaic, caused by virus (CMV-Pn), also damages plantations with incidence of small, narrow, tortuous leaves with yellowish areas. In the field there are evidences that the cv. 'Iacara' is more sensitive to the incidence of CMV-Pn (Serrano *et al.* 2006).

These diseases cause a high level of plant mortality (about 80 % of the diseased plots) and a drastic reduction of the useful life of pepper plantations, from 20 years to a maximum of 8 years, with severe damages to pepper growers (especially small growers), that unfortunately are pessimistic with the culture.

Important research works conducted in Brazil

Plant nutrition

According Veloso *et al.* (1995) the main production areas of pepper in Brazil are located in regions characterized for acid soils, with low base saturation and fertility and frequently having aluminium and manganese in enough quantities to limit the normal development of plants. These researchers concluded that the addition of 20 mg Al per liter in the substrate, reduces dry matter weight and nutrient and Al absorption, which was associated at the beginning of the toxicity effect. The initial toxicity symptom of Al was characterized by a delay in root growth, with an increase in root diameter. Pepper accumulates and tolerates the presence of aluminium concentrations under 20 mg/L in the substrate, however higher doses promote nutritional disturbances in the plant.

In the Amazon region of Brazil, Chiba & Terada (1976), determined the absorption march of macronutients in the field, concluding that nitrogen was absorbed in small quantities by young plants and absorption increased with plant growth. Nutrients absorbed in higher quantities by pepper plants were K and N, followed by Ca > Mg > S > P in a decreasing order. The absence of nitrogen affected plant development, followed by absence of calcium and potassium. Nutrient contents of leaves of the complete treatment and in the absence treatment were: N = 1.89 and 1.39%, P = 0.12 and 0.06%, K = 2.19 and 1.22%, Ca = 1.04 and 0.73%, Mg = 0.35 and 0.14%, S = 0.18 and 0.12% (Veloso & Muraoka 1993).

In the same region Veloso *et al.* (2000), reported a positive response to nitrogen with relation to pepper berries production with the application of 72 and 78 kg ha^{-1} of N, in cv. 'Cingapura' and 'Bragantina' respectively. Only cv. 'Guajarina' responded to phosphorus application. The addition of potassium favored the increase of berries production with the application of 42, 13 and 22 kg ha^{-1} of K_2O, for cv. 'Cingapura', 'Bragantina' and 'Guajarina', respectively.

A study performed in the State of Paraiba (Northeast Region) reported that pepper plants respond positively to bovine manure application. Maximum green pepper productivity per plant, from genotypes 'Bragantina (1012 g), 'Iacara' (11269) and 'Cingapura' (627 g), was obtained with doses of 7.3, 8.6 and 7.0 kg of manure per plant respectively. For dry pepper production, doses of 6.5, 8.9 and 7.8 kg of manure per plant resulted in maximum production of 358, 793 and 204 g $plant^{-1}$ in genotypes

'Bragantina, 'Iacara' and 'Cingapura' respectively (Oliveira *et al.* 2007). These authors also observed that higher quantities of manure may be detrimental to development of these cultivars.

Plant physiology

Whit the objective of simplifying foliar area evaluations among pepper cultivars planted in Brazil Partelli *et al.* (2007), determined equation in order to determine leaf area in a non-destructive method. The equations best-fitted to estimate leaf area (LA) based on circumscript rectangle were: 1) LA = 2.2689 + 0.6900 x leaf midrib length x maximum leaf broad width; 2) LA = 1.6402 + 0.6816 x leaf midrib length x maximum leaf broad width; 3) LA = 1.4942 + 0.6215 x leaf midrib length x maximum leaf broad width and 4) LA = 0.7467 + 0.6735 x leaf midrib length x maximum leaf broad width, for Bragantina, Iaçará, Guajarina and Cingapura cultivars respectively. For all equations predicted values had a high correlation coefficient with observed values, thus showing that these equations are variety specific and that they are appropriate for black pepper.

Genetics and breeding

In the State of Pará Gaia *et al.* (2005), analyzed 78 clones of *Piper nigrum* L. with isozymes electrophoresis techniques for the ACP, GOT, SKDH, ACO, G6PDH, PGI, 6PGDH and FUM systems, to evaluate diversity by means of polymorphic locus percentage, mean allele number per locus and mean heterozygosity. These authors detected 14 loci and 35 alleles. Loci showing higher diversity were: G6pdh-1, Acp-1 and Skdh-1. The percentage of polymorphic loci varied from 3.57% to 64.29%, mean allele number varied from 0.04 to 1.64 and mean heterozygosity varied from 0.036 to 0.321. The low values observed within the variation interval of mean heterozygosity are consistent with the narrow genetic base of the genotypes and the amplitude of this interval may be related with the hybridation degree (natural or artificial) of each clone. Genetic similarity varied from 65 % to 100 %, with 70 clones within the range of 85 and 100 %, thus confirming the narrow genetical base of the species and consequently the homogeneity of genomes planted in Brazil.

Diseases

While studying plants with *Fusarium solani* f. sp. *piperis* symptoms in the State of Alagoas (Northeast Rcgion) Carnaúba *et al.* (2007), this fungus was characterized based on morphology and size of reproductive structures. Macroconidia are falcate, some are almost straight, hyaline, with three to five septa, measuring 30.5 - 26.5 x 6.3 – 4.9 um, while microconidia are hyaline, unicellular, elliptic shaped or allantoid measuring 16.6 – 4.9 x 6.5 – 3.3 um.

In Brazil, pepper is multiplied especially through cuttings, however this procedure may facilitate *Fusarium solani* f. sp. *piperis* spread. Thus, the efficiency of pepper micro-propagation using different concentrations of BAP (0.5, 1.5, 3.0 and 4.5 mg L^{-1}), with the addition of 2 % activated charcoal to the culture medium was verified by Moura *et al.* (2008). These authors reported that after 45 days pepper stem tips cv. "Bragantina' reacted better to the lowest concentration of BAP (0.5 mg L^{-1}), with higher shoot and explants formation. The use of activated charcoal was not necessary during *in vitro* shoot and explants proliferation stage when using young tissues as initial source for cultivation, yet activated charcoal may be used at the final stages of the vegetative *in vitro* propagation process.

Human health

While studying the effect of pepper extracts over *Aedes aegypti* (transmission agent of the dengue fever – arthropod-born virus) Simas *et al.* (2007), verified that fractioning *Piper nigrum* ethanolic extract, in bioassays on pyrethroid-resistant *Aedes aegypti* larvae, resulted in the isolation of the larvicidal amides piperolein-A and piperine. Comparing LC50 values, the ethanol extract (0.98 ppm) was the most toxic, followed by piperolein-A (1.46 ppm) and piperine (1.53 ppm).

Product quality

With the objective of determine the identity and quality standard of berries papper in Brazil, the Agricultural Ministry approved in May 15th 2006, the 'Technical Regulation for identity and quality of pepper'. The quality characters determined for pepper of black and white classes are shown in table 2.

Table 2. Quality characters determined for black and white pepper

Classes	Moisture (max %)	Ether extract (min %)	Impurities (max %)	Lighat berries (max %)	Berries with fungi (max %)	Grey berries (max %)	Minimum density (g L^{-1})
				Black pepper			
Brasil ASTA	14	6.75	1.0	2	1	-	560
Brasil 1	14	6.75	2.0	5	2	-	540
Brasil 2	14	6.75	5.0	25	2	-	500
				White pepper			
Brasil ASTA	15	6.5	0.5	1	1	5	-
Brasil 1	15	6.5	1.0	2	2	15	-
Brasil 2	15	6.5	3.0	4	2	30	-

Final considerations

In Brazil, the necessity of having a high quality product, in accordance with actual market demmands has been discussed for a long time, however due to the cost of equipments and lack of political engagement there was an enormous delay to the implementation of an improved quality standard. With the implementation of the 'Technical Regulation of identity and quality of pepper' approved in 2006, there is a good prospect for a better product quality as well as the expectation for a better price paid to the growers that would join the regulation.

Despite the investment risks and great variation in prices, Brazilian growers are returning again to invest in this activity, due to the actual prices increment. It is also important to make available new management techniques as pruning techniques, organic fertilization, use of denser spacement plantation, use of live stacking, associated plantation with forest and other agricultural species, new systems of stacking, *etc.* Regardless difficulties and limitations for this activity Brazil show a great potential to increase its pepper production and competitivity on the international market. To achieve this objective some actions are being already implemented, as the creation and strengthening of cooperatives and research groups, higher quality control in plantations and cutting nurseries, execution of scientific and informative events and meetings, higher agricultural bank credits, *etc.* A strategic area that has deserved a special focus is cultivar breeding and genetic improvement of pepper, especially aiming resistance and tolerance to diseases, use of alternate stacking and irrigation.

References

Albuquerque F C & Condurú J M P 1971 Cultura da pimenta do reino na Região Amazônica. Instituto de Pesquisa Agropecuária Norte - IPEAN, Belém, 149 p.

Carnaúba J P, Sobral M F, Amorim E P R & Silva I O 2007 Ocorrência de *Fusarium solani* f. sp. *piperis* em *Piper nigrum* no Estado de Alagoas. Summa Phytopathologica 33: 96-97.

Chiba M & Terada S 1976 On the optimum amount of fertilizer based upon the amount of nutrients absorbed by pepper plant in Amazonia Region. Japanese Journal of Tropical Agriculture 20: 14-21.

EMBRAPA Embrapa Amazônia Oriental 2008 Sistema de produção da pimenteira-do-reino: cultivo da pimenta-do-reino na Região Norte. Available online at http://www.cpatu.embrapa.br (accessed on 17 October 2008).

Filgueiras G C 2002 Crescimento agrícola no Estado do Pará e a ação de políticas públicas: avaliação pelo método shift-share. MsC thesis. Universidade da Amazônia, Brasil, 156 p.

Gaia J M D, Mota M G C, Derbyshire M T V C, Oliveira V R, Costa M R, Martins C S & Poltronieri M C 2005 Diversidade e similaridade genéticas em clones de pimenta-do-reino. Horticultura Brasileira 23: 221-227.

Instituto Brasileiro de Geografia e Estatística – IBGE 2008 Pimenta-do-reino. Available online at http://www.ibge.gov.br/sidra (accessed on 15 October 2008).

International Pepper Community – IPC 2008 Brazilian Peppertrade Board: Statistics. Available online at http://www.peppertrade.com.br/statsini.htm (accessed on 15 October 2008).

Milanez D, Ventura J A & Fanton C J 1987 Cultura da pimenta-do-reino. EMCAPA, Vitória, 94p.

Moura E F, Menezes M C & Lemos O F 2008 Concentrações de citocinina e carvão ativado na micropropagação de pimenta-do-reino. Ciência Rural 38: 72-76.

Oliveira A P, Alves E U, Silva J A, Alves A U, Oliveira A N P, Leonardo F A P, Moura M F & Cruz I S 2007 Produtividade da pimenta-do-reino em função de doses de esterco bovino. Horticultura Brasileira 25: 408-410.

Partelli F L, Vieira H D & Viana A P 2007 Estimative of Black Pepper leaf area with basis on the leaf blade linear dimension. Ciência Rural 37: 1458-1461.

Santana A C & Silva M C 1998 Análise de mercado e ações para políticas. SAGRIFCAP, Belém, Brasil, 52p.

Serrano L A L, Lima I M & Martins M V V 2006 A cultura da pimenteira-do-reino do Estado do Espírito Santo. INCAPER, Vitória, Brasil, 34p.

Serrano L A L, Novak L R & Lima I M 2008 Colheita e pós-colheita da pimenta-do-reino. INCAPER, Vitória, Brasil, 40p.

Simas N K, Lima E C, Kuster R M, Lage C L S & Oliveira Filho A M 2007 Potential use of *Piper nigrum* ethanol extract against pyrethroid-resistant *Aedes aegypti* larvae. Revista da Sociedade Brasileira de Medicina Tropical 40: 405-407.

Veloso C A C, Carvalho E J M, Malavolta E & Muraoka T 2000 Resposta de cultivares de pimenta-do-reino aos nutrientes NPK em um Latossolo Amarelo da Amazônia Oriental. Scientia Agricola 57: 343-347.

Veloso C A C, Muraoka T, Malavolta E & Carvalho J G 1995 Efeitos do alumínio em pimenteiras do reino *(Piper nigrum* L.) cultivadas em solução nutritiva. Scientia Agricola 52: 368-375.

Veloso C A C & Muraoka T 1993 Diagnóstico de sintomas de deficiência de macronutrientes em pimenteira do reino *(Piper nigrum* L.) Scientia Agricola 50: 232-236.

An overview of black pepper genetic resources and crop improvement

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Introduction

Black pepper (*Piper nigrum* L.) known as the "king of spices" is one of the oldest spices known to the world. Native to India, pepper has played a very important role throughout the history and has been a prized spice since ancient times. Pepper became an important spice that catalyzed much of the spice trade. This has not only led to exploration of many undiscovered lands, but also to the development of major merchant cities in Europe and Middle East.

The major commercial producers of pepper are India, Vietnam and Malaysia. Indonesia, Brazil, Thailand and Sri Lanka are the other countries producing black pepper substantially. In India, Kerala, Karnataka, Tamil Nadu, Pondicherry and Andaman & Nicobar Islands are the pepper producing states.

Biodiversity and conservation

The genus *Piper* belongs to the family Piperaceae. *Piper* is the largest genera in the family (more than 1000 species) followed by *Peperomia* (more than 500 species). The genus *Piper* is of considerable economic importance, as a large number of its members are of medicinal and culinary importance. The genus included herbs, shrubs or lianas, with swollen node, simple entire and alternate leaves and leaf opposed spikes.

Trans Gangetic region and the South Deccan are considered to be the two independent centers of origin of the genus *Piper* in India (Hooker 1886). Maximum diversity of *Piper* spp. is occurring in American tropics (700 spp.) followed by Southern Asia (300 spp.), the South Pacific and the African tropics (Jaromillo & Manos 2001).

The *Piper* species originated from the South Asia are of more importance since the economically important species like *P. nigrum* (black pepper), *P. betle* (betel vine), *P. longum* (long pepper), *P. chaba* (Java long pepper) *P. cubeba* (cubeb or tailed pepper) *etc.* are originated from this region. The most economically important species, *P. nigrum* is believed to be originated from the wet humid regions of the Western Ghats of South India.

The sub-mountainous tracts of Western Ghats are considered as the centre of origin of black pepper-*Piper nigrum* L. Even though the ecosystem diversity does not contribute much to the diversity of black pepper, species diversity and varietal diversity are considerable. (Hooker 1886; Gamble 1925; Rahiman 1981; Ibrahim *et al.* 1985; Sasikumar *et al.* 1999a).

Hooker (1886) reported 45 species of *Piper* in his 'Flora of British India' under six sections *viz.* Muldera, Cubeba, Chavica, Pseudo chavica, Eupiper and Heckaria. Cooke (1906) in his 'Flora of the Presidency of Bombay' reported five species of *Piper*. Burkill (1923) included 13 species of *Piper* in his 'Flora of Abhor hills' of North Eastern India, while Kanjilal *et al.* (1940) in their 'Flora of Assam region' reported three species. Duthie (1960) in his 'Flora of Upper Gangetic plains and the adjacent Siwalic region and sub Himalayan tracts' included *P. longum, P. betle, P. mullesua, P. nepalanse and P. nigrum*. Haines (1924) in his 'Botany of Bihar and Orissa' reported five species of *Piper viz. P. longum, P. peepuloides, P. chaba, P. attenuatum and P. nigrum.* Rama Rao (1914) listed 14 species of *Piper* from Western Ghats. The most authoritative floristic study of Western Ghats was that of Gamble (1925), who in his flora of 'Presidency of Madras' listed 14 *Piper* species along with key for identification of each species.

A few more species were reported by researchers later. Ravindran *et al.* (1987); Velayudhan & Amalraj (1992); Nirmal Babu *et al.* (1993) reported four new taxa from the Western Ghats region of Kerala. The recently reported new species of *Piper* are: *P. silentvalleyensis, P. nigrum.* var. *hirtellosum*, and *P. sugandhi* from the Sugandhagiri hills of Wayanad district. Gajurel *et al.* (2000) reported a new record of *P. acutistigmum* CDC in India which is a nature of Myanmar. Gajurel *et al.* (2001 a, b & 2007) reported three new species *viz., P. haridasanii*- a rare species, *P. arunachalenisis*, and *P. nirjulianum*. The areas of distribution of some important *Piper* species are given in table1.

Table1. Details of the more important species of the *Piper* and their areas of distribution

S.No.	Species	Area of distribution
1	*Piper galeatum* Cas. DC.	Western Ghats from Coorg to Travancore, Wynad, Annamalais, hills of Courtallam, in forests at low levels upto 2500 ft.
2	*P. trichostachyon* Cas. DC.	Western Ghats, Konkan, Canara, Coorg, Wynad, Sivagiri, hills of Thirunelveli and Nilgiri hills – in forests upto 2500 ft.
3	*P. sumatranum* Cas. DC.	Andaman Islands
4	*P. griffithi* Cas. DC.	Assam
5	*P. caninum,* Blume var. *glabra,* Helfer.	Andaman Islands
6	*P. muricatum, Blume* var. glabrata *Giffith.*	Mishmi hills in upper Assam

7	*P. longum* Linn.	Hotter parts of India from Cental Himalayas to Assam. Khasi and Mikir hills, lower hills of Bengal, ever-green forests of Western Ghats from Konkan to Kanyakumari and Carnicobar Islands at lower elevations
8	*P. peepuloides* Roxb.	Tropical Himalayas from Nepal to Bhutan, Assam, Khasi and Mikir hills upto 3000 ft.
9	*P. chaba* Hunter	Cultivated in various parts of North Eastern India
10	*P. sylvaticum* Roxb.	Upper Assam in marshy districts
11	*P. petiolatum* Hook.	Upper Assam, Mishmi hills
12	*P. betle* Linn.	Cultivated in hotter and damper parts of India- Kerala, Karnataka, West Bengal, Tamil Nadu and Assam *etc.*
13	*P. boehmeriaefolium* Wall. Cat.	Tropical Eastern Himalayas, Sikkim ascending to 5000 ft., Assam, Silhet and Khasia mountains.
14	*P. anisotis* Hook.	Upper Assam
15	*P. aurantiacum* Wall.	*Assam*
16	*P. hapnium* Ham.	Western Ghats – in the hills of Kerala, Courtallam (Very rare, endangered species).
17	*P. mullesua* Ham. (*P. brachystachyum* Wall.)	Subtropical Himalayas from Simla to Bhutan- 2000-5000 ft., Khasia mountain – 3000-5000 ft., Western Ghats- Nilgiri hills, Annamalais, Pulneys and hills of Kerala in Shola forests about 5000 ft., Bababudan hills of Karnataka
18	*P. thomsonii* Hook.	Himalayas- Sikkim at 7000 ft., Khasia mountain from 3000-4000 ft.
19	*P. hamiltonii* Cas. DC.	Sikkim, Assam, Silhet and Khasia mountains
20	*P. hookeri* Miq.	Konkan and Canera – Mahabaleshwar and Bababudan hills of Karnataka
21	*P. schimidtii* Hook f.	Western Ghats: Silent valley, Nilgiri hills about 5000 ft. (rare, endangered species)
22	*P. nepalense* Miq.	Sub-tropical Himalayas 3000-5000 ft. from Garhwal, Bhutan and Mishmi hills, Khasia mountain 3000-5000 ft.
23	*P. khasianum Cas.*	Sikkim, Himalayas at 2000-6000 ft., Upper Assam Khasia mountains at 3000-5000 ft.

24	*P. nigrum* Linn	In the ever-green forests of Western Ghats well distributed up to 5000 ft. and largely cultivated in the States of Kerala, Karnataka and Tamil Nadu
25	*P. nigrum var. hirtellosum* Asokan & Ravindran	Silent Valley forests of Kerala
26	*P. attenuatum* Buch. Ham.	Eastern tropical Himalayas-Sikkim, Assam-Silhet and Khasia mountains, Western Ghats- Nilgiris, Thirunelveli in ever-green forests at low levels. Shevroy and Kolli hills and hills of A.P. and Orissa upto 3000 ft.
27	*P. sylvestre Lamk.*	Assam-Silhet and Courtallam
28	*P. argyrophyllum* Miq.	Western Ghats from Mysore and Bilgiris South-wards in ever-green forests at 1500 to 5000 ft.
29	*P. wightii* Miq.	Nilgiris and Pulney hills of Western Ghats above 6000 ft. in Sholas (rare, endangered species)
30	*P. barberi* Gamble	Hills of Thirunelveli and Breymore (Trivandrum) (very rare, endangered species)
31	*P. silentvalleyensis* Ravindran, Nair and Asokan	Silent valley forest, Kerala (very rare, endangered)
32	*P. sugandhi* Ravindran, Babu and Naik	Ever-green forests of Western Ghats, Sugandhagiri Project area of Wynad
33	*P. sugandhi* var. *brevipilis*, Ravindran, Babu and Naik	Ever green forests of Western Ghats, Sugandhagiri Project area of Wynad
34	*P. pseudonigrum* Velayudhan *et* Amal Raj	Silent valley forests of Western Ghats

Source: Ravindran P N & Nirmal Babu K (1994)

Cultivar diversity is one of the principal components of diversity in black pepper. The cultivars are evolved directly from the wild *P. nigrum*. Natural selection and conscious selection by human endeavor for various traits have created diversity in cultivars. Most of the vernacular names of black pepper varieties indicate a specific feature of the vine such as colour or appearance of the vine, leaf shape, spike features or the place from which the vine originated initially.

The easy movement of setters across the length and breadth of Kerala helped the spread of landraces (cultivars) to new areas, however, the advent of improved high yielding black pepper varieties is becoming a serious threat to many of the old local cultivars. These local cultivars/landraces may be lost if they are not collected and conserved. The species of *Piper* are the most affected by deforestation. Many of the taxa are now confined only to a few locations and may vanish from the planet, unless it is collected and conserved. *Piper* species like *P. barberi*, *P. hapnium*, *P. silentvalleyensis* are confined only to small pockets and they have been listed in the 'Red data' book published by the Botanical survey of India under the 'endangered' category.

Collection and conservation of black pepper germplasm is one of the important objectives of Indian Institute of Spices Research, Calicut (IISR). The scientists of IISR are conducting systematic surveys of all pepper growing areas, forests of Western Ghats, parts of North Eastern India, Andaman & Nicobar Islands for collecting the available variability and preserve them. Wide collection of both species diversity and cultivar diversity have been carried out and they are all being maintained at the conservatory of black pepper at IISR, Calicut with a total collection of 2575 accessions (1300 cultivars, 1266 wild and 9 exotic collections).

In situ conservation of Piper species

In situ conservation of biodiversity is more desirable than *ex-situ* since the species conserved is subjected to co-evolve with environmental changes. It is important that sanctuaries of wild relatives and other economically important species are to be established in the Western Ghats and the North Eastern India-the two independent centres of origin of *Piper* species in India. Velayudhan *et al.* (1999) suggested the establishment of gene sanctuary for *Piper* species at Silent valley, since the species diversity is more here. Utpala *et al.* (2006) have identified the Western Ghats region spreading from Wayanad to Palghat District and Kollam, Thirunelveli and Thiruvananthapuram as the hotspots for *Piper* in South India. It will be appropriate to establish gene sanctuaries of *Piper* in these areas.

Ex-situ conservation

Field genebank: The germplasm accessions collected by IISR are conserved in the field genebank and in the nursery. For safe guarding the germplasm accession, two alternate centres were identified at CPCRI, Seed Farm, Kidu and CRC Appangala, Karnataka for cultivars and wild germplasm, respectively.

In vitro Conservation: The slow growth technologies for *in vitro* conservation have been standardized and at present the *in vitro* gene bank is holding 35 accessions. Besides IISR, Calicut, the National Bureau of Plant Genetic Resources, New Delhi is also having *in vitro* conservatory for *Piper* species. In addition to IISR, Calicut, a few research centres under the All India Coordinated Project on Spices (AICRPS) are also maintaining the black pepper germplasm.

Germplasm registration

Registration of valuable and important germplasm will meet the requirement of the intellectual property right and released issues, breeders' right, farmers' right, *etc.* In this endeavor, IISR Calicut has registered three unique germplasm of *Piper*. They are,

- Collection No. 5455 (IC 370011) *Piper nigrum* wild – a local selection from Nelliampathy, Palghat district, Kerala for high oleoresin content and bold berries (INGR 0411).
- Collection No. 1041 (IC 316598) - a local cultivar – Thevammundi for its field tolerance to foot rot disease.
- CLTP 123 (IC 316588) – collected from Ponkunnam, Kottayam for high caryophyllene content.

Economically important *Piper* spp

It includes important cultivated species like *P. nigrum*, the black pepper and the betel vine *P. beetle*. The dried fruits, in powdered form or as a whole and oils and oleoresin extracted from the berries are the ones used all over the world. Besides black pepper, *Piper betle* L. is another economically important species which is widely cultivated in India for its leaves for the pan Industry. The essential oil from leaves is used in respiratory catarrh and also as an antiseptic. The plant is considered by the tribals as useful in treating madness, strangulation of the intestine, venereal sore, dysentery *etc*.

Long pepper (*Piper longum* L.) is used in Ayruvedic and Unani system. Long pepper forms as an important Ayurvedic preparation such as Trikadu (dry ginger-long pepper-black pepper) and panchakolam. Both fruits and dried roots are used for medical preparations. The long pepper of commerce appears to be derived from four *Piper* species. The dried spikes of *P. peepuloides* are also sold as long pepper. The spikes of *P. hapnium* and globoid spikes of *P. mullesua* are also sold as long pepper in the Indian market. The Indonesian or Java long pepper (*P. chaba*) is also known as gaja thippali or bengla thippali is another variety of long pepper. The species is cultivated in Assam and West Bengal and also in Indonesia/Malaysia. True Indian long pepper is derived from *P. longum*, from wild grown plants in Assam, West Bengal, Nepal, North Eastern region, Bihar, Uttar Pradesh, Kerala, Tamil Nadu, Andhra Pradesh *etc*.

Cubeb or tailed pepper (*Piper cubeba* L.) cultivated in Indonesia and Malaysia is having high therapeutic value. Fruits and oil extract of *P. cubeba* are used in treatment of asthma. Kawa pepper- *P. methysticum* G. Frost- a native of South Pacific Islands is used to make a non-alcoholic but narcotic drink, Kawa – a ceremonial drink among the Polynesians since ancient period. The roots of *P. sylvaticum* Roxb. are widely used in indigenous medicine as an effective antidote for snake poison. The safrole rich oil of *P. hispedinervium* Trel. is highly prized in the perfumery. The plant is very rich in safrole, which is a natural chemical of various Industrial use.

Besides these economically important species, *P. auritum, P. borneense, P. decurrens, P. magnificum, P. metallicum, P. ornatum, P. porphyrophyllum, P. rubronodosum, P. rubrovenosum etc.* are valued for ornamental purpose.

Crop improvement in black pepper

Pepper being a vegetatively propagated perennial, the major bottle neck is damage caused by nematode *Radopholus similis,* fungus *Phytophthora capsici* and the pest *pollu*. Resistant/tolerant sources are available in the germplasm. This coupled with retention of good quality parameters will help in producing high quality black pepper with less usage of pesticides and fungicides. The most probable approach to bring these characters into a single genotype is by gene pyramiding through conventional methods.

Conventional approaches for genetic improvement

Domestication of black pepper started thousands of years back. Today about 100 traditional black pepper cultivars are prevalent in Kerala and Karnataka. Clonal selection, hybridization and open pollinated progeny selection are the major approaches followed in genetic improvement of black pepper.

Selection: Wide variability for yield and quality characters, occasionally even within a cultivar, is common in black pepper. Clonal selection in highly popular cultivars like 'Karimunda' and 'Kottanadan' has resulted in identifying superior varieties.

Hybridization: Hybridization procedure involves the removal of the anther lobes of the female spike (female parent) before the emergence of the stigma with a fine needle. Usually only the upper 2/3 part of the spike is retained and the rest is removed. Emasculated spikes are covered with butter paper bag or finely perforated polythene cover. Undehisced anthers from the spikes of male parent are collected on the previous day evening prior to pollination and kept in a vial in a desiccator. Next day morning, the vials are taken out, the anther lobes are gently crushed, and the dehisced pollen grains are mixed with a drop of water and the pollen suspension is applied on the stigmas of the emasculated spike with a small camel hair brush, after removing the bag from the spike. The spikes are again covered after pollination. Pollination is repeated for 3-4 days. The cover is retained till the development of the berries. So far four hybrids have been released *viz.,* Panniyur-1, Panniyur-3, IISR Girimunda and IISR Malabar Excel.

Open pollinated progeny selection : IISR Shakthi, an open pollinated progeny of Perambramundi was released by IISR, Kozhikode. Two more black pepper varieties, Panniyur 2 and Panniyur 5 are released, so far, through open pollinated progeny selection. The improved varieties released through the above breeding strategies and their salient features are given in table 2.

Breeding for nematode, disease and insect resistance: Root knot nematode (*Meloidogyne incognita*) is a serious problem in some black pepper tracts and a nematode tolerant cultivar 'Pournami', through germplasm selection has been developed. *Phytophthora* foot rot (quick wilt) is another very serious disease of black pepper. Coll. 1041, a clone of 'Thevanmundi', is found to be highly tolerant to foot rot disease under Valparai condition of Tamil Nadu. This cultivar is having a mean yield of 5 kg fresh berries per vine and is released as 'IISR Thevam'. Vanaja *et al.* (2008) developed a partly fertile interspecific hybrid resistant to *Phytophthora* foot rot disease using a cultivated *P. nigrum* and *P. colubrinum*- an exotic wild species resistant to foot rot disease, as parents. Morphological, anatomical and molecular studies confirmed their hybridity and this hybrid can be considered as a successful breakthrough for introgression of resistance to the cultivated species *P. nigrum* from the wild species *P. colubrinum*. Four accessions of cultivated black pepper *viz.*, Acc. No. 816, 841, 1084 and 1114 are found to be relatively resistant to '*pollu*' beetle. Incorporation of '*pollu*' beetle resistance through interspecific hybridization involving *P. attenuatum* and *P. barberi* with *P. nigrum* has been achieved (Sasikumar *et al.* 1999b).

Breeding for drought tolerance: Screening of germplasm against moisture stress has resulted in identifying few promising Karimunda lines *viz.*, Acc. 931, 1495 and 813. These drought tolerant lines are further utilized in breeding programme.

Breeding varieties suitable for high altitude: Most of the black pepper varieties are not specifically bred for high altitudes, where it can be grown either as a monocrop or as an intercrop on the shade trees of tea or coffee or cardamom estates. Evaluation of 100 hybrids at Valparai (3000 ft MSL) has helped in identifying 2 hybrids *viz.*, HP-813 and HP-105, which are released as 'IISR Malabar Excel' and 'IISR Girimunda' respectively. 'IISR Thevam' is another variety performing well at higher altitudes.

Table 2. Improved varieties/hybrids of black pepper and their salient features

Name	Pedigree	Institute/ University	Oleo-resin (%)	Piperine (%)	E. oil (%)	Remarks
Panniyur-1	F_1 of 'Uthirankotta' x 'Cheriyakaniy-akadan'	Pepper Research Station, Panniyur, Kerala Agriuc-ultural University (KAU)	11.8	5.3	3.5	Suited to all black pepper growing regions. Not suited to heavily shaded areas.
Panniyur-2	Open pollinated progeny selection of 'Balankotta'	-do-	10.9	6.6	3.4	Shade tolerant.
Panniyur-3	F_1 of 'Uthirankotta' x 'Cheriyakaniy - akadan'	-do-	12.7	5.2	3.1	Late maturing, suited to all black pepper growing regions.

Panniyur-4	Clonal selection from 'Kuthiravally'	-do-	9.2	4.4	2.1	Performs well under a variety of conditions. Stable yielder.
Panniyur-5	Open pollinated progeny selection of 'Perumkodi'	-do-	12.3	5.5	3.8	Tolerant to nursery diseases and shade.
Panniyur-6	Clonal selection of 'Karimunda'	-do-	8.3	4.9	1.3	Suited to all black pepper tracts.
Panniyur-7	Open pollinated progeny of 'Kalluvally'	-do-	10.6	5.6	1.5	Suited to all black pepper tracts.
Subhakara	Clonal selection from 'Karimunda'	Indian Institute of Spices Research, Calicut	12.4	3.4	6.0	Suited to all black pepper growing regions.
Sreekara	Clonal selection from 'Karimunda'	-do-	13.0	5.1	7.0	Suited to all black pepper growing regions.
Panchami	Germplasm selection	-do-	12.5	4.7	3.4	Late maturing type suited to all black pepper growing areas.
PLD-2	Clonal selection from 'Kottanadan'	Indian Institute of Spices Research, Calicut and Central Plantation Crops Research Institute, Regional Station, Palode.	15.5	3.3	3.5	Suited to Thiruvananthapuram and Kollam districts of Kerala, India.
IISR Thevam	Clonal selection of 'Thevanmundi'	Indian Institute of Spices Research, Calicut	8.15	1.6	3.1	Tolerant to *Phytophthora* foot rot disease. Suited to high altitudes and plains.

IISR Malabar Excel	F_1 of 'Cholamundi' x Panniyur-1	-do-	13.5	2.96	3.2	Suited to high altitudes and rich in oleoresin.
IISR Girimunda	F_1 of 'Narayakodi' x 'Neelamundi'	-do-	9.65	2.2	3.4	Suited to high altitudes
IISR Shakthi	Open pollinated progeny of 'Perambramundi'	-do-	10.2	3.3	3.7	Tolerant to *Phytophthora* foot rot disease

Conclusion

As Western Ghats of India being the center of origin of *Piper nigrum*, cultivar diversity is maximum in India. Though other producing countries pose a challenge to India in black pepper production and trade, this will not be sustaining in the long run when one considers the strength of India in *Piper* genepool.

References

Banerji A & Dhara K P 1974 Lignan and amdes from *Piepr silvqlicum*. Phytochemistry 13 : 2327 – 2328.

Burkill I H 1923 The botany of the Abor expedition. Rec. Bot. Sur. India10 (1) : 1-154.

Cooke T 1906 Flora of the presidency of Bombay. III: London. (Rep.), pp. 428-430.

Hooker J D 1886 The flora of British India, V: Reevean Co. London (Rep.): 78-95.

Duthie J F 1960 Flora of the upper gangetic plains and the adjacent Siwalik and sub-himalayan tracts. II Botanical survey of India, Calcutta (reprint)

Gajurel P R, Rethy P & Kumar Y 2000 *Piper acutistigmum* C.DC. (Piperaceae) a new record for India. Rheedea 10 (2): 139-141.

Gajurel, P R, Rethy P & Kumar Y 2001a *Piper haridasanii*- a new species of *Piper* (Piperaceae) from Arunachal Pradesh, North Eastern India. J. Econ. Taxon. Bot. 25 (2): 293-296.

Gajurel P R, Rethy P & Kumar Y 2001b A new species of *Piper* (Piperaceae) from Arunachal Pradesh, North Eastern India. Bot. J. Linnean Society 137 (4): 417-419.

Gajurel P R Rethy P & Kumar Y. 2007 A new species of *Piper* L. (Piperaceae) from Arunachal Pradesh. Rheedea 17 (1 & 2) 35-39.

Gamble J S 1925 Flora of presidency of Madras (2) Bot. survey of India, Calcutta (reprint. 1961).

Haines H H 1924 Botany of Bihar and Orissa. (3) Botanical survey of India, Calcutta (reprint 1961).

Ibrahim K K, Sukumara Pillai V & Sasikumaran S 1985 Variability, heritability and genetic advance for certain qualitative characters in black pepper. Agric. Res. J. Kerala 23: 45-48.

Jain S K & Tarafder C R (1970) Medicinal plants- Love of santals. Eco. Bot. 24: 241.

Jaramillo M A & Manos P S 2001 Phylogeny and patterns of floral diversity in the genus *Piper* (Piperaceae). American J. Botany 88(4): 706-716.

Mark Greiffith 1992 Index to Garden Plants. Mc Millan, P 900.

Nirmal Babu K, Naik V G and Ravindran P N 1993 Two new taxa of *Piper*, Piperaceae from Kerala, India with a note on their origin and interrelationship. J. Spices and Aromatic Crops 2: 26-33

Kanjilal U N, Kanjilal P C & Das A 1940 Flora of Assam. Vol. IV, Govt. of Shillong. p. 31-38.

Rahiman B A 1981 Biosystematics studies in varieties and species of *Piper* occurring in Karnataka region. Ph.D thesis, University of Mysore, Mysore.

Rama Rao M 1914 Flowering plants of Travancore, Govt. Press. Thiruvananthapuram. p. 336-338 (reprint).

Ravindran P N, Nair M K & Nair R A 1987 New taxa of *Piper* (Piperaceae) from Silent valley forest, Kerala. J. Eco. Tax. Bot 10: 167-169.

Ravindran P N & Nirmal Babu K 1994 Genetic resources of black pepper pp. 99-120. In: Advances in Horticulture (9) Plantation and spices crops. Part-I Chadha K L & Rethinam P (Eds.) Malhotra Publishing House, New Delhi.

Ravindran P N 2000 Other economically important species of *Piper*. In : Black pepper *Piper nigrum* Ravindran P N (Ed.). Harwood academic publishers. p 497-509.

Ravindran P N & Sasikumar B 1993. Variability in open pollinated progenies of black pepper (*Piper nigrum* L.). J. Spices and Aromatic Crops 2: 60-65.

Sasikumar B, Haridas P, Johnson George K, Saji K V, John Zachariah T, Ravindran P N, Nirmal Babu K, Krishnamoorthy B, Mathew P A & Parthasarathy V A 2004 IISR Thevam, Malabar Excel and IISR Girimunda- three new black pepper (*Piper nigrum* L.) clones. J. Spices and Aromatic Crops 13 (1): 1-5

Sasikumar B, Krishnamoorthy B, Saji K V, Johnson George K, Peter K V & Ravindran P N 1999 Spices diversity and conservation of plants that yield major spices in India. *Plant Genetic Resource Newsletter* 118: 19-26.

Sasikumar B, Chempakam B, Johnson K George, Remashree A B, Devasahayam S, Dhamayanthi K P M, Ravindran P N & Peter K V 1999a Characterization of two interspecific hybrids of *Piper*. J. Hort. Sci. & Biotech 74: 125-131.

Sukumara Pillai V, Ibrahim K K & Sasikumaran S 1994 In : Advances in horticulture (9) Plantation crops & spices, Part I Chadha K L & Rethinam P (Eds.) Malhotra Publishing House, New Delhi. Pp 293-296.

Utpala Parthasarathy, George J K, Saji K V, Srinivasan V, Madan M S, Mathew P A & Parthasarathy V A 2006 Spatial analysis of *Piper* species distribution in India. Plant Genetic Resources News letter 147:1-5.

Vanaja T, Neema V P, Mammootty K P & Rajeshkumar R 2008 Development of a promising interspecific hybrid in black pepper (*Piper nigrum*) for *Phytophthora* foot rot resistance. Euphytica 161 (3): 437-445.

Velayudhan K C & Amalraj V A 1992 *Piper pseudonigrum*- a new species from Western Ghats. *J.* Eco. Tax. Bot. 16: 247-250.

Velayudhan K C, Amalraj V A, Abraham Z, Joseph John K, Abdul Nizar M & Asha K I 1999 Wild crop genetic resources of Silent valley with special reference to *in-situ* conservation of *Piper* species. Silent valley. Whispers of reason, Kerala Forest Development. p. 217-223.

Taxonomy and cytogenetic investigations in *Piper nigrum* (black pepper) and related species

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Introduction

The Western Ghats of India is considered to be the centre of origin and diversity of *Piper nigrum*. Advancement in conservation and utilization of genetic resource of the species is essential for overcoming the present day setbacks of low production of 'black pepper' in the country, and this necessitates thorough understanding of taxonomic and genetic interrelationships of intra- and inter-specific variants of the species occurring in the region. On considering the economic importance of 'black pepper', and the fact that the country possesses the cream share of the gene pool of the species, taxonomic and cytogenetic studies ought to have received special attention. Such studies of the species are the first step for knowing, assessing and inventorying the genetic resource of the region. This line of exercise is a prerequisite as it would go a long way in circumventing the prevailing tendency of loss of genotypes in the wild as well as from the farmer's fields. The results of the studies will be useful for identifying unique potential genetic resource of the species available in the Western Ghats, and thereby to utilize them, especially for crop improvement.

Taxonomy of *Piper* species of the Western Ghats

The genus *Piper* was established by Linnaeus (1753) in his *Species Plantarum*, in which he recognized 17 species, all in one genus, *Piper* L. (Ravindran *et al.* 2000). The earliest record of description of *Piper* of the Western Ghats was by van Rheede (1678 - 1693), who described five types of wild peppers.

The pioneering works of *Piper* of the region were made by Cook (1903), Fyson (1915), Lushington (1915) and Fischer (1925). Rama Rao (1914), Santapu (1960), Saldhana & Nicholson (1978) are some of the authors who made floristic enumerations of the species of *Piper* of the region. The first major work of Indian *Piper* was of Hooker (1886), who described 13 species, in five sections, in the Flora of British India. Gamble (1925) in his floristic study described 14 species (including *P. betle*) in his Flora of Presidency of Madras. A few new taxa were discovered by Ravindran *et al.* (1987, 1993); Velayudhan & Amalraj (1992). Other major contributions to taxonomy of *Piper* from the region include Rahiman *et al.* (1979); Rahiman (1981); Ravindran (1990); Mathew *et al.* (2002).

The genus *Piper* L. is considered to be a difficult one for taxonomic study, mainly due to the sir in gross morphological features, and this leads to difficulty in species discrimination. This p becomes more complex when working with herbarium specimens. The very small flowers and a of perianth also contribute to the complexity. The classical taxonomists (Hooker 1886; Barbe: who handled the Piperaceous members of the region had pointed out inadequacy and problems stand in the way of accurate discrimination of the taxa based on herbarium materials. Hooker had advised the local botanists of Indian region to 'examine the plants on the spot' and make a th study of all the aspects relevant to the systematics of the group.

According to Ravindran *et al.* (2000) the following are the *Piper* species occurring in the Western Ghats. He subdivided the genus into two sections, Pippali and Maricha based on orientation of spikes *i.e.,* erect or pendent. Scientific names of the species and references of their first valid publications are given below.

Sect. Pippali (spikes erect)

Piper longum L. Sp. Pl., 29, 1753.

Piper hapnium Buch.-Ham. *ex* Hook.f., FBI 5: 86.1886.

P. mullesua Buch.-Ham. *ex* D. Don., Prodr. Fl. Nep., 20. 1825.

P. silentvalleyensis Ravindran & Asokan, J. Econ. Tax. Bot., 10: 167. 1987.

Sect. Maricha (spikes pendent)

P. argyrophyllum Miq., Syst. Pip., 330. 1844.

P. attenuatum Buch.-Ham. *ex* Miq., Syst. Pip., 306. 1843.

P. nigrum L., Sp. Pl., 28. 1753.

P. pseudonigrum Velayudhan & Amalraj J.Econ. Tax. Bot.,16: 247. 1992.

P. sugandhi Ravindran, Babu & Naik, J. Spices & Aromatic Crops, 2: 26 – 33.1993.

P. trichostachyon (Miq.) C. DC., Prodr. 16 (1) 242. 1869.

P. schmidtii Hook.f., FBI 5: 89. 1886.

P. wightii Miq., Hook.'s London J. Bot. 5: 552.

P. barberi Gamble, Kew Bull., 387. 1924.

However, the following taxa form additions to the above list.

P. hookeri Miq. Hook.f. FBI 5: 88.1886.

P. nigrum L. var. *hirtellosum* Asokan & Ravindran, J. Econ. Tax. Bot. 10: 167. 1987.

P. sugandhi var. *brevipilis* Ravindran, Babu & Naik, J. Spices & Aromatic Crops, 2: 26 – 33.1993.

It is also noted that many authors have used *Piper trioicum* Roxb., Fl. Ind. 1: 151. 1820. as currently used name of *P. attenuatum* Buch.- Ham., and *P. brachystachyum* Wall. ex Hook.f. as a commonly used synonym of *P. mullesua* Buch.-Ham.

Hooker (1886) has described 45 species of *Piper* from Indian sub-continent, in the Flora of British India, which include the following 13 species of *Pipe*r of the Western Ghats. He grouped the species in six sections, namely Muldera, Cubeba, Chavica, Pseudochavica, Eupiper and Heckeria. The species of *Piper* described by Hooker, which belong to the Western Ghats are enumerated below:

Muldera - *P. galeatum, P. trichostachyon*

Chavica - *P. longum, P. hapnium, P. brachystachyum*

Heckeria - *P. subpeltatum*

Pseudochavica - *P. hookeri, P. schmidtii*

Eupiper - *P. nigrum, P. attenuatum, P. argyrophyllum, P. wightii, P. hymenophyllum*

Gamble (1925) described the following 13 species of *Piper* from the Western Ghats and grouped them as given below:

Group I - *P. galeatum, P. trichostachyon*

Group II- *P. longum, P. hapnium, P. brachystachyum, P. hookeri, P. schmidtii, P. barberi*

Group IIIA - *P. nigrum*

Group IIIB - *P. hymenophyllum P. argyrophyllum P. attenuatum P. wightii*

The *Piper* species described by Hooker include, *P. subpeltatum*, whereas Gamble considered it not as a species of *Piper*, but as a species of *Heckeria - H. subpeltata.* Gamble described *Piper barberi* as one of the 13 species of *Piper* occurring in the Western Ghats, and this species was not included by Hooker in the Flora of British India, since it was not discovered at that time.

In order to evolve a more natural grouping of the above mentioned 13 species of *Piper* given in the Flora of British India, aimed at revealing their interrelationship, Mathew (1998) has made a modest attempt for detailed morphological analysis of the species and their grouping as follows (table1), based on their prominent morphological characters.

Table1. Grouping of the 13 species of *Piper* based on their prominent morphological features

Group	Prominent morphological characters
Group I *P. galeatum* *P. trichostachyon* *P. nigrum*	Pendent spike having receptacles, leaves chartaceous, venation - acrodromous
Group II *P. longum* *P. hapnium* *P. brachystachyum*	Erect spike having peltate orbicular bracts, leaves- chartaceous, venation - acrodromous
Group III *P. hookeri* *P. schmidtii*	Pendent spike with peltate - orbicular bracts, leaf venation - acrodromous
Group IV *P. attenuatum* *P. argyrophyllum* *P. hymenophyllum* *P. wightii*	Pendent spike having adnate bract with decurrent free membranous margin, leaves chartaceous, acrodromous - venation
Group V *P. barberi*	Pendent spike having peltate - orbicular bracts and very long filiform peduncles, leaves- chartaceous, pinnately - veined (craspedodromous venation)

The present grouping of the 13 species is remarkably in agreement with the one proposed by the earlier taxonomist (Hooker 1886). The sections Chavica and Pseudochavica of Hooker perfectly agree with the present groups II and III, respectively. The section Chavica, (Group II) includes *P. longum*, *P. hapnium* and *P. brachystachyum* and Pseudochavica (Group III) comprises *P. hookeri*, and *P. schmidtii*. The sections Muldera and Eupiper of Hooker differ from the present groups I and group IV, only as to the placement of *P. nigrum*, which Hooker has grouped with *P. attenuatum*, *P. argyrophyllum* and *P. hymenophyllum* in the section Eupiper as against its inclusion along *P. galeatum* and *P. trichostachyon* in the present group I.

This grouping, however, shows more disagreement with the grouping of these species made by Gamble (1925). Only one grouping in the either system shows complete corroboration, namely group - III B of Gamble and the present group - IV, both of which include the same taxa (*P. hymenophyllum, P. argyrophyllum, P. attenuatum* and *P. wightii*). The taxa belonging to the group II of Gamble, find placement in three separate groups such as group II (*P. longum, P. hapnium* and *P. brachystachyum*), group - III (*P. hookeri* and *P. schmidtii*) and group V, exclusively for *P. barberi*. Another difference is concerning *P. nigrum*, which goes along with *P. galeatum* and *P. trichostachyon* in the grouping by Mathew (1998), while this forms a solitary member in Gamble's sub group IIA.

Thus, Mathew (1998) differs with Hooker and Gamble with regard to the grouping of *P. nigrum*. He included the species in the group along with *P. galeatum* and *P. trichostachyon*, and thereby pointed out that the most closely allied species of *P. nigrum* are *P. galeatum* and *P. trichostachyon*.

Rahiman *et al.* (1979) have considered *P. hymenophyllum* conspecific with *P. hookeri*, and have pointed out that these two species differ only in certain minor characters. But, it may be noted that the difference between these two species are not really minor as interpreted by them. A close observation of the two species could reveal many obvious features of distinction such as adnate decurrent bract, hairiness of the plant, stamen number (3 nos.), nature of filament (slender) shown by *P. hymenophyllum* as against peltate-orbicular bracts, glabrous or rarely pubescent nature, 2 stamens and stout filament in *P. hookeri*.

Taxonometric grouping of the taxa

In the systematic treatment of the South Indian species of *Piper*, there has been certain amount of discord (Hooker 1886; Gamble 1925; Rahiman & Bhagawan 1985; Ravindran *et al.* 1992; Mathew 1998). Thirteen indigenous species of *Piper* described in the Flora of Presidency of Madras have been subjected to phenetic analysis by metric method, for which 50 characters were taken into consideration (Mathew *et al.* 2002). The results of cluster analysis showed that they could be clustered into 5 groups. The first cluster consisted of three species (*P. galeatum, P. trichostachyon, P. nigrum*) which formed an 83% phenon. The second cluster was a 66% phenon, which comprised three species (*P. hookeri, P. schmidtii, P. brachystachyum*). The third group was a single member cluster (*P. barberi*). The fourth cluster included four species (*P. hymenophyllum, P. argyrophyllum, P. attenuatum, P. wightii*), which constituted a 66% phenon, while cluster V which was an 88% phenon comprised two species (*P. longum, P. hapnium*).

A comparison of the composition of the taxonometric grouping based on phenetic resemblance with the grouping proposed by Hooker and Gamble shows that the present grouping is in agreement with Hooker's, barring a few differences and to a large extent with Gamble's. Hooker's section Muldera (*P. galeatum, P. trichostachyon)*, and Eupiper (*P. nigrum, P. attenuatum, P. hymenophyllum, P. argyrophyllum, P. wightii*) are similar to the present clusters I and IV respectively, except for Hooker's inclusion of *P. nigrum* in his section, Eupiper, which on the other hand is clustered with *P. galeatum* and *P. trichostachyon* in the present cluster, I. Hooker's sections, Chavica and Pseudochavica differ from the present cluster V and II respectively, in regard to the placement of *P. brachystachyum*, which in Hooker's Chavica section goes along with *P. longum* and *P. hapnium* as against the present placement of this with *P. hookeri* and *P. schmidtii* in cluster II.

The composition of Gamble's group I and III B is in agreement with that of the present clusters I and IV respectively except for the placement of *P. nigrum*. While this species is associated with *P. galeatum* and *P. trichostachyon* in the present treatment, Gamble has treated *P. nigrum* as a single member in his sub group III A. Gamble's group - II is very much different from the groups of Mathew *et al.* (2002). Gamble has accommodated *P. longum* and *P. hapnium* and also *P. barberi* in this group along with *P. hookeri*, *P. schmidtii* and *P. brachystachyum* on the ground that all these taxa are characterized by flowers which are subtended by peltate orbicular bracts. In the taxonometric treatment of Mathew *et al.* (2002), *P. longum* and *P. hapnium* which constitute an 88% phenon are brought together into a separate cluster (V), while *P. barberi* which does not exhibit enough phenetic resemblance to any of the other species, is treated as a single member cluster. It may be noted that this species has a distinctive leaf venation (craspedodromous) as against the acrodromous condition in all the others.

Ravindran *et al.* (1992); Rahiman & Bhagawan (1985) have also attempted clustering of a few South Indian species of *Piper*, the former following the 'centroid linkage' method and the latter by D^2 analysis. Their groupings agree with the present only in certain respects. Ravindran *et al.* (1992) have clustered *P. schmidtii* with *P. galeatum* and *P. trichostachyon*; and Rahiman and Bhagawan (1985) have clustered *P. brachystachyum* with *P. galeatum* and *P. trichostachyon*, and *P. hookeri* with *P. argyrophyllum* and *P. attenuatum*. In the Rahiman *et al* treatment, *P. nigrum* and *P. wightii* are brought together in the same group. It may be noted that *P. nigrum* is clustered in the taxonometric grouping with *P. galeatum* and *P. trichostachyon* and the species showed highly significant similarity with *P. galeatum* (88%), which makes its clustering based on prominent morphological characters (Mathew, 1998) with the latter two justifiable from the taxonometric point of view.

The dendrogram revealed, inter- cluster distance between clusters II and IV is only marginal which is suggestive of their closer interrelationship. On the other hand, cluster V (*P. longum* and *P. hapnium*) is very distant from the rest of the groups. The taxa of this group exhibit a number of distinctive features, especially of habit, stipule (leafy), female spike (erect, short, cylindrical), anther-filament flat and fruit size very small. Although *P. brachystachyum* shares some of these features, its habit is remarkably different from both *P. longum* and *P. hapnium*. Metric analysis showed this species to have more phenetic resemblance with *P. hookeri* and *P. schmidtii*.

Cytogenetics of *Piper* species of the Western Ghats

Chromosome number

Chromosome reports made in a few species of *Piper* prior to 1950s (Darlington & Wylie 1956) were 2n= 24, 28, 32 and 128. The numbers seem to lead to confusion regarding the basic chromosome constitution of the genus. But, the study made by Mathew (1958) in a few South Indian species which showed, n=26, 2n=52, 78 and 104 had led to the recognition of a new chromosome line in the genus, and based on these counts he proposed x=13 as the basic chromosome number of the genus. Subsequent studies by a few others on some alien species showing 2n=26 (Smith 1966; Samuel & Bavappa 1981; Okada 1986; Samuel & Moravetz 1989) confirmed this basic number. Some of the Indian workers also, of late, have reported the same line of numbers (Mathew 1973; Jose & Sharma 1984; Rahiman & Nair 1986). The chromosome numbers of 13 species of *Piper* of the Western Ghats (Mathew *et al.* 1998) also constitute a euploid series on x=13 (2n=52, 78, 104 and 208).

Meiotic behaviour

Detailed accounts of meiotic behavior in *Piper* taxa are very much lacking. Available information shows meiotic behavior to be fairly normal in all the diploid species of *Piper*.

Although meiosis seemed to be normal in some of the higher ploid species of *Piper* of the region including *P. nigrum* from the Western Ghats, this was abnormal in a few others such as, the 8x *P. argyrophyllum* and 16x *P. brachystachyum* in which higher associations of chromosomes at meiosis and consequent irregular anaphase separation and significant fall in pollen fertility were evident; and this could be suggestive of their auto or auto-alloploid nature. In the 2n=78 hexaploid species, *P. betle*, meiosis has been reported to be highly irregular (Mathew *et al.* 1998) and the taxon is sterile with only less than 15% pollen fertility, and the species has been suggested to be of hybrid origin.

Karyomorphology

The karyotypes of species of *Piper* are characterized by small chromosomes ranging in length from 0.60 to 3.00 μm. Because of very small size of the chromosomes, coupled with indistinct centromere positions, especially in the smaller chromosomes, which form the bulk, species of *Piper* are not amenable for detailed karyomorphological study. Notwithstanding this limitation, some workers have ventured to carry out karyotype analysis in a few species (Sharma & Bhattacharya 1959; Dasgupta & Datta 1976; Jose 1981; Jose & Sharma 1984) and have suggested the larger chromosomes in the somatic complements to be nearly metacentrics and smaller ones submetacentrics. Mathew *et al.* (1988) however, have noticed the smaller category of chromosomes in the different South Indian species to be mostly subtelocentrics and the medium sized ones submetacentrics so much so their karyotypes considered fairly specialized. Almost all the studies indicate that, irrespective of ploidy difference, the karyotypes of species of *Piper* are of graded type, and exhibit gross similarity in chromosome size and perceivable features of chromosome morphology, and hence the genus *Piper* as a whole may be considered to represent a more or less homogeneous assemblage karyomorphologically as well. Cytological studies (Mathew & Mathew 1981) on *P. nigrum* cv. 'Panniyur-I' showed 2n= 52. The somatic chromosomes are small sized and they could be grouped into three size classes such as four pairs of relatively long and rod shaped (1.8 - 1.6μm), ten medium sized (1.3- 1.1μm) and twelve of very small sized (1.0 – 0.8μm) chromosomes. The somatic complements of different cultivated and wild forms of *P.nigrum* have high degree of intraspecific karyomorphologic uniformity (Mathew *et al.* 1998). This, considered against the profound degree of variability exhibited by the different cultivars of the species in diverse morphological characters (Mathew *et al.* 2002), may be suggestive that gene mutations and cryptic structural changes in different chromosomes may have been the causative factors in the evolution of such enormity of morphologically distinct genotypes in this crop species.

Polyploidy

Cytological data on *Piper* species, both indigenous and alien show that frequency of taxa with polyploid constitution is remarkable in the genus, in which 9 euploid levels exist on x=13, such as 2x, 3x, 4x, 5x, 6x, 8x, 10x, 12x and 16x. Polyploidy is also reported in *P. nigrum* (Nair *et al.* 1993). Striking incidence of 2n=4x=52 taxa of *Piper* occurring in the Western Ghats, showing normal meiotic behavior has prompted Mathew *et al.* (1998) to consider them as alloploids, because a criterion commonly used for distingushing between auto and allopolyploids is the frequency with which chromosomes associate at meiosis into multivalents in the former and regular bivalent formation in the latter.

Established aneuploid lines are almost non-cxistent on x=13 in *Piper*, except for the occurrence of a few aneuploid variant numbers reported in some of the cultivated varieties of *P. betle* (Jose & Sharma 1988). But there are a few reports of euploid cytotypes in some species of *Piper- P. argyrophyllum, P. attenuatum, P. betle* and *P. nigrum*. The overall cytological picture shows that polyploidy at both inter-and intra- specific levels has been significantly operative in the genus *Piper*, and it is evident that high speciation rate of the genus is obviously linked with polyploidy. Looking at the size of chromosomes of *Piper*, it is evident that the karyotypes of the species of *Piper* are highly specialized as a result of their chromosomes having undergone extreme size diminution, and may be that the very small size of chromosomes in *Piper* has influenced polyploidisation in the genus. This appears to be in conformity with the concept of Miksche & Holta (1973) that larger chromosomes and greater quantity and redundancy of DNA have retarded the rate of polyploidy and more active divergent evolution, while, on the other hand, very small chromosomes and small quantities of less repetitive DNA have brought about more dynamic polyploidy evolution and striking evolutionary versatility in the case of genus *Piper.*

Conclusion

Thorough knowledge on taxonomy and cytogenetics of *Piper* species of the Western Ghats is inevitable for assessing and understanding the genetic wealth of *P. nigrum* occurring in the region. The presently available knowledge on these aspects of the species is insufficient to capitalize on the full potential of the resource. Taxonomic revisionary work on *Piper* species of the Western Ghats, indepth studies on intraspecific variability of *P. nigrum*, especially of the wild genotypes occurring in the forests of the region and detailed cytogenetic studies, are the major gaps to be addressed in this regard. The information generated out of such studies will be beneficial for attaining better utilization of the genetic resource of the crop species and its conservation.

References

Barber C A 1906 The varieties of cultivated pepper. Dept Agr Madras Bull. 3: 126-132.

Cook T 1903 The Flora of the Presidency of Bombay Vol. 3: 18-19. London.

Darlington C D & Wylie A P 1956 Chromosome atlas of flowering plants. George Allen and Unwin Ltd. London.

Dasgupta A & Datta P C 1976 Cyto-taxonomy of Piperaceae. Cytologia 41: 697-706.

Fischer C E C 1925 Piperaceae In: Gamble J S (Ed.) Flora of Presidency of Madras. Botanical Survey of India, Calcutta.

Fyson P F 1915 Flora of Nilgiri and Pulney hill tops. Vol. 1: 342-345, Madras.

Gamble J S 1925 Flora of Presidency of Madras, (Repr. 1957) Vol. 2: Botanical Survey of India, Calcutta pp. 842-845.

Hooker J D 1886 The Flora of British India Vol. 5. L. Reeve and Co., London.

Jose 1981 Karyomorphological studies on *Piper attenuatum* Buch.- Ham.- a new record.

Jose J & Sharma A K 1984 Chromosome studies in the genus *Piper* L. J. Indian Bot. Soc. 63: 313 - 319.

Jose J & Sharma A K 1988 Karyomorphological studies on *Piper betle*. Acta Botanica Indica 16: 186 -194.

Linnaeus C 1753 Species Plantarum, Vol. 1. London.

Lushington A W 1915 Vernacular list of trees, shrubs and woody climbers in the Madras Presidency Vol. 2: 593. Govt. Press, Madras.

Mathew P J 1998 Morphological, cytological and palynological investigations on the family Piperaceae with special reference to the genus *Piper*. Ph. D. thesis, University of Kerala. Thiruvananthapuram.

Mathew P J & Mathew P M 2002 Classification of South Indian species of *Piper* L. (Piperaceae) by metric method. Rheedea 12 (2): 123 – 131.

Mathew P J, Mathew P M & Pushpangadan P 1998 Cytological studies in South Indian Piperaceae I. *Piper*. J. Cytol. Genet. 33(2):149 -153.

Mathew P M 1958 Studies on Piperaceae. J. Indian Bot. Soc. 37: 153-171.

Mathew P M 1973 Karyomorphological studies on *Piper nigrum* pp.15 -18. Nair N M (Ed.) In: Proc. National Symp. on Plantation Crops, Trivandrum.

Mathew P M & Mathew P J 1982 Cytology of the hybrid pepper variety, 'Panniyur-1'. Curr. Sci. 51: 530 -531.

Miksche J P & *Holta Y 1973 DNA base composition* and repetitious DNA in several conifers. Chromosoma 41: 29 – 36.

Nair R R, Sasikumar B & Ravindran P N 1993 Polyploidy in a cultivar of 'black pepper' (*Piper nigrum* L.) and its open pollinated progenies. Cytologia 58: 27-31.

Okada H. 1986 Karyomorphology and relationships in some genera of Saururaceae and Piperaceae. Bot. Mag. Tokyo 99: 289-99.

Rahiman B A 1981 Biosystematic studies in varieties and species of *Piper* occurring in Karnataka region. Ph.D. *thesis, University* of Mysore, Mysore.

Rahiman B A & Bhagawan S 1985 Analysis of divergence in eight species of *Piper* using D^2 statistics. Bot. Bull. Acad. Sinica 26: 39-45.

Rahiman B A & Nair M K 1986 Cytology of *Piper* species from the Western Ghats. J. Plantation Crops 14: 52-56.

Rahiman B A, Murthy K N, Nair M K & Nair N M 1979 Distribution, morphology and ecology of *Piper* species in Karnataka. Indian J. Plant. Crops 7: 93-100.

Rama Rao, R S M 1914 Flowering plants of Travancore, Trivandrum.

Ravindran P N 1990 Ecology and taxonomic note in *Piper* spp. from Silent valley forest, Kerala. J. of the Bombay Natural History Society 87: 421-426.

Ravindran P N, Balakrishnan R & Nirmal Babu K 1992 Numerical taxonomy of South Indian *Piper* (Piperaceae) I. Cluster analysis. Rheedea 2: 55- 61.

Ravindran P N, Nirmal Babu K & Naik V G 1993 Two new taxa of *Piper* (Piperaceae) with a note on their origin and distribution. J. Spices & Aromatic Crops 2: 26 -33.

Ravindran P N, Nirmal Babu K, Sasikumar B & Krishnamurthy K S 2000 Botany and crop improvement of 'black pepper'. pp. 23 – 142. In: Ravindran P N (Ed.) Black pepper – *Piper nigrum*. Harwood academic publishers.

Ravindran P N, Nair M K & Nair A 1987 New taxa of *Piper* (Piperaceae) from silent valley forest, Kerala. J. Econ. Tax. Bot. 10: 167-169.

Saldhana C J & Nicholson D H 1978 Flora of Hassan District Karnataka India. Amerind Pub. Co. New Delhi, pp. 50-54.

Samuel M R A & Barappa K V A 1981 Chromosome number in the genus *Piper.* Curr Sci. 20: 197-198.

Samuel R & Morawetz W *1989* Chromosomal evolution within Piperaceae. Plant Syst. Evol. 166: 105-117.

Santapau H 1960 The flora of Khandala on the Western Ghats of India. Rec. Bot. Surv. India 16: 256-257.

Sharma A K & Bhattacharya N K 1959 Chromosome studies on two genera of family Piperaceae. Genetica 29:256 -289.

Smith J B 1966 Chromosome numbers in *Peperomia* Ruiz & Pav (Piperaceae) and note on chromosome number of *Piper magnificum* Trelease. Kew Bull. Vol. 20: 521-526.

van Rheede 1678 -1693 Hortus Malabaricus Vol. 1 – 12. Bishen Singh Mahendra Pal Singh, Dehra Dun, India (Reprint edition).

Velayudhan K C & Amalraj V A 1992 *Piper pseudonigrum*- A new species from Western Ghats. J. Econ. Tax. Bot. 16: 247.

Crop improvement in black pepper

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Introduction

Black pepper (*Piper nigrum* L.) belongs to the genus Piper, of the family Piperaceae. The genus Piper was established by Linnaeus in his *Species Plantarum* in which 17 species were recognized in the Piper family. The genus name Piper was derived, probably from the Greek name for black pepper, piperi and according to Rosengarten, most European names for black pepper were derived from the Sanskrit root pippali, the name for long pepper (*Piper longum*).

Origin of *Piper nigrum*

Pepper has originated in the evergreen forest of the Western Ghats of Southern India. Cytological studies suggest that the basic chromosome number of *Piper* is x = 13 and *P. nigrum* with 2n =52 is a tetraploid. A study of the species occurring in Western Ghats indicated that *P. nigrum* might have originated through hybridization between species with or without polyploidization of the hybrid. Based on morphological and biosystematic studies, it was suggested that three species namely *P. wightii, P. galeatum* and *P. trichostachyon* as the putative parents of *P. nigrum*. All these are woody climbers, having more or less similar leaf morphology and texture. Their spikes and fruits are more similar to *P. nigrum* than those of other species. The fruit of all three have small amount of pungency and flavour. In *P. galeatum* the bracts are connate, fleshy and shoe shaped; in *P. wightii* the bracts are fully adnate to the rachis, the shape being more or less oblong. In *P. nigrum* the bracts form a shallow cup like structure, this character being typically intermediate between the first two cases.

P. wightii is a threatened species now, occurring only in high elevated areas and *P. galeatum*, occupying the lower elevation levels. In the past, forests were in continuous stretches which might have led to the overlapping of these species. Most probably as it happens even today, more than one species might have climbed the same support which facilitated natural crossing. Such natural crossing might have happened a great many times at many locations, gradually leading to the building up of large population of hybrids. The progenies once formed get effectively isolated from the parents and rest of the progenies, because of the absence of sequent gene flow. At the same time the highly successful vegetative propagation ensures their survival and spread. Because of the selection pressure for better fruit set the bisexual forms might have been selected as they give much better fruit set. This selection would have led to the directional evolution of bisexuality in the cultivated forms and the present day cultivars.

Phylogeny and interrelationships

Cytological evidence has shown that most of the South Indian species have somatic chromosome number of 2n = 52; and that the basic number as x =13. Pepper and all its related taxa are either tetraploids or higher polyploids and that polyploidy seems to have played an important role in the speciation of South Indian *Piper* (Mathew 1958; Rahiman 1981). From the ancestral forms more than one developmental lines can be visualized among the South Indian taxa of *Piper*, one of which leading to *P. longum, P. mullesua etc.;* second line leading to *P. galeatum, P. trichostachyon* and then to *P.wightii; P. nigrum,* a third one leading to, *P. attenuatum, P. argyrophylllum, P. hymenophyllum.*

The karyotype comparison of the different cultivated varieties based on absolute chromatin content showed that Karimunda had the smallest absolute chromosome size (62 μm) and the shortest spikes (9.1 cm) while cv. Aripadarppan having higher absolute chromosome size (74 μm) produced the longest spikes (15.5 cm).

Crop improvement

The important objectives for crop improvement in black pepper are, higher yield, resistance to *Phytophthora* foot rot disease, nematodes (*Radopholus similis* and *Meloidogyne incognita)*, resistance to insect pests (pollu beetle, scales, shoot borer and mealy bugs), drought tolerance and quality improvement.

Pepper, blessed with the twin advantages of vegetative propagation and viable sexual reproduction, offers much scope for exploitation of hybrid vigor as well as selection breeding. Clonal selection, hybridization, open pollinated progeny selection, mutation and polyploidy have been attempted in improving pepper. Recently biotechnology and tissue culture methods are being developed for black pepper improvement.

Clonal selection

Existing genetic variability in pepper can be exploited through clonal selection, as there are a number of pepper cultivars existing in India, with substantial amount of inter and intracultivar variability. An elite plant once identified can form the basis of a new variety. It can be multiplied vegetatively and subsequently can be released a new variety after sufficient yield evaluation trials. Clonal selection can be exercised in existing gene pool, introduced varieties, population created through segregation, hybridization or through other means.

Many of the popular pepper cultivars exhibit considerable intracultivar variability. In Kerala the best example is Karimunda. Clonal selection was carried out in this cultivar by the Indian Institute of Spices Research (IISR), Kozhikode. Based on survey, 216 elite individual plants were selected and their clonal progenies were further evaluated for yield and quality. This lead to the release of two varieties, Sreekara and Subhakara. Similarly, clonal selection in Sarawak, Malaysia, resulted in Semongok Perak variety. Clonal selection in cv. Kuthiravally carried out by the Pepper Research Station, Panniyur, has resulted in Panniyur 4. PLD-2 is a selection from cv. Kottanadan by the Central Plantation Crops Research Institute, Research Centre, Palode.

Intercultivar hybridization

Intercultivar variability exists in pepper for yield, quality and morphological features. This aspect coupled with viable sexual reproduction and vegetative multiplication have aided hybrid breeding in black pepper very attractive. Genetic improvement through hybridization generally involves selection of parents, hybridization and selection of progenies.

Hybridization work in pepper was started by 1959 in India at the Pepper Research Station, Panniyur. Evaluation of F_1 progenies of many crosses led to the hybrid Panniyur I, a selection from F_1 of a cross between cv. Uthirankotta X Cheriyakaniyakadan. This hybrid was released in 1967. Panniyur 3, hybrid of the same parents was developed and released during 1991.

In pepper, single crosses between different cultivars and varieties, single crosses between pepper varieties and other *Piper* sp. of economic importance, double crosses between promising F_1s of various crosses, three- way crosses between selected varieties and promising progenies of various crosses and back crosses of promising offspring to recurrent parent can be utilized for crop improvement.

Selection in OP progenies

Pepper being heterozygous and propagated mainly through cuttings, segregation of characters can be expected in the open pollinated and selfed progenies. Because of the geitenogamous mode of pollination, the open pollinated progenies are comparable to selfed offspring. There is thus a fair chance to locate useful genotypes in open pollinated progenies. Genetic variability within open pollinated progenies of a few varieties of black pepper has been reported. In Sarawak five promising genotypes have been identified from OP progenies. They are the third generation open pollinated progenies from the cvs. Balankotta, Cheriyakaniyakadan and Kalluvally (all of them introduced from India). These five lines (14452-14556) were multiplied and tested in replicated trials. Of these, line 14556 was the most promising, having long, well set spikes, and was susceptible to *Phytophthora* foot rot, and is also less susceptible to black berry disease caused by *Colletotrichum* than the cv. Kuching. Selection in OP progenies was carried out at the Pepper Research Station, Panniyur. Two cultivars, Panniyur 2 and Panniyur 5 were developed through selection in OP progenies of cvs. Balankotta and Perumkodi respectively.

Interspecific hybridization

Successful interspecific hybridization between *P. nigrum* x *P. attenuatum* and *P. barberi*, has been reported. The hybrids exhibited distinct morphological and anatomical features. Isozymes studies have shown hybrid specific as well as male parent specific bands. The hybrid had the same chromosome number (2n = 52) as that of the parents.

A partly fertile interspecific hybrid having partial resistance to the dreaded disease *Phytophthora* foot rot which has been developed through hybridizing *Piper nigrum* with the wild species *Piper colubrinum*. Hybridity of the promising interspecific progeny was established through morphology, anatomy, cytology, and molecular studies. The hybrid exhibited distinct anatomical and morphological features with a large number of long spikes but reduced setting percentage. The RAPD primers OPE 07 and OPG 08 were identified as hybrid specific molecular markers. This hybrid is considered as a successful breakthrough for introgression of resistance to *Phytophthora* foot rot to the cultivated species *Piper nigrum* from the wild species *Piper colubrinum*.

Polyploidy and its application

The possibility of using polyploidy in crop improvement was also explored. A natural triploid [2n (3x) = 78] was located among the germplasm and this has very bold fruits and low fruit setting. This triploid plant was used for generating a series of cytotypes. An induced tetraploid was developed in Panniyur-1 by treating the seeds with colchicine. This tetraploid having the somatic chromosome number of 2n (4x) = 104, has larger and thicker leaves but the growth was slower than the diploid parents, and was difficult to establish in the field.

Mutation breeding

Induced mutations were used in pepper mainly for broadening the genetic base, and also for producing mutants tolerant to *P. capsici* and nematodes. In Malaysia, the mutation breeding work was limited to the cultivar Kuching. In India, gamma rays were used for inducing variability in Karimunda, Panniyur 1, Kuthiravally, Kalluvally (Pulpally), Kalluvally (Malabar), Thommankodi and Aimpiriyan and 1 - 4 kr gamma rays were used for irradiation. Irradiation adversely affected the germination of seeds; as the dose increased, germination was delayed. Only in Kalluvally (Malabar) all the treatments gave above 50 per cent germination. Kalluvally (Pulpally), Karimunda and Aimpiriyan were most affected by the radiation treatment and Thommankodi the least. The M_1 population showed certain morphological abnormalities such as chlorophyll changes, twinning of seedlings, rosette leaves *etc.* The frequency of chlorophyll abnormalities in the M1 seedlings population ranged from 13 per cent in cv. Karimunda to 0.1 per cent in cultivars Kuthiravally and Kalluvally. Incidentally Karimunda gave around 3 per cent chlorophyll abnormalities even in the control population. The types of chlorophyll changes noted included albino, xantha (yellow) and variegated. The first two were lethal, whereas variegated ones later developed to normal plants.

In Malaysia, mutation breeding was used mainly to create genetic variability especially for developing tolerant lines against *P. capsici* and *M. incognita*. Cultivars Kuching and Seongok Perak were used in mutation breeding work. The ripe seeds were irradiated with gamma rays up to 100 Gy. .Both M_1 and M_2 were studied, mainly for locating resistance against *Phytophthora*. In addition to seeds, cutting were also irradiated and raised. Cutting back method was used in irradiation experiments with vegetative cuttings. In the cutting back technique the dormant buds are treated and the main shoot is removed at sprouting so that the MV_1 (first vegetative mutation generation) will originate from axillary's buds which are present. Cutting backs are done in successive vegetative mutation generation (MV_2, MV_3 *etc.*). This technique has been applied in many vegetative propagated plants.

Two nodal cuttings of Kuching with a leaf on the upper node were used for gamma ray irradiation ranging from 0-50 Gy. The irradiated plants were planted and MV_1 and MV_2 generations were studied. The LD_{50} was around 30Gy. Apart from gamma rays, EMS treatment was also used for inducing mutation; the LD_{50} was around 0.25-0.3 per cent. The progenies were subjected to the leaf screening method for locating tolerance against *P. capsici*. In this method a culture disc of *P. capsici* is placed together with a drop of distilled water on the abaxial surface of a recently matured leaf. The reactions were compared with the lesion developed on Kalluvally, Belantung and Kuching leaves used as checks (representing, tolerant, less susceptible, and susceptible respectively). Plants giving reactions similar to Kalluvally (less diameter equivalent to Kalluvally) were selected for further studies.

Genetical and biometrical studies

Studies on genotype and phenotypic variability, heritability and genetic advance using 28 lines of hybrids and open pollinated progenies revealed that spike yield, followed by spike number, showed the highest phenotypic coefficient of variation. The lowest variability was shown by fruit weight. Heritability values varied from 28 to 81 per cent, the highest for fruit weight followed by spike length. Spike yield and spike number had low heritability indicating that these characters are highly influenced by environmental fluctuations. Genetic advance was highest with respect to spike yield, indicating that selection will be advantageous in this character.

Panniyur -1 showed positive heterosis for length of spike, developed fruits, bisexual flowers per spike and for yield, but the fruit characters are found to be intermediate. Internodal length in the hybrid was greater than the parental values and showed significant difference compared to mid parental value. The cv. Arakulam munda showed high stability of expression over seasons for spike length.

Biotechnology

In vitro propagation

Shoot tip and eye bud explants were found to be the best explants for *in vitro* culture. Murashige and Skoog (MS) medium containing 0.5ppm NAA and 3ppm BA resulted in speedier establishment of cultures. MS medium with 10ppm BA induced better proliferation in shoot tip explants cultures. But in eye bud and floral apex cultures, BA 10ppm and NAA 0.5ppm were found to give better results. Better rooting was observed in Knudson medium containing 5ppm NAA. The plantlets established well when they were kept in distilled water for 8 hours followed by dipping in $1/10^{th}$ strong liquid MS medium for 8hours before they were planted outdoor.

Field evaluation of tissue culture plants

The tissue culture derived black pepper plants were hardened and successfully established in the field with >80 per cent survival and later field establishment. TC derived plants were also evaluated in the farmers' fields at Idukki, Thrissur, Wayanad and Kannur districts of Kerala. No significant difference was noted among the TC regenerants and also when compared with the conventional propagules. The bearing habit was stable and sterility was not observed in any of the TC regenerants. The quality attributes like driage, oil and oleoresin contents of the TC regenerants were good and comparable with the conventional propagules. No significant difference was noted among the regenerants for the quality attributes.

TCP had better root growth and establishment (86%) when compared to the conventional plants (70%) in farmer's fields. Twenty percentage of the TCP showed early flowering. In general, TCP showed better growth, early flowering and better yield compared to control. DNA profiling of TCP demonstrated that the TC plants are genetically stable.

Somaclonal variation

High amount of somaclonal variation is reported in callus cultures of black pepper. The extent of somaclonal variation is dependent on genotype. The cultivar Kalluvally exhibited high amount of somaclonal variation as compared to other cultivars like Cheriyakaniyakadan, Balankotta and Karimunda. Higher the duration in culture, higher was the variability observed.

In vitro screening using the non-specific toxic metabolites of P. *capsici* was effective in developing disease resistant plants. More number of tolerant plants could be isolated from unscreened population, revealing the possibility of exploiting somoclonal variation without *in vitro* stress for screening for resistance to *Phytophthora* foot rot. Variability among the calliclones of black pepper was noticed for morphological, yield and quality attributes and reaction to *Phytophthora* foot rot disease. The assessment of *Phytophthora* foot rot disease reaction of the calliclones revealed that the clones CC 43, CC 58 and CC 60 were highly tolerant. Five elite clones *viz.* CC 58, CC 43, CC 60, CC 56 and CC 57 with desirable traits like high yield, quality and tolerance to *Phytophthora capsici* were identified. Based on overall attributes, the calliclone 'CC 60' was selected as the superior one with high yield and high tolerance to *Phytophthora* foot rot.

Molecular markers

Sixty decamer primers were screened for amplification of black pepper genomic DNA. Ten primers selected for good amplification were used to screen five varieties of black pepper. Three primers (OPP-1, OPP-8 and OPP-14) which showed polymorphism and stability of amplification, were used for analysis of TC plants. All the regenerants studied gave a uniform RAPD profile except in two regenerants where there was difference in expression of two non-distinct bands.

Genetic transformation

Investigations on genetic transformation in black pepper variety Panniyur1, using *Agrobacterium tumefaciens* strain AGL-1; 1303 harbouring antibiotic resistant selectable markers genes (nptII and hpt IV) and GUS and GFP reporter genes were carried out. Black pepper tissues, both leaf and callus, were found susceptible to kanamycin and hygromycin when freshly prepared antibiotic stocks were used. Callus induction on leaf was completely inhibited at 50 mg l^{-1} of kanamycin and callus growth at 100 mg l^{-1}. Hygromycin at 10 mg l^{-1} completely suppressed callus induction on leaf and callus growth at 30 mg l^{-1}.

Cefotaxime at a strength of 500 mg l^{-1} effectively killed the *Agrobactrium tumefaciens* strain AGL-1;1303 in pure bacterial suspension cultures. Proline was found to increase the rate of multiplication of *A. tumefaciens* strains AGL-1: 1303. But, cefotaxime at strengths of 500 and 100 mg l^{-1} could not eliminate *Agrobacterium* effectively from the leaf tissues and cefotaxime at 500, 1000 & 1500 mg l^{-1} could not eliminate *Agrobacterium* effectively from callus tissue also.

Selected references

Ibrahim K K, Pillai V S & Nair S S 1985 Path coefficient analysis of some yield components in black pepper. Indian Spices 22(3):21-25

Ibrahim K K, Pillai V S & Nair S S 1986a Comparative genetic variability with open pollinated seedlings of certain varieties of black pepper. Agric. Res. J. Kerala 24(1):74-76

Ibrahim K K, Pillai V S & Nair S S 1988 Potential of black pepper cultivar Uthirankotta in the hybridization programme. Agric. Res. J. Kerala 26 : 130-132

Kueh T K & Khew K L (1980) A screeninig technique useful in selecting for resistance in black pepper to *Phytophthora palmivora* mf4. Mal. Agric. J. 52 : 37-45

Mathew P M 1972 Karyomorphological studies on *Piper nigrum. Proc. Natl. Symp. Plantation Crops.* J. Plantation Crops (Suppl.1) :15-18.

Nirmal Babu K & Ravindran P N 1992 Improved varieties of black pepper, In : Sarma Y R , Devasahayam S & Anandaraj M (Eds.). Black pepper and Cardamom. Indian Soc. Spices, Calicut, pp.61-64

Paulus D D 1993 Mutation breeding for creating genetic variability in black pepper. In : Ibrahim M Y, Bong C J & Ipor I B (Eds.). The pepper industry: Problems and prospects. Univ. Pertanin Malaysia, pp.58-71

Ratnambal M J, Ravindran P N, Nair M K & Nirmal Babu K 1990 Two high yielding selections of Karimunda. Spice India 3 (11) : 9-11.

Ravindran P N, Nair M K, Nirmal Babu K & Chandran K 1990 Ecological and Taxonomical notes on *Piper spp.* from Silent valley forests, Kerala. J. Bombay Nat. His. Soc. 87 : 421-426

Ravindran P N 1991 Studies on black pepper and some of its wild relatives. Ph.D. thesis, Univ. Calicut, Kerala

Ravindran P N, Balakrishnan R & Nirmal Babu K 1992 Numerical taxonomy of South Indian *Piper* L.(Piperaceae) 1. Cluster analysis. Rheedea 2 : 55-61

Sebastian A, Sujatha V S, Nybe E V, Nair G S & Augustine A 1996 Isozyme variation and species relationships in the genus *Piper.* J. Tropical Agric. 34 : 85-92.

Sim S L (1993) Clonal selection and hybridization in pepper. In : Ibrahim M Y, Bong C J & Ipor I B (Eds.). *The Pepper* industry : Problems and prospects. Univ. Pertanin Malaysia, pp.48-57.

Vanaja T, Neema V P, Mammootty K P & Rajeshkumar R 2008 Development of a promising interspecific hybrid in black pepper for *Phytophthora* foot rot resistance. Euphytica 161 : 437-445

Agrotechnologies in black pepper production – An appraisal

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Introduction

In India, black pepper is cultivated in an area of 2,45,970 ha with a production of 69,000 tonnes (2006-07). Kerala, Karnataka and Tamil Nadu are the important states where black pepper is mainly cultivated as inter or mixed crop in coffee, tea, coconut and arecanut plantations. It is also cultivated as monocrop in few places. The crop has got great potential to be grown in non traditional areas such as Pondicherry, Goa, Maharashtra, Andhra Pradesh, Orissa, West Bengal, NE States and Andaman and Nicobar Islands.

The productivity of black pepper is comparatively low (281 kg / ha) when compared to other important black pepper producing countries like Indonesia, Malaysia, Thailand, Brazil and Vietnam. The main reason attributed is that in India it is grown mainly as a subsidiary crop (except at few locations) with a population per ha varying between 100 and 1000 vines under the shade of live support. In other countries, it is managed intensively with relatively high plant population (around 2000 vines /ha) with non-living or living support without much shade. This paper gives an overview on the major aspects of productivity in black pepper, especially planting material production, management, nutrition, crop weather relationship and drought tolerance.

Soil characteristics, climate and crop-weather relationship

Soil characteristics

Black pepper is successfully cultivated between 20^0 North and 20^0 South of Equator and 1500 m above mean sea level. The major black pepper growing soils in India can be broadly classified into four major orders, *viz.,* mollisols (forest loam), alfisols (red loam), oxisols (laterite) and entisols (alluvial).

A soil survey was conducted to assess the physico chemical characteristics of major black pepper growing soils and their influence on black pepper production. Samples were collected from four major black pepper growing districts of Kerala –Idukki and Wynad (high elevation area), Calicut and Cannanore (low elevation area). Investigations showed that soils of high yielding gardens are high in sand and silt and low in clay fractions. They have acidic pH (near neutral), high exchangeable base, base saturation, CEC, organic carbon, major secondary and micronutrients with the exception of sulphur and molybdenum. Soils of higher elevations are low in clay and high in sand silt fractions compared to that of lower elevation. They have higher organic carbon, CEC, base saturation, secondary and micronutrients, which favors good growth of pepper. This is the reason black pepper thrives well in elevated areas and are suitable for black pepper production.

Climate and productivity of black pepper

Black pepper is a crop of humid tropics requiring 2000-3000 mm rainfall with a relative humidity of 60 % - 95 %. The crop tolerates temperature between 10-40°C and optimum soil temperature for root growth is 26-28°C.

Trend analysis carried out for the climate and productivity in important black pepper growing areas *viz.*, Wynad (Ambalawayal), Calicut, Cannanore (Panniyur), Idukki (Pampadumpara) and Trichur in Kerala; Coimbatore (Valparai) and Nilgiris in Tamilnadu and Coorg in Karnataka showed a decreasing trend in rainfall and productivity while T_{max} and T_{min} showed an increasing trend. The black pepper productivity is showing a decreasing trend which could be the result of increase in temperature and reduction in rainfall. The correlation between climatic parameters and productivity shows, in general, that in plains (Triehur and Kannur) T_{min} and T_{max} are generally negatively correlated while in higher elevations (Wynad, Nilgiris, Pampadumpara) T_{min} is positively correlated with productivity. T_{max} does not seem to have much influence on productivity in higher elevations. Thus, climate change especially the increase in minimum temperature may have positive influence on productivity in higher elevations while the same may have negative influence in plains. Increased rainfall during December and January tend to decrease productivity.

Crop-weather modeling in black pepper

The weekly weather data *viz.*, rainfall, maximum and minimum temperature, maximum and minimum relative humidity, sunshine hours, wind speed and evaporation were correlated with annual yield of black pepper (Panniyur 1 cultivar) by using second degree polynomial equation. The beginning and end of annual cycle of black pepper has been taken as 10th (5th -11th March) and 9th (subsequent year) (26th Feb – 4th March) meteorological week, respectively, to study black pepper yield - weather relationship. The derived relationship indicated that nature and magnitude of black pepper-weather relationship varied for different weather elements. The magnitude of relationship was in the following order: - maximum relative humidity (R^2=0.9904)>rainfall (R^2=0.9903)> minimum temperature (R^2=0.9549)>maximum temperature (R^2=0.8951)>sunshine hour (R^2=0.8564)>wind (R^2=0.8040)>minimum relative humidity (R^2=0.4688)>evaporation (R^2=0.3913). The requirement of heat sum for black pepper maturity was also calculated as 3600 degree days. A regression model for prediction of black pepper production in Kerala was developed with January, April, July and September monthly rainfall as predictors (R^2 = 0.7057).

Planting material production

Black pepper can be propagated through seed as well as vegetative means. Seed propagation is confined to breeding and vegetative propagation is preferred for commercial planting owing to the heterozygous nature of the crop. Regular high yielding healthy vines, free from pests and diseases and preferably 5-12 years of age are selected as mother plants. Three methods of planting material production are generally practiced in black pepper.

Conventional method: In the conventional method, 2-3 nodal cuttings of 20 cm length are separated from the runner shoots during February-march and planted in polybags filled with potting mixture made of soil, sand and FYM in the ratio 1:1:1. The cuttings will strike roots and will be ready for planting in May-June.

Rapid multiplication method: This efficient rapid method of multiplication of rooted cuttings, *viz.*, 'Bamboo method' has a multiplication ratio of 1:40. This is also called Sri Lankan Method, which utilizes bamboo splits which are arranged at an angle of 45^0 alternatively on either side on straight wooden poles fixed on small support from ground and tied to each other with coir rope at the free end. Trenches taken at the base (30 cm x 45 cm) are filled with soil, sand and FYM (1:1:1). Rooted cuttings are planted in the trench, one for each bamboo split. As the cuttings grow, bamboo splits are filled with FYM, coir dust and sand in equal proportion. The first harvest of cuttings is made at 3-3 1/2 months and subsequently at every 2 1/2 months. Each rooted vine can give about 10 cuttings in one harvest with 40 cuttings per year.

Serpentine method: This method of propagation has an efficiency of 1:60. Three node cuttings are planted in poly bags and kept in a corner of the nursery. When the plant develops two leaves, they are trailed horizontally in polybags containing potting mixture. Once 20 nodes get rooted, the first 10 with rooted nodes will be separated by cutting at the internodes. The internodal stub also should be pushed back in the potting mixture which will develop secondary root system. After 3 months these cuttings are ready for planting in the field. The recovery percentage is higher as compared to rapid multiplication method.

Rooting medium

Solarized potting mixture: Plants raised in solarized potting mixture have better growth than plants raised in nonsolarized potting mixture (soil, sand, and FYM in 2:1:1 proportion). The superiority of solarized potting mixture for reducing the incidence of diseases besides yielding vigorous planting material is indicated. Bio control agents or biofertilizer can be mixed with solarized potting mixture. Cost of production of rooted cuttings with biocontrol agents is cheaper in the case of rooted black pepper cuttings raised in solarized potting mixture.

Granite powder: Substituting sand with granite powder, a waste material obtained from stone quarries, is more economical due to the scarce availability of sand for potting mixture preparation and high cost. Rate of leaf production (4.6), leaf area development (136.8 cm^2), and biomass (3.9g) of black pepper rooted cuttings are higher for combinations of soil (S), granite powder (G) and FYM (F) (SGF 2:1:1), followed by (SGF 1:1:1), soil, granite powder and coir pith compost (CPC) (SG CPC 1:1:1) and soil, granite powder, *Azospirillum* and phosphobacteria (SG A+P 1:1:1). Production cost of rooted cuttings is less for SGF 2:1:1 and SGF 1:1:1 as compared to control.

Management

Spacing and standards: Spacing of black pepper varies depending on the spacing with which the standards are planted. Optimum spacing under monocropping system is 3m x 3m which can accommodate 1100 standards/ha. In sloppy lands, a spacing of 3m x 2m is recommended, whereas with non-living standards a closed spacing of 1.5m x 2m is preferred.

A field trial was undertaken to compare the advantage of growing pepper on non-living, dead and live standards. Three popular cultivars of black pepper namely Panniyur -1, Karimunda and Kalluvally were used at two sapcings (3 x 2 m and 3 x 3 m). The yield data indicated better performance of black pepper on living/dead standards (table 1). The yield increase of pepper vines on dead or non-living standards was about two-fold than that obtained from living standards. Among the spacings, though 3 x 2 m was superior obviously due to more number of vines per hectare, the initial establishment cost was considerably higher.

Table 1. Mean yields of black pepper (fresh, g/vine) under different spacing on five supports

Spacing	Variety	Standard/support				
		Erythrina indica	*Garuga pinnata*	RCC posts	Granite pillars	Teak poles
3 x 2 m	Panniyur-1	439	500	1064	1019	1419
	Karimunda	674	458	1145	1234	1242
3 x 3 m	Panniyur-1	455	368	782	619	703
	Karimunda	557	409	1574	1442	752
Mean	531	434	1141	1078	1029	

Spacing mean: 3 x 2 m = 919.4 g/vine; 3 x 3 m = 766.1 g/vine
Variety mean: Panniyur -1 = 736.8 g/vine; Karimunda = 948.7 g/vine

In a spacing cum varietal trial, during 1983, with four spacings (3 x 3 m, 2.5 x 2.5 m, 2.5 x 1.5 m and 2 x 1 m) and three varieties (Panniyur – 1, Karimunda and Aimpiriyan) using RCC posts as support, the mean yield of three years revealed no significant differences among the varieties. However, the differences were observed among spacings (table 2). The closer spacing of 2 x 1 m proved significantly superior to all other spacings.

Table 2. Black pepper yield (fresh, kg/ha) as influenced by varieties and spacing (mean of three years)

Varieties	Spacing (m)				Mean
	3.0 x 3.0 (1100)*	2.5 x 2.5 (1600)	2.5 x 1.5 (2600)	2.0 x 1.0 (5000)	
Panniyur-1	1593	2537	3491	5114	3184
Karimunda	1963	2525	4542	7358	4097
Aimpiriyan	1466	1910	3207	5520	3026
Mean	1674	2324	3747	5997	

C.D 5% Variety : NS; Spacing : 920; Interaction : NS
* values in parentheses are number of vines/ha

Weed management in black pepper garden: Black pepper is a widely spaced perennial crop and under mono-crop situation the spacing is 2.5 to 3 m x 2.5 to 3 m. If inter-space is not utilized effectively for raising intercrops, it will be used by weeds. Hence, weed management is essential. At IISR Experimental Farm, Peruvannamuzhi some of the prominent weed species in the black pepper field noted are *Achyranthus aspera*, *Chromolaena odorata*, *Circium arvense*, *Commelina benghalensis*, *Cynadon dactylon*, *Cyperus rotundas*, *Euphorbia hirta*, *Mimosa pudica* and *Sida rhombifolia*. Weed management studies showed that hand weeding basin area and digging interspaces followed by clean cultivation (digging entire area including basin area) gave higher yield over control and other weed management treatment.

Irrigation: Irrigating black pepper vines @100 litres/vine as basin irrigation taken around the plant at a radius of 75 cm, during summer has come out as a recommendation. It was found that irrigating black pepper @ 7 litre per day per vine through drip between October and May recorded the maximum fresh yield of 4.07 kg / vine compared to un-irrigated control that recorded 1.33 kg / vine.

Cropping system: Black pepper is amenable for plantation crops based cropping system. A variety of crops are grown along with black pepper, such as elephant foot yam, colocasia, ginger, turmeric, perennial fodder grass, vanilla and banana. Growing Congo signal grass (*Brachiaria muziziensis*) in pepper garden increased the organic matter status and nutrient status of soil, reduced soil erosion, bulk density, and soil temperature and aluminium toxicity. Leguminous cover crops are suitable for enriching nutrient status of black pepper gardens. The legumes - *Cassia obtusifolia* L., *Crotalaria verrucosa* L., *C. retusa* L., *C. striata* DC, *Mimosa invisa*, *Indigofera* spp. *Clitoria* spp., *Sesbania* spp., were grown and their dry matter content and nutrient composition was analysed at IISR farm. The maximum shoot mass noted in *Mimosa* (25.81 g / plant) whereas root mass was more in *Crotalaria striata* (11.3 g / plant) after six months of growth. N content was maximum in *Clitoria* spp (2.44 %). Other nutrients elements like P, K, Ca, Mg, Fe, Mn, Zn and Cu were also analysed. An evaluation of suitable intercrops including vegetable, fodder, spices, tuber crops and medicinal plants for enhancing productivity of black pepper garden is under way at this Institute. Multiple cropping with black pepper as one of the component crops offers immense scope in North Eastern states.

Drought tolerance

Black pepper is generally grown as a rainfed crop. Though black pepper growing regions in the country receive adequate rainfall, the spread is only from June to October. The rainfall received from November to May is very scanty and hence the crop suffers from severe soil moisture shortage during this period which affects productivity. Hence, drought management practices including identification/development of drought tolerant varieties assume great importance in sustaining the production.

Characterization of drought tolerance in black pepper was carried out at IISR, Calicut, based on morphological (leaf area development, root to shoot ratio, *etc.)*, physiological (stomatal conductance, transpiration rate, photosynthetic rate, leaf temperature, chlorophyll fluorescence, stomatal index, relative water content, cell membrane stability *etc.)* and biochemical (lipid peroxidation, enzyme activities, isozyme pattern and protein profiles *etc.)* parameters. Among the physiological and biochemical parameters studied, relative water content, cell membrane stability and chlorophyll fluorescence and catalase activity to some extent, showed correlation with drought tolerance. Preliminary screening of germplasm accessions for drought tolerance based on relative water content, cell membrane stability and chlorophyll fluorescence could identify certain accessions, which were further screened under pot and then under field conditions. Acc nos. 1495, 931 and 813 maintained higher relative water content and membrane stability compared to other accessions during summer months under field evaluation. The root to shoot ratio of these accessions was also higher two years after field planting. Now, these accessions are being utilized in breeding programme on drought tolerance.

Nutrient management

Nitrogen, phosphorus, potassium, magnesium and micronutrients are the most important nutrients for growth, development and yield of black pepper. Investigations on nutrition management in a lateritic soil poor in major nutrients for hybrid Panniyur-1 showed that application of 140:55:270 g N, P_2O_5 and K_2O vine^{-1} year^{-1} resulted in significant increase in availability of N, P and K in soil, higher uptake of the nutrients and optimum yield response. Studies on interrelation of phosphorus content and yield of pepper in ultisols indicated significant correlation between leaf P index [P/(N+P+K+Ca)] and yield (r = 0.81**).

Micro nutrients: Among the micronutrients, the most important for black pepper nutrition are zinc, molybdenum and boron. Mo content increases absorption of organic matter as it forms a complex which makes it more available to the plant for absorbtion. A study conducted at IISR, Calicut showed that application of NPK at 150:60:270 kg/ha with Zn, B and Mo at 5:2:1 kg/ha resulted in highest yield in Sreekara and Subhakara.

In another experiment to find out the response of black pepper to Mo, it was observed that an increase in Mo level increased the soil, leaf and berry Mo status both under greenhouse and field conditions. In Mo deficient soils Mo, @ 0.25 mg/kg of soil for potted bush and Mo @ 0.94 kg/ha for field condition were found optimum for increasing the yield and improving the quality of black pepper. Experiments were conducted to compare the effect of zinc sources, zinc sulphate ($ZnSO_4$) and zinc ethylenediamine tetraacetic acid chelate (Zn-EDTA) and methods of application (soil and foliar) to black pepper in a zinc deficient soil. It was found that application of Zn @ 5 mg /kg for potted bush and 6.2 kg/ha under field condition (as zinc sulphate) in zinc deficient soils was optimum for increasing yield and quality of black pepper.

Micronutrient interaction with yield of black pepper: A survey was carried out in major pepper growing areas of Kerala and Karnataka to study the relationship of nutrients with yield and slow decline of pepper. Soil, leaf and root samples collected from healthy and diseased gardens were analyzed for major and micronutrients. The pepper yield was correlated with DTPA extractable Fe (r = 0.545**) and Cu (r = 0.406**) in healthy gardens. The yield was also correlated with leaf iron (r = 0.562**) in healthy and also diseased gardens (r = 0.617**) with leaf manganese (r = 0.458**) in healthy gardens with leaf zinc (r = 0.270*) and also with leaf Cu (r =0.367**) in diseased gardens. Interactions studies of micronutrients showed that soil Fe was negatively correlated with soil K (r = 0.392**), positively correlated with soil Ca (r = 0.364**) and soil Mn (r = 0.452**) in healthy gardens. The soil Mn was correlated with leaf Fe (r = 0.339*), root Zn (r = 0.366**) in healthy and with leaf Zn (r = 0.226*) in diseased gardens. The soil Zn was correlated with soil K (r = 0.466**) in healthy gardens. The leaf Zn was negatively correlated with leaf Mg (r = 0.362*) in healthy gardens. The root Fe was correlated with root K in healthy gardens (r = 0.387**). The root Zn was negatively correlated with root Mg (r = 0.302*) in diseased gardens (r = 0.394**) and also in healthy gardens. The root Cu was correlated with root K (r = 0.354**). The study reveals the interplay between nutrients in different plant parts and yield. Micronutrients like Fe, Zn and Cu play vital role in suppressing the disease incidence and enhancing the yield of pepper.

Diagnosis and Recommendation Integrated System (DRIS)

For working out the soil fertility norms for black pepper (*Piper nigrum* L.), a survey was carried out in 579 locations of major pepper growing tracts of South India. Soil samples were collected and analyzed for various nutrients besides the yield data. Among 579 locations, 438 (76%) were high yielders (yield level > 1000 g/vine) and 141 (24%) were low yielders. Data collected from DRIS was worked out. For getting an optimum yield, ranging from 530 to 4210 g with an average of 2365 g/vine, the pepper growing soils should have an optimum pH of 5.45, organic carbon 4.65 per cent, Bray extractable P of 42.5 ppm, exchangeable K, Ca and Mg of 190, 730 and 96 ppm respectively and DTPA extractable Fe, Mn, Zn and Cu of 32, 15, 3.5 and 12 ppm respectively.

DRIS Leaf nutrient norms: DRIS was used for developing foliar diagnostic norms for black pepper. The nutritional survey carried out in 578 black pepper gardens covered major pepper growing areas of

Kerala and Karnataka states indicated that 63.6 per cent of the vines were high yielders. An optimum yield ranging from 561 to 4526 g per vine can be achieved if the recently matured leaf contains 1.65 to 2.79 per cent N, 0.11 to 0.26 per cent P, 0.18 to 2.84 per cent K, 1.42 to 3.33 per cent Ca, 0.40 to 0.60 per cent Mg, 0.09 to 0.29 per cent S, 126 to 1145 ppm Fe, 109 to 721 ppm Mn, 21 to 67 ppm Zn and 16 to 120 ppm Cu. Diagnosis of 210 low yielding pepper gardens indicated wide spread deficiency of Mg (41 per cent), sub optimum supply of N (7 per cent), P(18 per cent) K and Ca (10 per cent each), Mg(41 per cent) and Zn (16 per cent). The yield was low due to excessive Cu to the extent of 20 per cent in the leaf due to spraying of copper fungicides to check fungal diseases. The deficiency of Mg, hidden hunger of first order (Zn), second order (P) and third order (N) were also identified to take care of subsequent yield limiting nutritional factors on correction of most deficient nutrient.

Nutrient diagnosis of black pepper gardens: *DRIS* indices were worked out for soil and leaf nutrient status of black pepper. The nutrient analysis data obtained from extensive (130 samples) surveys of major black pepper growing tracts of Kerala and Karnataka was compared with already worked out soil and leaf nutrient DRIS indices values to find out the deviation of nutrients from the corresponding critical concentrations. The results revealed that the soils in most of the gardens were acidic (pH 4.4 to 6.7). Soil sample analysis showed that 88% gardens had organic carbon (OC) status below the critical values, 74% had Zn, 36% had P and 28% had Ca status below the required levels. Leaf analysis showed that 46% samples had Mg, 39% samples had Cu and 12% samples had P, K and Zn status below the required critical values. The order of limiting nutrients was: OC > Zn > P > Ca > K > Mg for soil and Mg > Cu > P = K = Zn > Mn for leaf samples; The study revealed the importance of manuring black pepper gardens with organic manures supplemented with secondary and micronutrients.

Fertilizer use efficiency

Slow release nitrogenous fertilizers: The effect of slow release nitrogenous fertilizers *viz.*, urea formaldehyde, cyclo-diurea, Nimin coated urea and pellet in comparison with prilled urea was studied under upland condition in an oxisol for four years using Panniyur-1 as a test crop. The transformation of N source into various inorganic fraction such as urea-N, NH_4NO_2+NO_3-N and soil reaction were studied during 1989 at 1, 5, 10, 30 and 90th day respectively after application. Laboratory incubation studies were also carried out using the above fertilizers besides gypsum – coated urea and mussoorie rock phosphate – coated urea, Nimin coated urea followed by cyclo-di-urea @ 100 g kg P_2O_5 vine^{-1} year^{-1} was significantly superior over prilled urea as evidenced by the recovery of nitrogen, increased availability of various fractions of N in the soil, N uptake, yield response and agronomic efficiency of nitrogen by black pepper. The information may be helpful in modeling future development of urease and nitrification inhibitors.

Use of rock phosphate : Application of MRP @ 80 kg ha^{-1} year^{-1} along with N and P at 100 and 140 kg ha^{-1} gave sustained pepper productions. On farm trials conducted in 51 farmer's holdings on 30,000 vines for five years increased yield by 250 to 300 per cent, thereby corroborating the findings.

For bush pepper grown in pots containing 10 kg soil, application of 0.5 g P_2O_5 as MRP with N and K @ one and two gram respectively at bimonthly intervals was optimum. Application of MRP @ 80 kg P_2O_5 ha^{-1} $year^{-1}$ in a laterite soil over ten years did not contribute to the build up of toxic heavy metals like cadmium, chromium or aluminium either in the soil, leaf or berry at hazardous levels.

Effect of potash: The poor soil nutrient status and inadequate nutrient supply and management are attributed to low productivity of black pepper in India. The beneficial effect of sulphate of potash was also established in augmenting black pepper yield and quality and it is a suitable component in organic production system of black pepper.

Long term effect of fertilizers on black pepper: Effect of continuous NPK fertilization for 18 years in a laterite soil under humid tropical condition of the west coast of Kerala was studied from a field experiment started in 1979 in a 3^3 confounded factorial experiment. Continuous fertilization brought down the soil pH significantly. There was marginal increase in soil organic matter content and concomitant increase in soil P and K status. Regarding the secondary elements, there was significant increase in the contents of Ca and S in the plant due to the application of single super phosphate. Among the micronutrients, significant increase in Fe and Mn content in the soil was seen due to decrease in soil pH. The level of Zn in the soil was almost constant, while Mo level increased with concomitant increase in the level of N. The N level did not show any regular pattern due to the application of fertilizers.

Biofertilizer: Effect of *Azospirillium,* phosphobacteria and vesicular arbuscular mycorrhiza on growth and nutrient content of black pepper cuttings indicated that growth parameters were on par with control when these three biofertilizers were applied individually, but, their combination enhanced growth significantly over control. Inoculation with a combination of two / three bio-fertilizers enhanced plant height, leaf area, biomass and dry matter production and nutrient content significantly over un-inoculated control.

A field experiment was conducted to study the application of *Azospirillum* on yield, quality parameters and economics of black pepper. Five sub plot treatments consisting of application of FYM 10 kg alone, inorg N 50% + 10 kg FYM, inorg N 50% + Zn + boron + molybdenum, Inorg N 50% + Mg, and NPK alone and two main plot treatments were tested in split plot design with four replications. The treatment inorg N 50% + Mg significantly increased the yield (1741g/plant) and accrued highest net return (Rs. 39,548) and benefit: cost ratio (1.9) followed by application of NPK alone (1.4). No pronounced effect of inoculums and nutrients application on quality parameters of berries was observed.

Nutritional requirement of bush pepper : A noval method of growing black pepper as a bush was standardized at IISR, Calicut and is becoming popular amongst the farmers. Investigations showed that application of NPK fertilizer at the rate of I, 0.5, 2 g/pot at bimonthly interval increased the spiking intensity and yield of bush pepper by 240 per cent over no fertilizers. Application of oil cakes like neem cake at the rate of 30 g/ pot or groundnut cake at the rate of 14 g/pot was equivalent to fertilizer application as evidenced by the nutrient availability in soil and yield response. There was no significant difference in yield and economics between Panniyur-1 and Karimunda.

Integrated nutrient management: Integrated nutrient management involving application of NPK fertilizers and organics like FYM, compost and green leaves increases soil fertility. Composted coir pith was evaluated at Madikeri (Karnataka) under integrated plant nutrient management system to substitute chemical input of fertilizers for improving the yield and quality of black pepper. Application of composted coir pith (CC) @ 2.5 t ha^{-1} with full recommended dose of NPK (100:40:140 kg ha^{-1} of N, P_2O_5 and K_2O) yielded the highest (4.18 kg $vine^{-1}$) which was on par with 1.25 t ha^{-1} CC + full NPK, 2.5 t ha^{-1} CC + 1/2 NPK + *Azospirillum* sp., 1.25 t ha^{-1} CC + 1/2 NPK + *Azospirillum* sp. and 2.5 t ha^{-1} CC alone. The levels of composted coir pith application were on par with regard to quality (piperine and oleoresin contents) of black pepper. The highest benefit-cost ratio of 1.94 was recorded in the treatment with composted coir pith @ 1.25 t ha^{-1} + *Azospirillum* sp.

Organic fertilizers on black pepper: Investigations revealed that among the organic manures, vermicompost, followed by FYM significantly increased the availability of soil organic carbon, P, Ca, Mg and micronutrients in the soil. At the time of harvest, the availability of the nutrients was at a subdued level compared to that of 90^{th} day. The increase in pH was from 5.3 (check) to 7.2 in the vermicompost and 7.4 in FYM treated pots. This may be due to the release of Ca and Mg from the material. At crop maturity the yield of black pepper and uptake of NPK increased with the application of organic fertilizers for both the varieties, Panniyur and Karimunda. Inclusion of organic fertilizers significantly improved the quality *viz.*, piperine and oleoresin contents over check and the application of chemical fertilizers in both the varieties.

Application of FYM @ 10 t ha^{-1} improved the organic matter status, water holding and cation exchange capacity of soils. The nitrate content in soil was minimal. For growing bush pepper in pots (holding 10 kg soil), application of 30 g neem cake or 15 g groundnut cake with bimonthly application of NPK @ 1, 0.5 and 2 g pot^{-1} was economical with regard to nutrient availability in soil, yield response and uptake of nutrients. Nitrogen application @ 100 kg ha^{-1} improved pepper productivity as well as piperine content. The application of organic cakes enhanced the water holding capacity and reduced bulk density of soil. The organic matter could be correlated with water holding and cat ion exchange capacity of the soil. Treatment with organic manures reduced hardness of soil. Therefore, the soil physical, chemical and biological properties can be enhanced by the integrated nutrient management with the use of organic and inorganic fertilizers with least hazard to environment.

Thus, application of organics increased pH to neutrality, improved the fertility status of the soil by significantly increasing the availability of major, secondary and micronutrients and build up of microbial population. The highest yield of 8.3 kg $vine^{-1}$ with high benefit cost ratio of 4.15 was recorded with FYM application followed by application of vermicompost (7 kg $vine^{-1}$). Release of non exchangeable

K to the crop uptake was minimum with the addition of FYM and composts as their addition significantly increased the available K content by 3.8 times over no organics application. For nutritional management under organic farming, a judicious application of a combination of organic manures such as farm yard manure 5 kg, neemcake 1 kg and vermicompost @ 1 kg per vine per year can be made during May-June. Biofertilizers *viz.*, phosphobacteria and *Azotobacter* can also be applied @ 100 g/vine mixed with farm yard manure in the second year of planting.

Conclusion

A concerted effort to orient the research programmes in the following broad areas is essential to enhance the productivity of black pepper.

- Maximizing productivity per unit area by developing suitable spice based cropping systems
- Developing region-specific agro technologies and IPNM with low input management, especially in the field of organic spice sector.
- Enhancing the production of quality planting material of high yielding varieties by private agencies under a certification programme.
- Crop modeling studies for targeted yield prediction.

Selected references

Hamza S & Sadanandan A K 2005 Soil amendments and molybdenum on yield and quality of black pepper (*Piper nigrum* L.). Indian J. Agric. Sciences 75(11): 735-737.

Hamza S & Sadanandan A K 2005 Effect of sources and method of application of zinc on yield and quality of black pepper (*Piper nigrum* L.). J. Spices Aromatic Crops 14 (2): 117-121.

Hamza S, Srinivasan V & Dinesh R 2007 Nutrient diagnosis of black pepper (*Piper nigrum* L.) gardens in Kerala and Karnataka. J. Spices Aromatic Crops 16 (2):77-81 .

IISR 2006 Indian Institute of Spices Research Annual Report 2005-06. Indian Institute of Spices Research, Calicut, p 28.

Menon K S, Nair M K & Sharma O P 1982 Preliminary report on the performance of black pepper on non-living standards. Indian Spices 19: 3-5.

NRCS 1990 National Research Centre for Spices Annual Report 1989-90. National Research Centre for Spices, Calicut, pp. 17-18.

Ravindran P N, Nirmal Babu K, Sasikumar B & Krishnamurthy K S 2000 Botany and crop improvement of black pepper. In: Black Pepper *Piper nigrum*. Ravindran P N (Ed.), Harwood Academic Publishers, Amsterdam, pp. 23-142.

Sadanandan A K & Hamza S 1993 Comparative efficiency of slow release nitrogenous fertilizers on transformation of nitrogen and yield response of black pepper (*Piper nigrum* L.) in an oxisol. J. Plant. Crops 21 (Suppl): 58-66.

Sadanandan A K 2000 Agronomy and nutrition of black pepper. In: Black Pepper *Piper nigrum.* Ravindran P N (Ed.), Harwood Academic Publishers, Amsterdam, pp. 163-223

Sadanandan A K & Hamza S 1998 Studies on nutritional requirement of bush pepper (*Piper nigrum* L.) for yield and quality. In: Developments in Plantation Crops Research. Mathew N M and Kuruvilla Jacob (Eds.). Allied Publishers Ltd., New Delhi pp. 223-227

Sadanandan A K, Bhargava B S & Hamza S 1996 Leaf nutrient norms for black pepper (*Piper nigrum* L.) using DRIS. J. Plant. Crops 24 (Suppl): 53-59

Sadanandan A K & Hamza S 2002 Long-term effect of inorganic fertilizers on black pepper in laterite soil. In: Plantation Crops Research and Development in the New Millennium Rethinam P, Khan H H, Reddy V M, Mandal P K & Suresh K (Eds.), Coconut Development Board, Kochi, pp. 336-347.

Sadanandan A K, Peter K V & Hamza S 2002 Role of potassium nutrition in improving yield and quality of spice crops in India. In: Potassium for sustainable crop production. Pasricha N S & Bansal S K (Eds.), Potash Research Institute of India, Gurgaon, Haryana and International Potash Institute, Switzerland, pp. 445-454.

Spices Board 2006 India's Spices Export – Volumes and Values. Accessed from http// www.indianspices.com, on 6th March 2006.

Spics Board 2004 Spices Statistics. V Edn, Spices Board, Cochin, p 281.

Thankamani C K, Srinivasan V, Hamza S, Kandiannan K & Mathew P A 2007 Evaluation of nursery mixturc for planting material production in black pepper (*Piper nigrum* L.). J. Spices Aromatic Crops 16 (2): 111-114.

Input use efficiency in black pepper

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Black pepper, *Piper nigrum* L. is an important spice crop and foreign exchange earner of our country. India once had a monopoly in pepper production and trade. However, today India is facing a stiff competition from other pepper producing countries.

Table 1 shows that India has lost the lead in pepper production, with Vietnam emerging as the strong competitor for Indian pepper. In India, pepper is cultivated in Kerala, Karnataka, Tamil Nadu and Andaman & Nicobar Islands. Kerala has 94 per cent share of area and 96.4 per cent of production of Indian pepper.

Table1. Black pepper production in major producing countries (tonnes)

Year	Vietnam	Malaysia	Sri Lanka	Brazil	India	Indonesia	Others	Total
2003	85,000	21,000	12,660	50,000	65,000	80,000	48,500	362,160
2440	100,000	20,000	12,820	45,000	62,000	31,000	52,660	323,480
2005	95,000	19,000	14,000	44,500	70,000	35,000	36,770	314,270
2006	100,000	19,000	14,330	44,500	55,000	20,000	40,900	289,230
2007	90,000	20,000	14,640	35,000	50,000	25,000	36,360	271,000

Major reason for India losing the lead in pepper production is our poor productivity. Black pepper is a crop originated in India. Being the homeland and being a highly cross pollinated crop, propagated through seed and vegetative means, the extent of variability existing in pepper in India is very large Farmers knowingly or unknowingly have domesticated this variability. This has resulted in a large number of genotypes under cultivation with widely varying productivity. Farmers of India, generally practice their own methods of cultivation, which is mostly plant and harvest method. In addition to these, presence of large number of senile unproductive vines, homestead system of cultivation and pest and disease problems, contribute to low productivity of pepper in India.

Climatic requirements

Pepper is a crop of hot humid tropics. Characteristic climatic requirements are high rainfall, uniform temperature and high relative humidity. Well distributed heavy rainfall ranging from 1000-3000 mm is required for proper growth and development of pepper plant. However, the distribution of rainfall, drainage status and moisture holding capacity of the soil are more important than the total quantum of rainfall. Long spells of dry weather are always harmful.

Prolonged spells of drought had resulted in drying up of the crop during 1973, 1977, 1983, 1987 and 1989 (Sadanandan 1993). In such situations life saving irrigations is recommended. Lateritic/alluvial soils rich in humus and with good drainage are the best suited for black pepper. Therefore, ideal sites satisfying the climatic and soil requirements should be selected for pepper cultivation.

By increase in irrigated area, use of high yielding varieties, chemical fertilizers and pesticides it was expected that productivity of pepper in the country should increase but in spite of being the homeland of pepper, our productivity levels are very low. Indian pepper cultivation has to become more remunerative with high productivity levels to take advantage of the new international trade regime.

Planting material

One of the major reasons for low productivity in pepper is the existence of poor genetic stock. A good number of high yielding improved varieties are now available. The variety suited best to the locality should be selected for cultivation. Good quality rooted cutting is the best planting material. Two cuttings per standard will be sufficient. However, many farmers are planting 5-6 cuttings per standard, which has to be discouraged.

Support trees

Use of ideal support trees play a significant role in the growth and yield of pepper. Studies conducted at Kerala Agricultural University (Manjusha 2007), have shown that coconut followed by jack and ailanthus are best supports in terms of growth and yield of pepper. Support trees propagated through cuttings generally showed competition with black pepper in the feeding zone for moisture and nutrients. However, among them garuga was found to be a better option which is less prone to pests and diseases and gives medium yield of pepper.

Water management

In India, irrigating pepper during summer is beneficial. A field experiment conducted at the Pepper Research Station, Panniyur, Kerala to study the effect of irrigation showed that irrigation at IW/CPE ratio of 0.25 significantly increased productivity of pepper by over 90%. Effect was more significant in Karimunda than in Panniyur 1 (Satheesan *et al.* 1997). A study at IISR, Calicut had showed that irrigating pepper vines with 7-10 litres of water/day during summer recorded higher yield of green pepper (4.07 kg/vine/year) compared to control (1.33 kg/vine/year) (IISR 1997). Thanuja (2002) found that summer irrigation of pepper vines @ 10 litres/vine/week by basin method from December to March improved yield by 48%.

Influence of nutrient elements on yield

Nitrogen, phosphorus, potassium, magnesium and micronutrients are the most important for growth and yield of pepper. Sadanandan *et al.* (1990) reported that the quantity of fertilizers required to get high yield vary among locations. Pillai *et al.* (1979) reported that the higher levels of N adversely affected the yield of Panniyur1. There are reports of positive influence of liming in black pepper (Yufdy 1991; Thalib *et al.* 1991; IISR 1997).

Investigations on the mineral nutrition of variety Panniyur1 in a laterite soil, poor in major nutrients indicated that application of 140 g N, 55 g P_2O_5 and 270 g K_2O/vine/year resulted in significant increase in the availability of N, P and K (Sivaraman *et al.* 1987). Sadanandan (1994) reported that 140 kg N, 55 kg P_2O_5 and 270 kg K_2O/vine in two equal split doses is optimum and most economic in terms of yield response.

Yield variability in relation to soil fertility in pepper plantations was examined by Mathew *et al.* (1995). Near neutral soil pH, high organic matter content and high base saturation with Ca and Mg were found to influence the nutrient up take and productivity. The magnitude of the nutrients removed was in the order of N>K>Ca>Mg>P>S>Fe>Mn>Zn and recommended yield based fertilizer recommendations for enhancing yield.

In a study conducted at Kerala Agricultural University (Anon 1996) it has been shown that the nutrient requirements for production of one kg of pepper berries are to the tune of 6.35g N, 6.33g K, 0.47g Mg, 0.44g P, 0.29g S, 42.82mg Fe, 34.45 mg Mn and 4.2 mg Zn. This requirement was irrespective of the yield potential indicating that plants with higher production potential require higher doses of nutrients.

Pepper requires large quantities of K for growth and fruiting and its requirement is associated with the content of other nutrients in the plant especially N. Pillai *et al.* (1979) obtained highest yield with NPK ratio of 5:5:10 whereas Sadanandan (1993) suggested a ratio of 2.5:1:5 for getting highest yield. It was also suggested that an NK ratio of 1:2 is best for pepper.

Application of Ca and Mg at 50 kg each per ha increased the exchangeable Ca and Mg in the soil and in the plant indicating the significance of these elements in the balanced nutrition of pepper. Of the various micronutrients, most important for pepper nutrition are zinc, molybdenum and boron as these become deficient in acid soils by leaching or precipitation (De Waard 1969).

Nutrient levels and recommendations for sustainable pepper production for India (Sadanandan 2000) at a desired soil pH of 6.5 is as follows.

Soil nutrients	Desired level (mg kg^{-1})	Recommended dosage (kg ha^{-1})
Organic matter	2.5 %	140
Phosphorus	18	55
Potassium	150	270
Calcium	1500	Lime application takes care
Magnesium	300	20
Sulphur	20	75
Iron	10	10
Manganese	10	10
Zinc	1.6	5
Copper	0.6	5
Molybdenum	0.3	0.5
Boron	0.8	2

Nutrient deficiencies

Nutrient disorders and deficiencies are often encountered in the field. Nybe & Nair (1986; 1987a; 1987b; 1987c) conducted a series of studies to assess nutrient deficiency symptoms of major and micro nutrients.

Deficiency symptoms of macronutrients except Ca and S were first manifested on older leaves while that of micronutrients on younger leaves. Symptoms of N deficiency were expressed as uniform yellowing followed by necrosis whereas purple to bronze yellowing with ash coloured necrotic areas were the symptoms of P deficicncy. Potassium deficiency symptom was characterised by tip and marginal necrosis which later progressed to two – thirds distal portion of lamina. Ca deficiency symptoms appeared as tiny brown necrotic spots on chlorotic area near margins, which later enlarged to form black necrotic areas. Visible symptoms of Mg deficiency were oval interveinal chlorotic area followed by black ncerotic patches. Sulphur deficiency was manifested as uniform yellowing with brown necrotic spots. There was profound reduction in vegetative growth due to deficiency of macronutrients. Reduction in shoot growth and leaf area index was maximum in case of deficiency of N (56 and 63% respectively). Reduction in root growth was quite high due to deficiency of Ca (61%), P (45%) and N (39%).

Interveinal chlorosis was the initial symptoms of deficiency of all micronutrients. However, symptoms were specific to nutrients concerned. Iron chlorosis was characterised by the presence of green bands along major veins whereas bronze yellow colour of the interveinal area was the specific symptom of Mn deficiency. Bronze colour of entire lamina with necrotic tips and margins were the symptoms of Cu deficiency.

Zinc deficiency was unique with little leaf and rosetting. Due to B deficiency leaves become large, thick and brittle, with orange yellow mottles on upper surface and grey brown interveinal patches on lower surface. Unlike macronutrients, there was no marked reduction in vegetative growth due to deficiency of micronutrients except in iron and boron which recorded 35 to 22% respectively in total dry matter production. Boron deficient plants registered 18% increase in leaf area index.

Fertilizer requirements

Quantity of NPK required to get high yield varies largely among locations. Location specific recommendations for pepper advocated by Kerala Agricultural University are given below (KAU 2005).

General recommendation :	50:50:150 (N, P_2O_5 and K_2O g/vine/year)
Panniyur and similar areas:	50:50:200 (N, P_2O_5 and K_2O g/vine/year)
Kozhikode and similar areas:	140:55:275 (N, P_2O_5 and K_2O g/vine/year)

Apply 1/3 dose for one year old plants and ½ dose for two year old plants. Fertilizers may be applied in two split doses, first in May - June with organic farming and second in September- October.

Organic nutrition

Application of chemical fertilizers to pepper in general was very low in all southern districts of Kerala surveyed by the Kerala Agricultural University during 1999 - 2004. Farmers usually resort to use of organic manures (89.1% in Idukki). Use of biofertilizers is found on the increase in all the districts surveyed. Maximum adoption of biofertilizer application was in Pathanamthitta District (13.6%).

Biomass production in black pepper was significantly increased following incorporation of organic material into soil. When different levels of organic sources were compared, total biomass production of the vine was affected by the application of coffee and black pepper leaves. However, there was a steady increase in biomass production with increasing levels of garuga leaf application (Sivakumar & Wahid 1994).

Significant increases were noticed in N, P and K concentrations of leaves and stem, Mg concentration of leaf, S concentration of leaf and stem, Fe content of stem and foliar Mn content of vine following organic matter treatments. The vine removed significantly higher quantities of N, P, K, Mg, S, Fe and Mn following soil application of leaf material as compared to control vines. Significant increase in major micronutrient availability was noticed following incorporation of leaf material.
To study the influence of organic manures and biofertilizers, in comparison with inorganic ferilizers, in improving growth and yield of black pepper, trials were under taken in farmers fields in different pepper

growing regions of Kerala and at KAU campus, Vellanikkara. Results revealed that chemical fertilizer use in black pepper can be minimised considerably by substituting with organic manures and biofertilizers. The promising manurial schedules which vary with locations include substitution of 50% of inorganic fertilizer with FYM on N equivalent basis and remaining dose met either through inorganic P + *Azospirillum*, inorganic N and P, inorganic N + *Phosphobacterium* +VAM or composite culture of three biofertilizers (Nybe 2004).

Another study was designed to formulate agronomic techniques, which require only minimum investment but can ensure comparatively high yield and profit in black pepper.

Growing cowpea in the interspaces and basins, applying composite culture of *Azospirillum, Phosphobacterium* and VAM, application of zinc sulphate and skipping of phosphorous are a few of the promising technologies that can lower input use in black pepper in different locations.

Influence of organics (FYM, neem cake) biofertilizers (*Azospirillum*), phosphate solubililising bacteria and arbuscular mycorrhizal fungi on yield and quality of black pepper, varieties Panniyur 1 and Panniyur 2 were studied. An integrated nutrient management with biofertilizers, organic and inorganic fertilizers was superior with respect to quality attributes *viz.*, essential oil, oleoresin and piperine content. In general, treatments involving complete organic and biofertilizers, organic and inorganic combinations exhibited high values of soil nutrients except S, Ca and Zn. Biofertilizers applied plots registered higher soil microbial population of fungi, bacteria and actinomycetes. Two most important nutrient elements which are highly essential for production of pepper were suggested as K and P in view of their high direct and indirect effects on yield.

Organic farming

Kerala Agricultural University has formulated an *adhoc* recommendation for organic farming in black pepper. The salient points of the recommendations are

Manuring

Apply 10 kg FYM/compost/green leaves and one kg neem cake / plant at the onset of South - West monsoon and 5 kg FYM and 1kg neem cake / plant at the onset of North - East monsoon. Apply lime at the rate of 500 g/vine in April – May. Apply biofertilizer combination of *Azospirillum* (25 g/plant), Phosphobactor (25 g/plant) and AMF (110 g/plant) along with FYM application.

Pest management

Pollu beetle: Neem oil + garlic 2% + Karanji oil 1% as 3 sprays at spike emergence, berry formation and berry maturation stage.

Root knot nematode: Application of talc based formulation of *Bacillus macerans* @ 10 g/vine in basins (10^6cfu/g) at the time of planting of vines or just before monsoon

Disease management

Nursery diseases (rotting and fungal pollu): Enrich the organic manure (cow dung) with native isolates of *Trichoderma.* Treat pepper cuttings with *Pseudomonas fluorescens* P_1 suspension for 15 minutes before planting. Spray and drench the plants at fortnightly interval with 2% *Pseudomonas fluorescens*. Inoculate the cuttings with AMF at the time of planting in the nursery.

Main field (foot rot and anthracnose): Remove and burn all infected or dead vines. Organic manure used for main field planting should be enriched with native isolates of *Trichoderma.* Inoculate with native arbuscular mycorrhiza in the main field at planting. Soil drenching and foliar spraying with *Pseudomonas fluorescens* P_1 suspension (2% concentration) during May – June and October has to be taken up. The frequency of application may be adjusted based on disease incidence and intensity.

Chemical control: After the receipt of monsoon showers (May - June) all the vines are to be drenched over a radius of 45 – 50 cm with 0.2% copper oxy chloride at the rate of 5 - 10 litres per vine. A foliar spray of 1% Bordeaux mixture is also to be given. Drenching and spraying are to be repeated just before the North - East monsoon. A third round of drenching may be given during October if the monsoon is prolonged. In plots where biocontrol agents are incorporated, CoC should be replaced with 0.3% potassium phosphonate for drenching and spraying.

Conclusion

Pepper cultivation in India will continue to be in two systems of cultivation in the immediate future. One is the homestead system of cultivation as an intercrop and the other as a pure/commercial crop in the hilly areas of Western coast of India. In either case use of high yielding varieties, judicious manuring, shade regulation and plant protection measures can definitely improve the yield of pepper in India. However, to win over the enviable production and productivity of Vietnam and to regain our past glory, area under improved varieties in pure cropping and improved agronomic practices should be considerably increased. With the joint effort of research institutes, State Agricultural Departments, progressive farmers and support from state and central governments, it will not be a difficult task.

References

De Waard P W F 1969 Foliar diagnosis, nutrition and yield stability of black pepper (*Piper nigrum* L.) in Sarawak. Commun. Dep. agric. Res. Amsterdam. 58, Royal Tropical Institute, Amsterdam, the Netherlands, pp.150.

IISR 1997 Annual Report. Indian Institute of Spices Research 1996-97, Calicut, Kerala, pp. 50-51.

KAU 2005 Package of Practices Recommendations "Crops" – 2005. Kerala Agricultural University, Kerala, India.

Manjusha C M 2007 Crop standard interactions in black pepper (*Piper nigrum* L.). Ph.D thesis, Kerala Agricultural University, Thrissur, pp.166.

Mathew P G, Wahid P A & Nair S G 1995 Soil fertility and nutrient requirement in relation to productivity in black pepper (*Piper nigrum* L.). J. Plantation Crops 23: 109-115.

Nybe E V & Nair P C S 1986 Nutrient deficiency in black pepper (*Piper nigrum* L.). Nitrogen, phosphorus and potassium. Agric. Res. J. Kerala (24):132-150.

Nybe E V & Nair P C S 1987a Nutrient deficiency in black pepper (*Piper nigrum* L.). Calcium, magnesium, sulphur. Agric. Res. J. Kerala (25):52-65.

Nybe E V & Nair P C S 1987b Nutrient deficiency in black pepper (*Piper nigrum* L.). Iron, manganese, copper. Agric. Res. J. Kerala (25):147-158.

Nybe E V & Nair P C S 1987c Nutrient deficiency in black pepper (*Piper nigrum* L.). Zinc and boron. Agric. Res. J. Kerala (25): 191-200.

Nybe E V, Peter K V & Miniraj N 2004 Integrated cropping in coconut involving in spice crops. Indian Coconut J. 34 (10): 3-9.

Pillai V S, Chandy K C, Sasikumaran S & Nambiar P K V 1979. Response of Panniyur 1 variety to nitrogen and lime application. Indian Cocoa Arecanut and Spices J. 6(1): 7-9.

Sadanandan A K 2000 Agronomy and nutrition In: Ravindran P N (Ed.) Black Pepper, *Piper nigrum*. Harwood Academic Publishers, India, p 196.

Sadanandan A K 1994 Nutrition of black pepper. In: Chadha K L & Rathinam P (Eds.), Advances in Horticulture. Vol.9- Plantation and Spice Crops.

Sadanandan A K, Abraham J & Anandaraj M 1990 High production technology in black pepper. National Research Centre for Spices, Calicut, p 6.

Sadanandan A K 1993 Water management of spice crops- problems and prospects. Proc. Seminar on water management for plantation crops, Trivandrum, pp. 200-205.

Sastheesan K N, Rasjagopalan A, Pillai V S, Jagdeeshkumar T N , Mammootty K P & Nair U P K 1997 Influence of irrigation levels on yield, quality and incidence of pests and diseases in black pepper (*P. nigrum* L.) (Abstract) National Seminar on water and nutrient management for sustainable production and quality of spices, Madikeri, p 21.

Sivakumar C & Wahid P A 1994 Effect of application of organic materials on growth and foliar nutrient contents of black pepper (*Piper nigrum* L.). J. Spices and Aromatic Crops (3): 135 –141.

Sivaraman K, Sadanandan A K & Abraham J 1987 Effect of NPK on nutrient availability and yield response of black pepper in an ultisol (Abstract). National Seminar on recent advances in soil research, Pune, p 46.

Thalib H, Hamin H & Barnawi H 1991 The effect of liming on the growth of pepper seedlings Proc. Seminar Sehari Pnanggulangan Masalah Lad di Lampung, pp. 43-55.

Thanuja T V (2003) Physiomorphological and biochemical responses of black pepper to irrigation, pruning and hormone application for flusing, flowering and fruit set. Ph. D thesis, Kerala Agricultural University, Kerala, India, p 233.

Yufdy M P (1991) Effect of liming on the growth of different black pepper varieties in the red and yellow podzolic soil. Industrial Crops Research J. 17(2): 31-36.

Black pepper – An inevitable crop component in plantation crop based cropping system

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Introduction

In India, plantation crops like coconut and arecanut comprise an area of about 2.25 M hectares. The coconut is grown in a wide range of agro-climatic conditions, but palm is widespread in the coastal areas of the country, while arecanut is largely cultivated in the plains and foothills of Western Ghats and North Eastern regions of India. These crops, being perennial in nature, the land planted with remains committed to it for several decades. Further, the coconut and arecanut holdings in India are small and majority of the farmers have less than one hectare in size. The income derived from such small holdings is not sufficient to sustain even a small family. This made the practice of growing other intercrops inevitable in coconut and arecanut plantations.

Black pepper (*Piper nigrum* L.), the king of spices is sufficiently shade tolerant; and is ideal for mixed cropping with coconut and arecanut palms and can be conveniently trained on the palms once the stem grows to a certain height. Presently, black pepper is being cultivated in about 0.195 M ha area with the production of about 53011 tonnes in India. Of this, more than 90 per cent of the area and production of pepper is from the State of Kerala alone. India is the leading exporter of black pepper with about 40000 tonnes to other countries contributing nearly 25 per cent of the total export value of spices. The estimated global demand for black pepper is 2.1 lakh tonnes by 2025 AD. There is a potential to capture at least 50 per cent of global market by India, for which its production should be increased to 1.25 lakh tonnes. As the scope for increase in area is limited, cultivation of pepper as mixed crop in the existing areca and coconut plantations is a viable alternative to increase the production to meet the growing demand.

Resource use in coconut and arecanut plantations

Coconut palm like all monocots has a typical adventitious root system. Under favorable conditions, as many as 4000 to 7000 roots are found in the middle aged palms. Kushwah *et al.* (1973) reported that about 74 per cent of the roots produced by a palm under good management did not go beyond 2 m lateral distance and 82 per cent of the roots were confined to the 31 to 120 cm depth of soil. Further studies have confirmed that more than 80 per cent of the root activity was confined to a lateral distance of 2 m from the trunk (Anil Kumar & Wahid 1988). Thus, the active root zone of coconut is confined to 25 per cent of the available land area and the remaining area could be profitably exploited for raising subsidiary crops.

As far as light is concerned, the Venetian structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed, but clumped around a few widely spaced growing points. This non-random distribution will also lead to low extinction coefficient of around 0.65 for PAR. The light intensity at ground level was always higher than 6700 lux at all parts of the year (Nair 1979). Of the solar radiation received, on an average about 50 per cent alone is intercepted by the coconut canopy.

Similarly, arecanut (*Areca catechu* L.) as a sole crop does not fully utilize the natural resources such as soil, space and light. The compact nature of arecanut crown, raised well above the ground (10 to 15 m), allows more sunlight to pass down to ground and maintain high humidity which, in turn, favour excellent growth of shade loving crops. Studies at CPCRI have revealed that orientation and structure of arecanut canopy permits 32.7 – 47.8 per cent of incident radiation to penetrate down depending on the time of the day (Muralidharan 1980). Studies on rooting pattern revealed that arecanut palms planted at 2.7 x 2.7 m spacing could use only 30 per cent of the land area (Bhat & Leela 1968). The normal cultural operations are also confined within about 75-80 cm radius from the base. Thus, the areca palm exploits only 2.27 sq.m of (r=0.85 m) land area out of 7.29 sq.m (2.7 x 2.7 m) land available to each palm. Further, arecanut plantations are mostly located in fertile soils in the coastal and Ghat regions in Kerala and Karnataka, and show good soil fertility and moisture holding in the soil throughout the year except for a few months in the summer. These make arecanut plantations also are more ideal for inter/mixed cropping.

Selection of pepper variety and multiplication

It is important to cultivate only varieties which are proven to be highly productive. Karimunda and Panniyur-1 perform better under mixed cropping situations (Potty *et al.* 1979). Nayar (1982) recommended the black pepper hybrid Panniyur-I for well spaced (2.7 x 2.7 m) arecanut gardens where the infiltration of light is higher and Karimunda for more densely planted gardens. In recent years, many new pepper varieties/hybrids have been developed in the country. The improved varieties emerging from breeding programmes need to be tested as mixed crop in coconut and arecanut gardens from time to time to find out the best variety suitable for growing under coconut and arecanut shade.

Mother plants should be selected based on yield and other desirable attributes such as vigorous growth, maximum number of spikes per unit area, long spikes, close setting of berries, disease tolerance *etc.* Selected mother plants should be in the age group of 5-12 years. Rooted seedlings from these selected mother palms are propagated vegetatively from shoot cuttings. The runner shoots (even terminal shoots also can be used) from the vines should be separated in February-March for multiplication purpose.

Agrotechniques for pepper mixed cropping

A spacing of 7.5 x 7.5 m in the square system is recommended for coconut (175 palms/ha) but in the homestead gardens of Kerala, the density is much higher (200-250 palms/ha) whereas in the Malnad region of Karnataka State, much wider spacing are adopted with densities as low as 120 palms/ha. In the young coconut from planting to 8 years age, there will be adequate space and light for intercropping with short stature annuals. Under no circumstances, perennial crops like pepper should be planted during this period, because they may overgrow the palms and affect their growth. In the second phase, from 8 to 20 years, there will be very little penetration of light downwards and practically no cropping is possible during this period. In the third phase from 20 years onwards, pepper can be mix cropped in coconut gardens. By this time, the coconut palm attains a height of about six meters, and about 55 per cent of light is available below the palm canopy.

Arecanut is planted mostly at recommended spacing of 2.7 x 2.7 m. Though the natural resources like soil, space and light are not fully utilized in a sole crop in the young palms, pepper mixed cropping is possible only in areca gardens aged over 15 years.

Rooted cuttings of pepper raised in polybags may be planted in 0.5 m^3 pits at a distance of 1 m away from the bole of the palm (areca/coconut) on the Northern side. The pits have to be half filled with a mixture of farm-yard-manure or compost, 5 kg neem cake and top soil. The soil around the pit may be treated with 50 g *Trichoderma* culture as a precaution against quick wilt of pepper. The vines may be trained on to the palm as and when they grow and tied to the trunk for the first two years. In the later years, the aerial roots of pepper vines itself gets attached with the coconut/arecanut trunk. Both crops have to be adequately manured to prevent competition for nutrients between crops. Fertilizer at the rate of 100: 40:140 g of N, P_2O_5 and K_2O respectively have to be applied for an adult vine every year in two equal split doses during May and September along with the recommended dose of fertilizers for coconut and areacnut. Fertilizers for pepper may be applied at a distance of 30 cm around the plant and earthed up. One-third of the full dose is to be given in the first year, two-third in the second year and full dose from the third year onwards. Application of lime at the rate of 500 g/vine during April-May in alternate years is reported to be beneficial (Nayar 1982). Care should be taken not to damage the surface roots of pepper while doing cultural operations and fertilizer application in coconut and arecanut plantations.

Mixed cropping of pepper should be practiced under assured water supply conditions throughout the year. Sprinkler or perfo-irrigation is preferable as it wets the entire surface. Irrigation at the rate of 20 mm water once in a week has been found to be optimum for arecanut-pepper and coconut-pepper mixed cropping system. Even pepper can be drip irrigated along with coconut and arecanut depending on weather conditions. The establishment, growth and yield under irrigated condition will be very good. Pepper has 10-12 adventitious roots, 3-4 m long, and penetrates to a depth of 1-2 m with an extensive mat of surface feeding roots. Care should be taken not to damage the surface roots of pepper while doing cultural operations and fertilizer application for coconut/arecanut. In the early years of planting, banana may be grown as an intercrop, which provides shade to young plants and protects them from drying up during summer months. However, it is not recommended beyond three years as it may compete with pepper and reduce the pepper yield.

Pepper is a climbing vine and usually it grows as tall as coconut and areca palms. But the height of pepper vine is to be restricted to 12 ft by pruning. This helps in harvesting of coconuts by climbing the tree up to the pepper height with the help of ladder by the climbers without damaging pepper vines on the trunk.

Pepper begins to yield in the third year and comes to full bearing by 7th or 8th year. The yield declines after 15 years but vines have been found to yield even upto 60 years. It flowers during April-May and comes to maturity after 6-8 months. During this period, dry spells will adversely affect the pepper yield. Therefore, the vines are to be irrigated and optimum moisture maintained in the soil. The berries are harvested manually when two or three berries in a spike turns red in colour. The separated berries are to be sun dried for 7 –10 days till they turn black in colour. The recovery of black pepper from the fresh is around 33 per cent. On an average 1 kg dry pepper can be obtained from a single vine trained on coconut and areca palms.

Performance of pepper as mixed crop

Coconut plantations: Pepper is raised exclusively as mixed crop in homestead gardens in Kerala and Karnataka and over 90 per cent pepper is trained on coconut and arecanut trunks. In all these traditional systems, the requirement of each crop in respect of various crop production factors/inputs is practically ignored, and hence the gross productivity of the system is lower than that of sole crops. Way back in 1971-72, pepper variety Panniyur-1 planted as mixed crop in coconut garden and trailed on palms aged over 60 years at CPCRI, Kasaragod yielded a mean of 2 kg dry black pepper/vine/year. The highest per vine yield was 5.5 kg black pepper/year. Coconut-pepper system was found more remunerative. This system could generate a net return of Rs 26200/ha/year in a coconut garden as compared to Rs. 22300/ha/year from coconut monocrop.

In 1970's, CPCRI has developed a multistoreyed cropping model, the most productive and remunerative combination of coconut-pepper (trained on coconut palms)-cocoa-pineapple system. These crops developed their canopies at varying heights, simulating the features of a multistoreyed building. The labour requirement of a sole crop coconut plantation of one hectare was 157 man days in a year. The multistoreyed cropping model requires 366-400 man days labour per year and the work is also evenly distributed round the year. The annual cost of cultivation and returns recalculated based on the revised market rates for the inputs and outputs data of 1976 are presented in table 1.

Table 1. Labour requirement and returns from multistoreyed cropping in coconut plantations (1 ha)

Crop	Labour (man days)	Yield	Annual cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)
Coconut	157	17500 nuts	22000	87500	43500
Pepper	16	88 kg (dry)	5000	8800	3800
Cocoa	163	500 kg beans	5000	10000	5000
Pineapple	30	3710 kg	3000	22260	19260
Total	366		35000	128560	71560

(coconut: Rs 5.00/nut; pepper: Rs 100/kg; cocoa: Rs 20/kg beans: pineapple: Rs 6/kg)
(Source: Nelliat & Krishnaji 1976)

Mixed farming in coconut involved establishment of fodder grass in the interspaces of coconut palms and maintenance of milch animals and recycling of cattle manure in the coconut-fodder-pepper mixed crops stand. This model at CPCRI, Kasaragod generated additional employment to the tune of 850 man days and ensured good returns without any yield decline in coconut. The out put from the 1.04 ha model yielded 11276 coconuts, 60 kg pepper, 250 kg banana and 14495 litres of milk. In coconut based high density multispecies cropping system (HDMSCS) model at Kasaragod, the black pepper (Panniyur-1) yielded 1.66 kg dry pepper/vine/year under 2/3rd recommended fertilizer dose (Palaniswamy *et al.* 2007). In root (wilt) affected area, among the pepper varieties trailed on coconut under HDMSCS model, Karimunda and Panniyur-1 performed better with an average yield of 1 to 1.2 kg /vine/year (Maheshwarappa & Anitha Kumari 2005).

Experiments conducted in Goa conditions revealed that black pepper grows satisfactorily as mixed crop in coconut gardens and the plants started yielding from the third year onwards. The average yield obtained from one-hectare coconut garden was 0.76 t/ha and 0.44 t/ha of dry pepper, respectively from Panniyur-1 and Karimunda (Mathew *et al.* 1993).

Arecanut plantation: The advantages of pepper mixed cropping in areca plantations are not fully exploited by most of the farmers due to the fear that growing black pepper on arecanut may depress the yield of arecanut. Nair (1982); Khader (1982) found pepper as a profitable cash crop, suitable for mixed cropping in areca gardens. According to Singh *et al.* (1982) pepper can be recommended as a mixed crop along with areca in North Bengal. Experimental data from mixed cropping of arecanut and black pepper for 10 years showed that there was no detrimental effect on the yield of arecanut palms due to training black pepper on them. Further, it helped to augment the income of the farmer by about Rs 8940/ha from black pepper alone (Nayar 1982).

A study conducted to investigate the performance of four varieties of pepper as a mixed crop in a 19-year-old arecanut garden with six planting densities revealed that in arecanut garden with recommended spacing of 2.7 x 2.7 m, 43 per cent of sunlight is available to other crops. Pepper as a mixed crop did not influence the yield of arecanut. As regards the yield of pepper, 1.8 x 2.7 m spacing had given significantly more yield per plot (7.09 kg) followed by 1.8 x 3.6 m spacing. Among the cultivars of pepper, Karimunda gave the highest yield (8.92 kg/plot) followed by Panniyur-1 (6.68 kg/plot). The cultivars Uddakare and Malligesara resulted in poor yield (Khader *et al.* 1993).

The yield and economics of arecanut and other intercrops in a high-density multispecies cropping model involving six crops, *viz.* banana, pepper, cocoa, clove, coffee and pineapple was laid out in CPCRI Regional Station, Vittal during 1983 in an 17 year old arecanut plantation (1984 to 1988) is presented in table 2. Black pepper proved to be better mixed crop by providing revenue of Rs 49630/ha from the sale of pepper alone (Khader *et al.* 1992).

Table 2. Yield of different crops in the arecanut multistoreyed cropping model at Vittal

Crop	Plant population/ha	1984	1985	1986	1987	1988
Arecanut (chali)	1300	1582 (39550)	2490 (62250)	4130 (103250)	3507 (87675)	3832 (95800)
Banana (fruit)	390	-	2650 (5300)	2146 (4292)	1422 (2843)	391 (781)
Pineapple (fruit)	2400	-	1263 (2526)	419 (838)	244 (488)	427 (854)
Pepper (dry)	1300	-	-	45 (1575)	320 (11183)	1418 (49630)
Cocoa (pods)	210	-	-	71 (142)	941 (1882)	1084 (2160)
Coffee (dry beans)	780	-	-	10 (160)	(480) 31	(1088) 68
Clove (kg)	180	Not flowered				
Total (Rs)		39550	70076	110257	104551	150313

(figures in parantheses are total revenue - Rs/ha)
(Source: Khader *et al.* 1992)

A similar high-density model consisting of pepper-cocoa-coffee-mulberry-elephant foot yam was laid out in a 20-year-old arecanut plantation in the maidan parts of Karnataka (CPCRI, Research Centre, Hirehalli) indicated that arecanut yield increased by 7 to 20 per cent due to cropping system. Among the component crops, pepper was found to perform better. The net returns at eighth year of experimentation, the system as a whole produced Rs. 171734/ha as compared to Rs. 140612/ha in the arecanut monocrop (Sannamarappa 1993). Another high-density multispecies cropping model consisting of arecanut-pepper trained on areca palm-banana-turmeric-pineapple studied under three levels of fertilizer management full, two-third and one-third dose of recommended fertilizers for productivity at CPCRI Research Centre, Kahikuchi, Assam. Nine years of mean economic yield revealed that full dose of recommended fertilizer application resulted in higher production with areca chali yield of 2405 kg/ha, dry pepper yield of 1252 kg/ha, pineapple fruit yield of 987 kg/ha and 2127 kg turmeric/ha. The system generated a net return of Rs 185520/ha in 1995-96 under full dose of fertilizers (Ray *et al.* 2000). The major contribution towards this net return was from the component crop pepper (48 per cent) and this was followed by main crop, arecanut (31.3 per cent). This clearly demonstrated the potential of pepper as a mixed crop in arecanut plantations.

Disease and pest management

Adoption of integrated management practices for diseases and pests is very essential in coconut-pepper and arecanut-pepper mixed cropping systems. The microclimate in the mixed crop models provides ideal environment for the multiplication and survival of pests and diseases causing microbes. Regular monitoring and timely control measures will help to control pests and diseases and realize optimum yields.

Advantages of pepper mixed cropping

Social benefits: Social benefits are the food and nutritional functions of fresh nuts of coconut and coconut products, and pepper produced under coconut and areca plantations. With pepper mixed cropping, the same coconut/areca lands can be used to produce pepper (spice for food flavouring, and vitamins and minerals).

Ecological benefits: Compared to the ecological conditions of the long-term single crop farming, those of lands under mixed cropping are more favourable and stable for intensive and sustainable agricultural production. This is highly attributed to more efficient utilization of the land resources as a result of: maximization of solar energy capture; optimization of soil moisture use and retention capacities; enhancement of soil fertility build up due to higher biomass generation over time and minimal soil erosion and nutrients losses largely attributed to effective and efficient crop canopies and root systems.

Employment generation: Coconut and areacnut as a monocrop do not provide employment continuously through out the year and consequently the family labour remains unemployed for larger parts of the year. The mixed cropping of pepper with coconut and areacnut generates higher employment and higher returns to the family labour.

Conclusions

In pure stand of coconut/arecanut farming, with or without higher price to its produce, the pepper mixed cropping systems guided by the modern and scientific principles involved, the social, environmental and economic benefits are substantially enhanced and become highly attractive to coconut/arecanut farmers.

References

Anilkumar K S & Wahid P A 1988 Root activity pattern of coconut palm. Oleagineux 43 (8-9): 337-342.

Bhat K S & Leela M 1968 Cultural requirements for arecanut. Indian Fmg. 18(4): 8-9.

Khader K B A 1982 Inter and mixed cropping in arecanut gardens. Indian Fmg. 32(9): 21-23.

Khader K B A, Balasimha D & Bhat N T 1992 Resource use in arecanut based high density multispecies cropping system. J. Plantn Crops 20 (Supplement): 19-24.

Khader K B A, Nair M G K & Yadukumar N 1993 Performance of four cultivars of black pepper as mixed crop with arecanut under planting densities. J. Plantn Crops 21 (Supplement): 7-11.

Kushwah B L, Nelliat E V, Markose V T & Sunny A F 1973 Rooting pattern of coconut (*Cocos nucifera* L.). Indian J. Agron. 18: 71-72.

Maheshwarappa H P & Anitha Kumari P M 2005 Agronomic strategies for managing root (wilt) affected coconut gardens. Tech. Bull. CPCRI, Rs, Kayamkulam, 17p.

Mathew P A, Nagabhushanam S & Dhandar D G 1993 Multicropping trials in coconut in Goa. *In:* Advances in Coconut Research and Development, pp. 437-439, Oxford and IBH Pub. Co. Pvt. Ltd., New Delhi.

Muralidharan A 1980 Biomass productivity, plant interactions and economics of intercropping in arecanut. Ph.D thesis, University of Agricultural Sciences, Bangalore, India. 271p.

Nair M G K 1982 Intercropping with pepper. Indian Fmg. 32(9): 17-20.

Nair P K R 1979 Intensive multiple cropping with coconut in India, Principles- Programmes-Prospects. Verlag Paul Parcy-Berlin and Hamburg. Adv. in Agron. and Crop Sci. 6.147p.

Nayar T V R 1982 Grow pepper in arecanut gardens. Indian Fmg. 32(1): 27-31.

Nelliat E V & Krishnaji N 1976 Intensive cropping in coconut gardens. Indian Fmg. 26(9): 9-12.

Palaniswamy C, George V Thomas, Dhanpal R, Subramanian P, Maheshawarappa H P & Upadhyay A K 2007 Integrated nutrient management in coconut based cropping system. Tech. Bull. No.49, CPCRI, Kasaragod, 24 p.

Potty N N, Radhakrishnan T C & Asokan P K 1979 A note on the early growth and performance of six varieties of pepper in the multistoreyed cropping programme in coconut gardens. Agric. Res. J. Kerala 17(1): 151-152.

Ray A K, Srinivasa Reddy D V & Sairam C V 2000 Performance of areca based high density multispecies cropping system under different levels of fertilizers. J. Plantn Crops 28(2): 110-116.

Sannamarappa M 1993. Arecanut-based cropping system in maidan parts of Karnataka. J. Plantn Crops 21(Supplement): 3-6.

Singh R K, Kumar N Y, Roy Burman & Roy A C 1982 Intercropping in arecanut gardens. Indian Fmg. 32(9): 13-15.

Mechanization of post harvest processing and value addition of black pepper

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Pepper (*Piper nigrum*) popularly know as the 'king of spices' is the most important spice of India. It is the dried fruit of perennial climbing vine, mostly found in hot and moist parts of Southern India. Kerala alone contributes 96% of the total production in India. Apart Kerala, pepper is also cultivated in the beautiful hill districts of Karnataka and Tamil Nadu. Besides India, pepper is also cultivated in Brazil, Indonesia, Malaysia, Vietnam, Sri Lanka and Thailand. India produces 60,000 tonnes of pepper from an area of 1.8 lakh ha. Pepper is widely used as a condiment, preferred for its characteristic aroma, pungency and biting taste. It is used to garnish culinary preparations, ketchups, sauces and pickles and in pharmaceuticals. India is the largest producer, consumer and exporter of black pepper. India contributes about 25 to 40 % to the total world production and thus occupies the unique position in the international trade of pepper.

Production of black pepper

The unit operations involved in the production of black pepper are harvesting, threshing, drying, cleaning, grading, packaging, storage and distribution.

Harvesting

The stage of harvest is very important for the production of black pepper. Well-matured but unripe berries are harvested. Pepper becomes ready for harvest in about 6-8 months after flowering, during November-December and harvest continues up to March-April. The spikes are picked when they are blackish green and most pungent. Harvesting is done manually, by climbing on the ladders. The well-matured spikes, in dark green colour are picked by the person standing on the ladder and dropped.

Threshing

In most of the plantations, threshing is done by manual trampling, which involves either a man / woman labour. The labour charge for threshing of pepper spikes is paid on daily rate basis. In a day, a labourer will be able to trample about 200 kg of spikes and separate the berries.

Hand operated pepper thresher: To overcome the drudgery to the labourer in manual threshing, a hand operated pepper thresher has been developed at Tamil Nadu Agricultural University, Coimbatore, suitable for medium and small farmers. This pepper thresher consists of a metallic drum provided with rasp bars, concave, power drive with a handle and a sieve for separating the empty spikes. The metallic drum is made of 1.5 mm thick mild steel sheet and made to a diameter of 250 mm and length of 350 mm. On the periphery of the drum, 8 numbers of rasp bars made of wood of size 20 mm x 15 mm are mounted. The drum is placed inside a concave of diameter 300 mm made of mild steel with an opening at the centre of 12 mm width. The cover of the concave is made to half round and the hopper is fitted to the cover at an inclination of about 35°. The power to the drum is transmitted through a gear wheel and handle and made to rotate the drum at about 250-300 rpm. The pepper spikes fed through the hopper reach the threshing drum and undergo threshing. The separated berries and empty spikes fall on the sieve and separated. Efficiency of the thresher is 96%. Capacity of the thresher is 60 kg/hour. Savings in time and cost are 60 and 75%, respectively. A view of hand operated thresher is given in Fig. 1. Performance evaluation of thresher is presented in table 1. Comparative quality evaluation of manual and hand operated thresher is presented in table 2.

Table 1. Performance of the hand operated pepper thresher

Speed (rpm)	Capacity (kg/h)	Efficiency (%)		Breakage (%)	
		First pass	Second pass	First pass	Second pass
250	50.5	88.0	90.5	3.1	3.6
275	56	90.2	92.1	3.6	4.0
300	61	91.5	96.2	4.1	4.4

Table 2. Quality Evaluation of pepper threshed using thresher and by trampling

Test	Moisture content	Threshing using hand operated thresher			Threshing by trampling		
	% (w.b)	Volatile oil (%)	Oleoresin (%)	Piperine (%)	Volatile oil (%)	Oleoresin (%)	Piperine (%)
1	10.54	4.41	12.31	3.21	3.81	11.12	2.86
2	9.81	4.38	12.54	3.34	3.92	11.52	2.46
3	9.91	4.61	11.98	2.96	3.84	11.95	2.94
	Mean	4.47	12.28	3.17	3.86	11.53	2.75

Power operated pepper thresher: A mechanical rasp bar drum type pepper thresher of capacity 400 kg per hour has been developed at Tamil Nadu Agricultural University, which is operated by a 2 hp electric motor. This pepper thresher consists of a metallic drum provided with rasp bars, concave, oscillating sieve, power source and power drive. The metallic drum is made of 1.5 mm thick mild steel sheet and made to a diameter of 330 mm and length of 450 mm. On the periphery of the drum, 8 numbers of rasp bars made of wood of size 30 mm x 15 mm are mounted and lined with 1.5 mm thick rubber sheet. The drum is placed inside a concave of diameter 370 mm made of mild steel with an opening at the centre for 12 mm width. The cover of the concave is made to half round and the hopper is fitted to the cover at an inclination of about 35°. The oscillating unit is made to a size of 400 mm x 600 mm and provided with an eccentric of 5 mm and receives the power from a one hp electric motor and oscillates at a speed of 90 strokes / minute. The power to the drum is also transmitted through V pulley arrangement. The performance of the thresher was evaluated for the capacity, breakage and threshing efficiency at various speeds of operation. The capacity of the thresher increased from 320 to 400 kg/h as the speed of the drum increased from 300 to 450 rpm. An increase in the speed also increased the efficiency of threshing. The percentage of broken berries was negligible and the threshing efficiency was above 95% at 300 rpm of drum speed. The thresher is operated by a single phase 2 hp motor. The performance evaluation of power operated thresher is presented in table 3. A view of power operated pepper thresher is presented in Fig. 2.

Table 3. Performance of the power operated pepper thresher

Speed rpm (m/s)	Capacity (kg/h)	Efficiency (%)		Breakage (%)	
		First pass	Second pass	First pass	Second pass
300 (4.71)	320.5	89.5	95.1	3.5	3.8
360 (5.65)	364	90.2	96.3	3.9	4.1
450 (7.07)	398	95.8	98.1	4.2	4.5

Drying of pepper

The freshly harvested berries contain moisture of above 70% (w.b.). The berries, as soon as harvested are separated from spikes and spread out on mats for drying. In about 2 days, the moisture content decreases to 20-25%. Due to enzymatic oxidation of colourless compounds present in the skin, the colour of pepper fruits turn black and masks the green colour after drying. The subsequent operations involve further drying to safe moisture level below 11% (w.b). Sun drying with periodic turning is commonly adopted, since it is feasible when the quantity is small and monsoon does not interfere. But for large scale drying, artificial drying is preferred. The moisture in partially sun-dried pepper is brought down from 25 to 10% in 2 stages in a counter current hot air flow system. Complete artificial drying is too expensive hence drying should be done partially in mechanical drier to a certain moisture level and then in sun drying to the desired moisture content to avoid mould growth on raw spice during prolonged sun drying.

Solar tunnel dryer for pepper: The solar tunnel dryer consists of a single drying chamber of 2 m x 3 m to a height of 2 m for drying 100 kg of chillies and pepper as shown in Fig. 3. The chamber is semi cylindrical shaped tunnel constructed using pipe frame structure called hoops that are placed at equal distance from one another and cross connected. The floor is covered with a black sheet of 200 microns thickness, which acts an absorber for better absorption of solar radiation. The black body absorbed more heat energy from the surrounding, thus increasing the temperature inside the tunnel. The metallic frame structure of the tunnel dryer is covered by UV stabilized semi-transparent polyethylene sheet of 200 microns thickness. The solar radiation is transmitted through plastic sheet, which has a transmitivity of 90 %. To prevent the entry of rain water inside the tunnel, the cover is fixed like a sloping roof. The UV sheet is transparent to the short wave radiations and opaque to long wave radiations. During bright day light, the short wave radiations are entrapped through the UV sheet, heated the absorber and get converted into long wave radiation. This conversion of short wave radiation to long wave radiation caused an increase in the temperature inside the dryer. Heat is transferred from the absorbed to air in the collector and heated air from collector while passing over the products absorbs the moisture. Solar radiation which passes through the transparent cover of the dryer, heats up the products in the drier. This enhances the drying rate and the temperature inside the drier than the ambient one.

The door, as a roller at one end of the metallic frame, is provided with an area of 1.6 x 1 m size for loading and unloading the produce. It is supported at the top and sealing tapes are provided at the sides thereby it can be opened any time. At the bottom of the door sheet, roller is provided for rolling the sheet. The natural ventilation to the dryer is provided at the front end of the door sheet using chicken mesh, having an area of 40 x 80 cm which causes the air to move faster through the dryer, reduces its humidity and acts as an inlet to the dryer. The provision for ventilation in solar tunnel dryer helps in efficient removal of moisture from the produce by allowing the entry of fresh air from the bottom and removal of moist air through the top by natural convection. A PVC pipe of 10 cm diameter and a length of 70 cm height are placed at the rear end of the tunnel to remove the moisture naturally. It is provided with a "T" shaped pipe in order to prevent the rainwater entry. The heated air from the inlet passes over the product evaporates the moisture and escapes through the chimney. The trays used during the drying experiment are of two types. The trays without perforations and the trays with perforations. The perforation area 10 and 20 per cent for pepper were used for drying. The dimensions of the trays were 48 x 32 x 5 cm. Two frames for the trays were provided inside the dryer for holding the materials being dried. The dimension of tray frame is 108 x 70 x 120 cm, where frame can hold 16 trays. A view of solar tunnel dryer for pepper is shown in Fig. 3. Efficiency of solar tunnel dryer for pepper is given in table 4.

Cleaning and grading

The dried pepper is cleaned to get rid of extraneous matter such as dirt, stones, stalks, leaves *etc.* Magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibratory conveyors with inclined decks in combination of air classification are used for efficient de-stoning of spices. The ungarbled black pepper contains pinheads, immature pepper and large berries. Broken pepper and light pepper grades are separated pneumatically; pin heads which come along with garbled pepper are separated by sieving. As the export market potential for pepper is more, the market value

Table 4. Performance of solar tunnel dryer for pepper

Time of the day (h)	Solar insolation (kJm^{-2}-h^{-1})	Ambient temperature (°C)	Product temperature (°C)	Dryer temperature (°C)	Collector efficiency (%)	Heat transfer efficiency (%)	Overall efficiency (%)
9.00	1361	28.9	36.3	35.4	28.64	67.63	15.1
10.00	1616	29.7	40.2	39.9	34.09	61.15	21.0
11.00	2142	30.4	44.6	43.1	41.41	66.27	27.4
12.00	2178	31.0	51.4	50.7	54.25	61.51	34.0
13.00	2239	32.5	54.2	53.6	43.10	61.09	26.3
14.00	2480	33.7	59.9	58.7	49.34	62.25	31.0
15.00	2034	33.1	53.7	52.11	43.11	64.40	28.0
16.00	1728	31.6	48.4	46.6	40.78	66.53	27.1
17.00	1073	30.1	42.9	40.2	52.59	75.28	40.0
Average	1872.3	31.22	50.5	46.7	43.04	65.12	28.7

can be increased by the removal of unwanted foreign materials. Tamil Nadu Agricultural University has developed an inclined belt separator for the effective separation of foreign material from pepper. By using this equipment, it is possible to achieve a maximum effectiveness of separation of 98% at a capacity of 50 kg/h. A spiral separator has been developed at Tamil Nadu Agricultural University for pepper cleaning. The developed unit is a stationary one and doesn't need any power to operate as it works based on the gravitational force. The effectiveness of the unit is 98% with a capacity of 90 kg/h.

Grading is done by a combination of size sieving and weight classification by air blast. The major grade is the average sized black pepper known as Malabar Garbled (MG), which constitutes 95 per cent of India's export. Tellichery Garbled (TG) is another bold grade of black pepper. The recovery of black pepper from fresh berries is 33-36 per cent. After drying the pepper berries are cleaned for the removal of foreign matter, impurities *etc*. At the plantation level no mechanical gadget is used for cleaning and grading of pepper. During the cleaning process, the pieces of broken spikes, leaves and plant portions, mud, stone, broken berries *etc*. As such are removed no grading according the size is practiced at plantation level.

Hand operated rotary type cleaner cum grader for pepper: The dried pepper is cleaned to get rid of extraneous matter such as dirt, girt, stones, stalks, leaves *etc*. and graded into commercial grades for higher returns. The manual process is time consuming and an inefficient one. Also, employing the power operated gadgets at plantations lead to dependency on electricity or fuel. Considering this, a hand operated rotary screen cleaner-cum-grader for pepper has been developed. The unit consists of a rotor made of sieves, shaft, screw auger, handle, hopper, frame, outlets and handle. The rotor is made to a size of 1.35 m length and 400 mm diameter with provision to place any sieves. Along the length the rotor is divided into three segments of each 450 mm to mount sieves of various opening. A screw is provided inside the rotor for easy conveying of the feed materials to the sieve perforations.A feed hopper to hold about 15 kg of pepper has been provided at the feed inlet end with appropriate side slopes for easy feeding of the feed into the sieves. Four inclined outlets are provided for the collection of impurities, cleaned and graded products. A semi circular cover is provided above the sieve assembly to avoid spilling of the material when the sieve assembly is rotated. The unit is provided with three sieves with round holes of sizes, 3.5 mm, 3.8 mm and 4.8 mm diameters, which are the sieves as per the Agmark specifications for the grades, 2, 1 and Bold, respectively for pepper.

White pepper production

White pepper is preferred over black pepper by the people of certain countries as its colour matches with light coloured food preparations, sauces and soups. Also white pepper is used in white sauces, salads and other dishes, in which black specks are undesirable and only a mild flavour is required. When pepper is processed to white pepper, the market price is two to three times higher than black pepper. White pepper is prepared by removing the outer mesocarp of harvested ripe red or green berries. The ripe berries are rubbed by hand or trampled to remove the outer soft skin after retting process in the traditional method of white pepper production.

Peeler cum washer for production of white pepper: Manual method of white pepper production is unhygienic and time consuming. Hence, a peeler cum washer for production of white pepper has been developed at the Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore. The unit consists of feed hopper, rotor shaft, perforated cylinder, mild steel blade and nylon brush, water tank, pump, water distribution pipe, discharge outlet and motor. Mild steel blade and nylon brushes are mounted on the shaft. Nylon brushes are provided to avoid clogging of screen of 2x20 mm perforations. A perforated cylinder is placed over a bottom trough. Water for washing the peeled berries is supplied by 0.5 hp mono block self-priming pump from the water tank. The water distribution pipe is placed on the semicircular cover placed above the bottom trough, fitted to the frame. The outlet for white pepper is provided in the cover plate to the thick flange of the perforated cylinder.

The well ripe berries fed into the peeler undergo rubbing action between the perforated peeling drum and the rotor. The skin passes through the perforation and reaches the skin out let. The pepper after skin removal as white pepper reaches the white pepper outlet. The water fed inside the peeling chamber helps in washing and cleaning the product, besides easy peeling and removal of skin after peeling. The pepper peeler can also be operated manually by making modifications in the power drive during electricity failure. Capacity of the unit is 125 kg per hour (power operated) and 15 kg per hour (hand operated). Retting is not required and hence hygienic process. Water requirement is 50 % less, since it is recirculated during washing. Efficiency of the unit is 91%. The same unit can be operated manually during electricity failure. A view of the unit is given in Fig. 4. Performance evaluation of the unit is presented in table 5.

Table 5. Performance evaluation of white pepper peeler cum washer

Clearance (mm)	Peeling efficiency (%)	Brokens (%)	Quantity of wash water (lit/kg)
Peripheral speed: 141 (m/min)			
4	90.0	14.8	0.54
6	89.6	15.3	0.65
8	79.4	6.9	0.61
10	75.2	4.7	0.58
Peripheral speed: 189 (m/min)			
4	88.7	17.2	0.57
6	92.8	15.9	0.54
8	89.6	8.1	0.48
10	87.0	5.1	0.49
Peripheral speed: 236 (m/min)			
4	91.8	18.6	0.46
6	90.4	17.1	0.48
8	87.2	9.3	0.46
10	76.8	4.9	0.54
Peripheral speed: 283 (m/min)			
4	91.4	18.4	0.53
6	88.7	16.5	0.52
8	86.0	9.4	0.54
10	83.2	5.4	0.54

Prototype pepper polisher for production of white pepper from black pepper: The unit consists of a horizontal truncated cone abrasive stone (A46 grade) with maximum diameter of 145 mm and minimum diameter of 110 mm and with a length of 100 mm, mounted on a mild steel shaft. A mild steel rotor shaft of diameter 32 mm and 110 mm length was mounted on pillow block bearing at both ends, which rotates at 1100 rpm. The stone is housed in a perforated drum of 170 mm diameter. Inlet for black pepper is provided with an inclination of 42°. When pepper travels in between the rotating abrasive stone and perforated cylinder, polishing takes place. Outlet with a swinging shutter was placed at the other end, so that when required load is reached, the shutter opens and discharges the polished pepper. The decrease in clearance from the feeding end to outlet improves the polishing efficiency and minimizes the broken. The black skin passing through the perforated sieve is collected at the bottom. The whole unit is mounted on 40x40x3 mm 'L' angle frame. The unit is powered with 1 hp single phase electric motor. The capacity of the unit was 8 kg/h. Since thc pre-treated (boiled and steamed) samples increased the colour value, untreated samples were used for the study and the results showed that polishing efficiency was 70.4 %, recovery was 60.4 % and broken percentage was 22.5. Samples were analyzed for colour, volatile oil and piperine content and the values were found to be on par with the samples obtained from lab model pepper polisher. A view of the unit is given in Fig. 5.

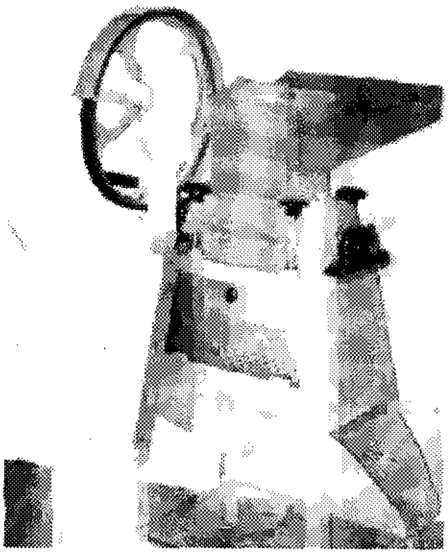

Fig.1. Hand operated pepper thresher

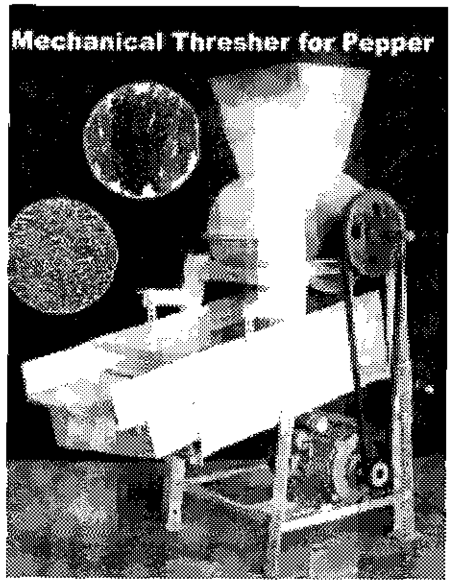

Fig.2. Power operated pepper thresher

Fig. 3. Solar tunnel drier for pepper

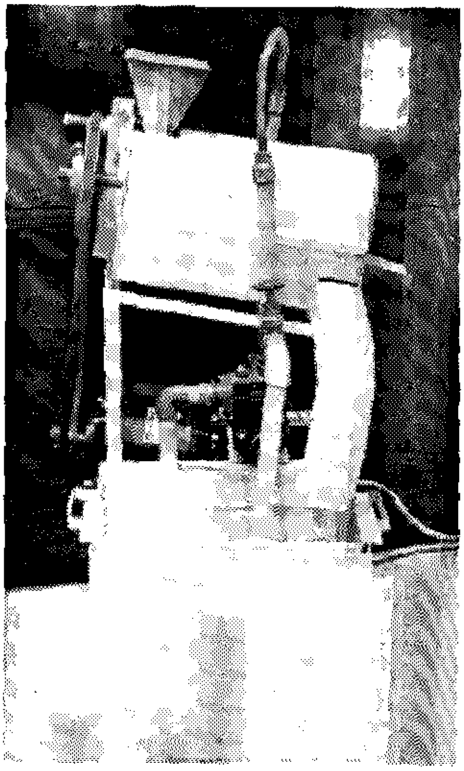

Fig. 4. White pepper peeler cum washer

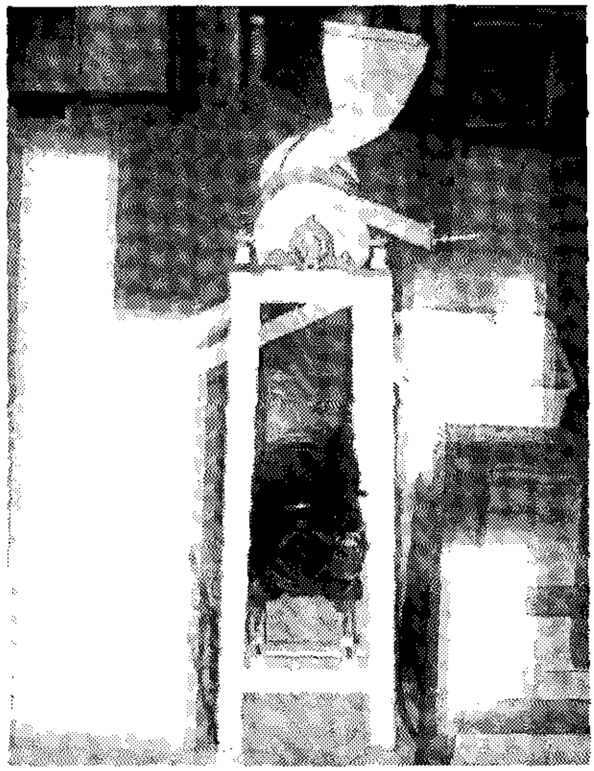

Fig. 5. Pepper polisher for white pepper from black pepper

Conclusion

About 95 per cent of the spices produced in the country are consumed by the domestic market and only five percent is exported, which helps in earning a substantial amount of foreign exchange. Though India is the largest producer of spiees accounting for 61 per cent of world production and 39 per cent of world export, it secures only 9 per cent in terms of value. The reasons are that our country does not produce high quality spices those fetch good price and most of the spices are exported raw without any value addition. Hence, mechanization and value addition of spices, in particular pepper will reduce the human drudgery, improves safety and quality, which in turn increases the earning of foreign exchange.

Recent development in packaging of black pepper and betel vine and their products

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Introduction

Packaging is an integral part of the techniques used to extend the shelf life of any food product by the application of heat processing, application of cold temperatures, drying, use of preservatives *etc.* and is an important component of product development. Black pepper and its value added products have greater export value and the packaging of these products to international standards is very vital

Black pepper and its products

Pepper *(Piper nigrum),* the king of spices, is one of the oldest and the world's most important spice. Black pepper is a native to Malabar, a region on the Western coast of South India where it is still restricted as a wild plant. It occurs wild in the hills of Assam and North Burma. The black pepper and its other products have great export value and packaging of their products to international standards has become very vital.

The major constituents of pepper are starch, fibre and ash but more significant ones are piperine and volatile oil, which contribute pungency and aroma respectively. The piperine, volatile oil, starch, and fiber values show marked variations and are indicative of the quality of pepper. Piperine, volatile oil, and fibre are low in the Malabar variety, while starch is high. Starch is the predominant constituent of black pepper, ranging from 35 to 40% of its weight. It is much higher in white and decorticated peppers, with values ranging from 53 to 58% in white pepper to 63% in decorticated pepper.

Value added products

- Black pepper
- White pepper
- Pepper oleoresin
- Pepper oil
- Pepper powder
- Cryo-ground pepper
- Green pepper in brine
- Dehydrated green pepper
- Sterilized black pepper
- Green pepper sauce
- Pepper tea
- Pepper coffee

- Canned green pepper
- Bottled green pepper
- Freeze-dried green pepper
- Pepper sweet
- Pepper hull

Packaging and storage

The microbial status and degree of infection are important quality criteria for allowing import into any country; these are closely related to good manufacturing practice, packing, storage, and transportation. Both black and white pepper, after drying and garbling at the exporting center, are generally bagged in double gunnies (burlap bags) and stored on dunnage mats in godowns (ware houses) awaiting shipment. The storage takes place in the post monsoon period in India, but in Indonesia storage period correspond to the rainy season. Because of high humidity, the stored pepper in the latter countries has been reported to become mouldy and subsequently infested, necessitating washing and redrying before shipment. Pepper, free of all surfaces moulds and dried to 11 per cent moisture, remained free of all moulds as long as its moisture content did not increase. The use of moisture-resistant linings for burlap back is the natural answer to prevent the pick up of excessive moisture.

Betel vine and its products

Betel vine (*Piper betle* L.) is an importance crop of social, cultural and medicinal importance. There are about 100 varieties of betel vine in the world, of which about 40 are found in India. Betel leaf is a very perishable commodity and therefore, always subject to wastage by quick spoilage due to dehydration, fungal infection, dechlorophyllation *etc.* This may cause a post harvest loss ranging from 35% to 70% during transport and storage. Particularly in the rainy season a large portion of the leaves remain unsold or sold at a throw away price. A strikingly contradictory situation may be observed during the peak demand period in the winter season when there is a huge demand in the market. In view of the alarming losses, attempts are being made to minimize the wastage by drying the leaves, controlling senescence, by chemical treatments, manipulation of storage temperature, adopting better packaging materials and methods besides curing and bleaching of the leaves. Such wastage may also be minimized by extracting essential oil from the stranded or unsold leaves be it fresh or stale or or even partially decayed.

These constituents from betel vines/ oil are the sources of the medicinal, aromatic, stimulant, tonic and various other useful properties found in the leaves. Such useful properties of the oil indicate a promising industrial future for it as a raw material for manufacturing skin emollients, tooth-pastes, tooth-powders, paan masala, perfumes, room fresheners, de-odorants, soaps, face creams, antiseptic creams and lotions, cold drinks, chocolates, incense sticks, appetizers, carminative mixtures, digestive agents, tonics, medicines *etc.*

The essential oil has shelf life of 1 year when kept in cool preferably at about 20-25 °C dry place and protected from light in their original packaging. Keep containers tightly sealed. Each container that has been opened should be used rapidly or repacked in sterile packaging and conditions.

Packaging and its role

In order to maintain the quality during handling, transportation, storage and distribution, the packaging material to be used is to be selected with care, keeping in mind the functional as well as the marketing requirements. The packaging requirements are

- To protect the product from spillage and spoilage.
- To provide protection against atmospheric factors such as light, heat, humidity and oxygen.
- The packaging material should have a high barrier property to prevent aroma/flavor losses and ingress of external odour.
- The volatile oil present in the spice product has a tendency to react with the inner/contact layer of the packaging material, at times leading to a greasy and messy package with smudging of the printed matter. The packaging material should therefore be grease and oil resistant and compatible with the product.
- Besides the above functional requirements, the packaging material should have good machinability, printability and it should be easily available and disposable.

The protection offered by the packaging may be either active or passive. In passive protection, packaging mainly serves as a barrier between the product and the external medium and is independent of the foodstuff preparation and preservation techniques. Passive protection therefore encompasses protection of the product against light, heat, mechanical damage and also protection from microorganisms in the atmosphere. Indirect effects such as permeability of the packaging barrier to gas and water vapour can include food spoilage and are also important. In active protection, packaging is designed for a particular preservation and performs some role other than providing an inert barrier to external condition.

Spoilage factors

In order to select a suitable packaging material/type of package it is essential to know the factors which affect the quality such as moisture content, loss of aroma/flavour, discolouration, insect infestation and microbial contamination.

Packaging criteria: Package development is based on, and influenced by many entities and could be broadly classified into five criteria groups *viz.*, appearance, protection, function, cost and disposability.

Appearance: The appearance of a package is dependent on shape and surface decoration.

Protection: The protection required by the product will vary enormously with the nature of the product itself, the final destination, the distribution system and the total time (shelf life) that protection is required.

Function: The functions that a package is expected to perform will depend on the end use requirement to suit the packaging line/system.

Cost: The preparation and implementation of package cost reduction programme is one of the main responsibilities of the package function.

Disposability: The term disposability can mean, any way in which packaging material can be eliminated or converted at the end of its useful life as a package.

Systems for pepper packaging

Bulk packaging: The traditional method is to use gunny/jute bags for packaging of whole spices, with capacities ranging from 10 kg to 70 kg. The jute bags may be provided with a loose liner bag of polyethylene or may be without a liner. At times double gunny bags are also used, especially for whole black pepper. The double gunny bag is provided with an inner polyethylene liner. There is no standardization on the type and quality of the fabric used.

Recently, some of the spice traders/packers use alternate bulk packaging media such as woven plastic bags which may be laminated or provided with a loose liner bag and multiwall paper sacks with a plastic liner bag. The plastic based alternate packaging materials are used to overcome the contamination problems associated with jute. Moreover, the plastic bags / liners also help in retaining the quality of the spices packed inside for a longer time.

The latest trend is to use jumbo bags (Flexible Intermediate Bulk Containers) (FIBCs) for export of spices. These bags have a capacity of up to 1 tonne and offer various advantages such as:

- Bags are flexible, collapsible and durable
- Can be used for packaging of granules, powder, flakes and any free flowing material
- Product wastage / spillage and tampering can be avoided
- Since the handling is mechanised, less labour is required
- Saving in time for loading and unloading
- Bags are light in weight and, therefore, freight costs are reduced
- Creates eco-friendly, pollution free working atmosphere

The jumbo bags are sometimes made from cloth but mainly from plastic fabric, which can be laminated or provided with an inner plastic liner bag. The bags are provided with filling and discharge spouts and slings for hanging during loading/unloading operations. For designing a jumbo bag, factors such as capacity, product protection requirement, bulk density of the product, filling and discharge facilities available at the user's end, are to be considered.

Institutional packages: The spice traders also use institutional packs of capacities ranging from 2 kg to 10 kg. The variety of packages used includes laminated flexible pouches and plastic woven sacks which replace traditional material like tinplate containers and jute bags.

Consumer packages: The options available to the traders/exporters of spices in the selection of a consumer pack for domestic and export market are quite wide. However, the selection/choice of the packaging material/ system depends upon a number of factors, which are broadly listed below

- Shelf-life period
- Climatic conditions during storage, transportation and distribution
- Type/sector of market
- Consumer preferences
- Printability and aesthetic appeal

The package types generally used as consumer packs are:

- Glass bottles of various sizes and shapes with labels and provided with metal or plastic caps
- Printed tinplate container with/without dispensing systems
- Composite containers with dispensers
- Plastic containers with plugs and caps with dispensing and tamper evidence features
- Printed flexible pouches – pillow pouch, gusseted pouch, stand-up pouch.
- Lined cartons

The printed flexible pouches have recently become very popular due to their easy availability, excellent printability, light weight, machinability and cost-effectiveness. Also, depending upon the functional and marketing requirements, the laminate/film can be tailor made to serve a specific need. The printed flexible pouches are generally laminates of various compositions. Some of the commonly used laminates are

- Polyester/metallised polyester/LDPE
- BOPP/metallised polyester/LDPE
- BOPP/LDPE
- Polyester/Al foil/LDP

Polyester and BOPP based laminates are generally more popular for spice packaging due to certain advantageous characteristics of each of these two films. Polyester used for lamination is generally 10 or 12μ thick. The film is highly transparent with excellent clarity, gloss and printability thus enhancing the sales appeal. The film has very low moisture and gas permeability and, therefore, ensures prolonged shelflife of the contents with aroma, flavour and taste retention. The very high mechanical strength (tear, puncture, burst and flex) minimizes damage to the contents during handling and transportation. The film has good machinability as well as printability. The latest printing technologies help in improving sales promotions. The film is free from additives and, therefore, does not impart any odour or taint to the sensitive spice product that is packed.

BOPP films may be heat sealable or non heat sealable. The film has high yields, is stable under climatic changes and has excellent moisture barrier. This film is smooth, glossy, crystal clear and has high mechanical strength and non-contamination property for food contact applications.

Composite Containers: The sealant layer of LD – HD or LDPE can be replaced by LLDPE or cast PP. Co-extruded films can also be used. PVDC, EVOH and EVAL based flexible materials also need to be studied as they are now in the market and these materials have high barrier properties.

A very important aspect to be considered in the selection of flexible laminate, besides the factors mentioned earlier, is the compatibility of the contact layer of the packaging substrate with that of the product packed inside. The volatile oils present in these spices can react with the contact layer and cause stickiness and can also affect the printing. De-lamination of the substrates may also occur. For these products, it is best to avoid the use of LDPE (low density polyethylene) as the heat sealant or the food contact layer. The better option for sealant or contact layer could be co-extruded film of LD-HDPE (with HDPE in contact with the product) or cast polypropylene. Alternatively, ionomer (surlyn) or EAA (primacor) can also be considered as the sealant layers. The types of pouches from flexible plastic based materials could be variable *viz.*, Centre seal formation, three sides seal formation, four sides seal formation and strip pack formation

The vital link in the performance of the pouch is the seal integrity. The performance of the heat seal layer is very important. Even if the film structure has been designed with exceptional properties, with excellence in interlayer lamination, if the sealing of the pouch fails, the product may get contaminated and in some cases become unfit for consumption.

Factors governing selection of packaging materials

- Strength: tensile, impact, stiffness, bursting and tear
- Transmission / barrier: moisture, oxygen / carbon dioxide, flavors and colors
- Optics / appearance: clarity, haze and gloss
- Performance: COF (coefficient of friction), blocking, heat salability, dimensional stability, crease / flex-crack resistance
- Ease in transportation and distribution
- Cost
- Government approval

Package evaluation: There are three reasons for making tests on packages

- To predict performance in practice and to ensure that pack is satisfactory under all conditions of use at the minimum cost.
- To control quality.
- To obtain comparative information in order to modify, or to improve or reduce the cost of package.

Effects of hazards on the package

Drop / impact	Breakage cracks, dismantling of machinery parts, denting, crushing of fruits and vegetables.
Vibration	Damage or loosening screw parts and hence movement of machinery, serious damage to the electronic items like calculator, may cause loosening of contacts and hence the leaking of current. It may cause structural failure in packaging materials.
High temperature	Accelerate corrosion, other chemical reaction, biological change, change of colour *etc.*
Low temperature	*E.g.* Adhesive - adverse effects, undergo physical change, will freeze water vapor component and then break the emulsion.
Light	May affect adversely on many products - change of colour, embrittlement of some plastics, and chemical reactions such as oxidation of fats giving rancidity, loss of therapeutic of pharmaceutical products.
Dust	May damage costly equipment like electronic items and make them out of order, painted surface may become dirty.
Water vapor	Product becomes soggy, loss of texture. Shine, may change in product characteristics.

Packaging material

Metal

The metal packaging industry in the last five decades has grown steadily. During this period, both steel and aluminium has grown equally well. At the same time, significant advances in material science tooling, lithography and other aspects of can making have taken place. Containers made of tinplate, tin free steel and aluminium has been used for packaging. Among metal containers tin plate container is considered as ideal for packaging of food products.

Tinplate containers

Among metal containers, the tinplate container is considered as ideal because of its resistance to corrosion ease of fabrication, strength to withstand processing, lightweight and ease with which it can be handled on high speed sealing machines.

The tinplate is a low carbon steel plate coated with tin on both sides. It is used for making open top sanitary cans. These make excellent containers for packing processed food products. The modern trends in the packaging of thermally processed products is to use tinplate with reduced thickness of tinplate with suitable lacquer coating, to reduce the thickness of base steel by double reducing process. Soldered cans have been replaced with welded cans to avoid the contamination of lead.

Tin free steel cans

Tin free steel has been developed in Japan as an alternative to tinplate for packaging. Depending on the nature of coating, tin free steel has been divided into different groups such as chromium, chromium oxide, chromate phosphate types *etc.*

Advantages

- The base layer of chromium acts as a corrosion barrier.
- The superimposed layer of chromium oxide prevents rusting iron taste pickup.
- Organic coating adheres exceptionally well.
- Suitable for attractive printing.
- Strong resistance to sulphur staining.
- Ease of fabrication.
- It can be joined by welding and cementing.
- Good chemical and thermal resistance.
- Tolerance to high processing temperature.
- Resistance to greater internal pressure.
- Flexibility in can shape.
- Improved and more reliable double seam.

Disadvantages

- Limitation for packaging of acid products.
- Compulsory lacquering.
- Not suitable for soldering.
- Problems in welding.

Aluminium containers

In recent years, a number of products are commercially packed in aluminium cans. Aluminium and its alloys are used widely in a variety of forms in the field of packaging. The future of the use of aluminium cans depends largely on a price in, which must be competitive with that of other metal cans.

Advantages

- It is estimated that about 60% of world output of bauxite is available in India.
- Aluminium cans are lightweight, which is an economic advantage.
- It is versatile in terms of performance, aesthetic appeal, and design.
- From the consumer's point of view, aluminium has a modern, clean and bright image.
- Aluminium is relatively easy metal to fabricate in can manufacture.
- It is compatible with a variety of substances and is capable of accepting protective coatings and decorative finishes but lacquer adhesion is better.
- Easy open-ends with apertures can be prepared from aluminium.
- Corrosion of the can does not produce coloured products as in the case of tinplate, where black sulphides are sometimes produced.
- Aluminium is non-toxic, odourless and does not have a metallic taste.
- Even thin aliminium foils are impervious to moisture and gases, which is necessary for food packaging.
- Generally, aluminium foils at thickness 0.025 mm and above are essentially pinhole free.

Disadvantages

- Energy intensive production.
- Aliminium cannot be soldered.
- Empty aluminium cans cannot be supplied in flattened condition as in the case of tinplate cans and hence transportation cost is high.
- Aluminium is softer than tinplate and must be handled with care during packaging and transportation.

Glass

To some extent, glass and metal containers are interchangeable, though each has its own advantages. Chief of these, for glass, is the element of visibility. Glass has numerous key properties and major advantages.

- Natural, immediately recognizable products.
- Appealing material.
- Pressure resistant.
- Inexpensive.
- Re-usable.
- Ovenproof.
- Long shelf life.
- High chemical resistance.
- Highly aesthetic.
- Multiple colour variations.

- Re-cyclable.
- Environmentally safe.
- Numerous cap and closure possibilities.
- Will not affect the taste or smell of the filled product.
- Hermetic sealing properties.
- Sterile and aseptic.
- Antistatic.

Paper

Paper plays an important role in packaging. It is estimated that majority of the packaging media used today constitutes of paper and paper derivatives.

Varieties of paper and board used for packaging

- *Greaseproof:* Greaseproof paper is a protective wrapping paper used for wrapping. The sheet made from such a stock is very dense and is resistant towards oil grease
- *Glassine:* Glassine is supercalendered, smooth, dense, transparent or semi-transparent sheet of paper used as a protective wrapper. This paper is grease- resistant and has a high resistance to the passage of air and other vapours.
- *Kraft:* Kraft paper plays an important role in the whole distribution system. One of the significant developments in new paper products is a patented stretchable paper, called clupak. These papers have very high stretch.
- *Tissue:* Tissue papers are lightweight 15-50 grams (m^2) papers being increasingly used for packaging. Wrapping tissues may be white or coloured as the chief use if fancy wrapping. The important characteristics for this purpose are toughness, even formation, finish and in some cases anti-tarnish properties.
- *Duplex board*: Duplex board is a general term used for a board of two different stocks. Top silver is generally of a superior chemical wood pulp or rag pulp and bottom liner of waste paper and mechanical pulp. Such board offers better appearance and printing surface, although the amount of cheap furnishes is more.
- *Pulp board:* Pulp boards are homogeneous board manufactured from one type of pulp.
- *Waxed paper:* Wax can either coated on paper to form a film by wet waxing or penetrated by mechanically forcing wax into interstices of paper by dry waxing process.

Packaging of whole black pepper

Traditionally black pepper is packed and traded in bulk quantities in gunny bags. A market study carried out indicated that the product would have better acceptability in the domestic as well as export market with improved packaging method, specially, by introducing a shift in the packaging trend from the practice of bulk packaging to modern concept of value addition through consumer packaging. An extensive study on shelf-life / storage of whole black pepper revealed that the packaging materials which could offer the product a shelf-life of around one year and more at normal climatic conditions (27°C ± 1°C and 65% ± 2% RH) in order of performance are

- 40 gsm paper / 0.12mm Al foil / 25µ LDPE
- 12µ metallised polyester / 50µ LDPE
- 25µ BOPP / 40µ LD – HD
- 12µ polyester / 50µ LDPE
- 90µ LD – Tie – Nylon – Tie – LD

The above materials (a, b, c & d are laminates and e is a co-extruded film) as well as other materials with similar barrier properties were recommended for use as consumer pack materials. These materials could be used as flat pillow pouches or stand-up pouches *etc*. It is to be noted that over the period of years, the traditional packaging materials have been replaced by plastics based materials, recommended above as well as similar materials.

The study also concluded that if the upper moisture limit is 11.5%, then, at the time the product is packed, the moisture content should not be more than 10%. It is also significant to specify upper moisture levels/limits at the time the product is manufactured and packed, not only in the case of black pepper and spices, but also for all hygroscopic / moisture sensitive products.

Packaging of pepper powder

CFTRI, Mysore has carried out detailed storage studies for pepper powder. The studies were carried out in 100 gram capacity pouches of flexible packaging materials at standard conditions of 27°C, 65% R.H. is given table below

Pouch packaging materials	Shelf life (days)
200 gauge (LDPE) low density polyethylene	30
350 g LDPE	50
200 g (HDPE) high density polyethylene	60
200 g Polypropylene(PP)	40
350 g PP	60
300 MXXT Cellophane	25
Double pouch of glassine gusset inside + 250 g LLDPE	35
Double pouch of 300 MSAT cellophane inside + 250 g LDPE	40
Metallised polyester12µ / 150 g LDPE laminate	120
Paper / 9µ Al / foil / 150 g poly	One year

Initial moisture content = 9.5 per cent; Critical moisture content = 11-12 per cent
The results of the study indicate that for long time storage at standard conditions of 27°C, 65% R.H. the materials which are suitable are laminates of cello / poly, metallised polyester / poly and paper / foil / poly which offer shelf-life of 200 days, one year and over one year respectively. Pouches of mono films of 200-gauge polypropylene or high density polyethylene can be considered for short term storage of about 90 days.

Packaging of pepper oil and oleoresins

Oleoresins and volatile oils are obtained from ground dried pepper and have a good potential in the export trade. These products are sensitive to light and are highly volatile in nature and therefore need to be suitably packed and protected. These products are packed in epoxy coated narrow mouth aluminium container of 1 to 5 litres capacity. Stretch blown PET bottles are also being used because of their excellent barrier properties to oxygen and volatile oils and compatability with the product. Five litres food grade HDPE Jerry cans and 25 kg wide mouth HDPE containers with high thickness are also used.

Recent trends and developments in packaging

Improvements in the processing technologies have lent a thrust to the packaging industry as these processes are now commercially adopted on a large scale.

High barrier plastics

It was earlier believed that the ultimate high barrier plastic would have a permeability-approaching zero. However now it has been realized that infinite barriers like that of glass and metal are not always required. Polyvinylidene Chloride, Ethyl Vinyl Alcohol, Ethyl Vinyl Alcohol Copolymers are found t fulfill the requirements of high barrier properties. These are used as coatings or films. A recen development combines scavenging with barrier plastics to provide a near-perfect barrier to oxygen.

Retortable pouches

It is a flexible pouch capable of withstanding autoclavable temperature (about 120°C) when a produ is packed and sealed inside it. The final product is commercially sterile and can be shelf-stable witho refrigeration. Retortable flexible pouches are constructed from the following combinations:

- PET/Adhesive/Aluminium foil primer/Adhesive/PP PET/PVDC/PP
- Nylon/PVDC/Nylon/Tie/Sealant/Extrudate/SealantPP/Regrind/Tie/ EVOH/Tie/Regrind/PP

Micro-ovenable packages

The most commonly used material today is crystallized polyester (CPET) in the form of trays. The advantages of using these trays are with respect to flexibility in shape and design and resistance to oils and greases. These trays have another distinct advantages of dual ovenability. PP (Polypropylene) co-extruded with barrier resins such as EVOH is used when a longer shelf life is required.

Modified atmosphere packaging/ gas flushing / vacuum packaging

These are packaging methods for extending the life of products by changing the atmosphere surrounding the food inside the package. In modified atmosphere packaging the gas mix (carbon dioxide, nitrogen and oxygen) inside the package, suppresses the aggragavates naturally occurring reactions of the food. There is a flow of gases from outside as well as inside the package. Right gas mixtures have to be established for each product taking into account the product nature and its requirements, potential gas absorption, and the utilization of barrier packaging materials.

In gas flushed package, the package is flushed with an inert gas and oxygen is eliminated. When we pack high moisture product at low temperature, there is a tendency for fog appearance on the inside of the film. Hence for MAP system films with antifog property (*e.g.* PS, PVC films) are used whereas for the gas packaging/vacuum packaging very low permeability structures with good oxygen barriers such as EVOH, PVDC, polyesters, nylon are used.

Edible films and coatings

The concept of using an edible coating to extend the shelf life of a product is a very old practice. The advantages of using edible films over non-edible polymeric packaging materials are manifold.

- The film can be consumed with the packaged products and there is no packaging to dispose.
- They are readily degradable, even if they are not consumed.
- Can provide nutritional values
- Can be carrier of anti microbial or anti-oxidant agents.

Legislation standards for different standards for different packaging materials is quoted in the Indian standards and also in the ASTM standards.

Conclusion

Knowledge of the functions of packaging and the environments where it has to perform will lead to the optimization of package design and the development of real, cost-effective packaging. Despite the wide number of functions which a package must perform, this paper focuses almost exclusively on the protective functions of the package and possible product /package interactions in relation to the packaging environment.

References

Amala Dhas P H & Korikanthaimath V S 2003 Processing and quality of black pepper- a review. J. Spices and Aromatic crops 12(1):1-13.

CFTRI 1976 The challenge of food packaging - CFTRI's services. Indian Food Packer 30 (4): 61-63.

Indian Institute of Packaging 1998 Modern Food Packaging (Text).

Indian Standard 1964 Methods of test for metal containers. IS: 2471-1963. Indian Standard Institution. New Delhi-2.

Mathew A G 1994 Blackening of pepper. Intl. Pepper News Bull. 18(1): 9-12.

Milton E Parker, Ellery H Harvey & Stodeler E S 1954 Elements of food engineering. Reinhold Publishing Cooperation, New York.

Narasimhan K R 2001 Global trends and policies in food packaging. Indian Food Industry 20(2)

Narayanan C S, Sreekumar M M & Sankarakutty B 2000 Industrial processing, In: Ravindran P N (Ed.) Black pepper (*Piper nigrum*) Harwood Academic Publishers. Amsterdam. p. 367-379

Natarajan C P 1981 Pepper industry in India. In: Processing of pepper and pepper products. Central food Technological Research Institute, Mysore, pp. 7-13.

Newell Stephenson J 1953 Manufacture and Testing of Paper and Board. Vol. 3. McGraw-Hill Book Company, Inc. New York, Toronto & London.

Pruthi J S 1997a Diversification in pepper utilization, Part-I, Green pepper products, Intl. Pepper News Bull. 21(4):5-9.

Pruthi J S 1997b Diversification in pepper utilization, Part-II, Green pepper products, Intl Pepper News Bull. Bull. 21(5):6-9.

Pruthi J S 1980 Spices and condiments: Chemistry, microbiology and technology. Academic press Inc. New York

Sucheta B 2000 Developments in packaging of processed food. Processed Food Industry 3: 15-18

Sudharshan M R 2000 White pepper: A simple value addition to pepper 13(6):10-12

Thomas P P & Gopalakrishnan N 1992 A processes for the production of unwrinkled dry ball shaped green pepper. Indian Spices 29(4): 9-191

Vijaya Sankar V 2001 Advantages of glass as a packaging medium for food products. Indian Food Industry 20(2): 62-66.

Clean production of white pepper from fresh and black pepper (*Piper nigrum* L.)

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Introduction

White pepper is the most appreciated form of decorticated green or black pepper (*Piper nigrum* L.). The white pepper berries are light yellow grayish in colour; nearly globular in shape, around 5mm or less in diameter; smooth, striated with small protuberance at the base. The striations on the berries are vascular bundles, very distinct in some berries, indistinct and not visible in others. White pepper is obtained by dismantling the outer skin, namely pericarp and outer portion of the mesocarp or the white inner corn obtained after removing outer skin or pericarp of the ripe or matured berries.

White pepper is preferred to black pepper in Europe, U.S.A and Japan because of the charming colour, suitability to use in all food preparations, less microbial load, free from many contaminants and no substantial difference in pungent principles to that of black pepper (Gopalam *et al.* 1991). It is widely used for making mayonnaise, salad dressing, sausage, and for flavouring of ice cream and where black pepper is not suitable (Furia & Bellanca 1970). The organoleptic properties of white pepper have been extensively studied and found it significantly unchanged. It is reported that white pepper has slightly more piperine content than black pepper (Lewis *et al.* 1969b). Rathnawathie and Buckle (1984) have accounted higher starch content in white pepper. The loss of skin does not affect the pepper oil content substantially (Mathew & Sankarikutty 1977).

Chemically white pepper is more or less similar to that of black pepper except certain parameters. Pepper skin contributes nearly 25 % of the dry weight of black pepper berry. It contains fairly good number of oil-bearing cells and fibers. Thus the white pepper generally has lesser quantity of volatile oil and crude fiber content. White pepper contains more starch content than black pepper by percentage weight. The International Pepper Community (IPC) specifies the quality of white pepper.

Current methods of preparation

Various methods are tried to produce white pepper from fresh or black pepper. Only mature berries are used for the preparation of white pepper, even otherwise immature berries are shrunken in the process and need to be rejected while grading. White pepper is traditionally prepared by retting methoc in which the matured green pepper berries are separated from spike after harvest. The separated berries are filled loosely in gunny bags or knitted nylon bag of 25-50kg capacity and are soaked in flowing water stream or rivers for 2-3 weeks (Natarajan 1967; Natarajan *et al.* 1967; Lewis *et al.* 1968 & Lewis *et al.* 1969a). The removal of pepper skin has can also be done by soaking of pepper in concrete tanks for more than nine days (Sudarsan 2000). According to Madhusoodanan *et al.* (1990) complete skin removal of mature pepper requires 15 days of soaking (retting) in flowing water. After retting the skin is mechanically or either removed manually- by trampling. Thorough by washed pepper is sun dried to the moisture content of 8-12 %.

Major disadvantages of these methods are the long retting period of 10- 15 days, the development of a characteristic foul smell, fading of colour, loss of piperine and retention of microorganisms (Natarajan *et al.* 1967; Lewis 1982).

Joshi (1962) has patented a chemical process for the preparation of white pepper. Whole dried black pepper is steeped in about 5 times of its weight of water for 4 days. The steeped pepper is boiled with 4 % NaOH solution. In this treatment the skin detaches, which is removed completely by agitation with a stirrer at 1600 rpm. The product thus obtained is bleached with 2.5 % hydrogen peroxide and washed to get good coloured white pepper.

Another method of white pepper production is steeping of red ripe or nearly ripe berries in water for 2-3 days that helps to remove the skin easily. After skinning the berries are washed and sun dried which yields 27 % white pepper by dry weight of fresh berries (Krishnamurthy 1969). Natarajan *et al.* (1967) have produced white pepper by the above process in about 7 days. The collection of ripe or nearly ripe berries is impractical as the farmers are unwilling to leave the berries for ripening to red, which results in loss of berries due to shattering and picking by birds (Kachru *et al.* 1990).

In another approach of white pepper preparation, commercially graded black pepper is kept in water. Soaking in water leads to fermentative degradation and softening of skin in about 10-12 days. The partially degraded skin while soaking is removed using a fruit-pulping machine. The skinned pepper is subjected to chemical bleaching for improved whiteness (Lewis *et al.* 1969a). Long duration of water soaking and chemical bleaching result in colour.

A different two-step process has been developed to prepare white pepper by Lewis (1982). In this the mature green pepper is blanched to inactivate the blackening enzyme, which is followed by a mild bleaching with SO_2. White pepper obtained has wrinkled skin, but cream colour. Unacceptability of chemical bleaching and unavailability of fresh matured green pepper for commercial operation are the real problems of this process.

Selective grinding of black pepper to remove the outer coat has been tried to produce white pepper. In this the skin of black pepper is mechanically removed (Thomas *et al.* 1987) This process is seldom practiced because the requirement of relative grading to collect uniform sized berries, and significant loss of aromatic principles from the upper layer of the mesocarp on grinding (Mangalakumari 1983).

Rathnawathie & Buckle, (1984) experimented white pepper preparation by cooking of harvested berries in boiling water for 5 minutes and removing the pericarp by hand. The white pepper thus obtained is washed and dried in sun for 2-3 days. Gelatinisation of the starch in pepper and loss of volatile principles while treating with boiling water, are the major drawbacks of this method.

In another attempt to prepare white pepper ripe black pepper berries are buried in damp ground for 5 days. The pepper skin is degraded partially by this method, which is washed off and the corns are dried in sun (Verghese 1999).

Fermentation with cellulase producing bacteria *Bacillus subtilis* has been tried to make white pepper by Thankamony *et al.* (1999). Introduction of this non-pathogenic soil isolate is claimed to degrade the skin of black pepper with 2-4 days incubation on a shaker at room temperature in a nutrient broth *solution. The complete removal of skin, however, was achieved only by repeated washings. The skinned* pepper is dried in sunlight until the moisture content become 10-12 %. Limitations of this method include the requirement of expensive growth medium for the bacterium and long time aeration.

Fermentative skin removal was studied to prepare white pepper from fresh and black pepper (Gopinathan & Manilal 2005). In this method four bacterial isolates namely, *Xanthomonas sp., Pseudomonas sps. Bacillus sp.,* were introduced together as a consortium to clean water amended with [g/l (w/v) of NH_4NO_3-1.00, NH_4Cl-0.3, KH_2PO_4-0.5, $MgSO_47H_2O$-0.02, $CaCl_27H_2O$-0.01 by maintaining a ratio of 40:50 (w/v) with green or presoaked black pepper. These bacteria could degrade the skin of fresh pepper completely in three days and the skin of presoaked black pepper in four days of incubation at the pH ranging from 6.7 to 7.0, and mesophilic temperature.

A faster and cleaner method using pectinase was described for the removal of skin (Gopinathan & Manilal 2004; Manilal & Gopinathan 2005). At optimum condition pectinase can facilitate green pepper decortication in 24 hours and black pepper in 40-45 hours to provide creamy white pepper.

Most of the methods described above are seldom practiced in commercial scale. Biological retting is the one widely employed for the production of white pepper. It is observed that heavy processing costs and deterioration of the product quality are the major criteria for their rejection in the field. India, the largest pepper producing country in the world is placed far behind to Indonesia, Malaysia and Brazil in terms of white pepper production. The present paper discusses development of a clean method of white pepper production that opens up wider market for Indian pepper and new hope for pepper producers and dealers.

Clean process for white pepper production

This is a process developed to get high quality white pepper (patent under processing). In the earlier studies it was achieved by the treatment of pectinase (Gopinathan & Manilal 2004; Manilal & Gopinathan 2005), but is proven costly. Beyond this the recovery of values from the wastes requires additional facilities. Being a seasonal crop conversion of fresh pepper alone is obviously unviable and impractical for production units. All these aspects were considered in the development of the new process for white pepper production.

In the process the fresh and black pepper are loaded into a closed tank containing anoxic water which is cycled through an anaerobic reactor containing microbial populations. This anaerobic treatment enables production of skin degrading enzymes (pectinases), degradation of polymeric organic compounds to simpler molecules such as acetic acids and conversion of acetate to methane and carbon dioxide. The skin residues collected on washing of the white pepper is a biomanure. Complete removal of the skin requires 2 days for mature fresh pepper and 4 days for black pepper if the temperature of the system is between 20 to 35°C.

Mechanism of pepper skin degradation in fermentation

During the anaerobic treatment enzymes are produced which attack mainly and initially on pectin compounds, the intercellular cementing substance present in the pulpy upper mesocarpic area of pepper skin and causing the skin to break apart from the core (Figs.1& 2). More than 90% of the pectin in pepper skin (total pectin 11.2 %, w/w) is removed by the treatment (Fig. 3). The neutral liquid medium turns slightly acidic due to release of galacturonic acid from pectin break down (Gopinathan & Manilal 2003), but the presence other bacteria and methane producers utilize these compounds, converted methane and finally removed as biogas from the system. It is estimated that more than 25 litres of gas is produced on processing a kg pepper.

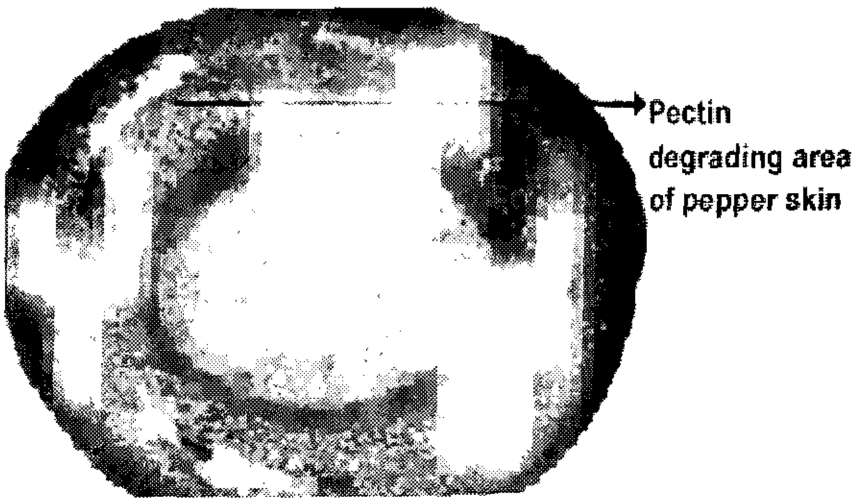

Fig. 1. Degraded tissues of pepper skin bearing pectin on anaerobic treatment (8X)

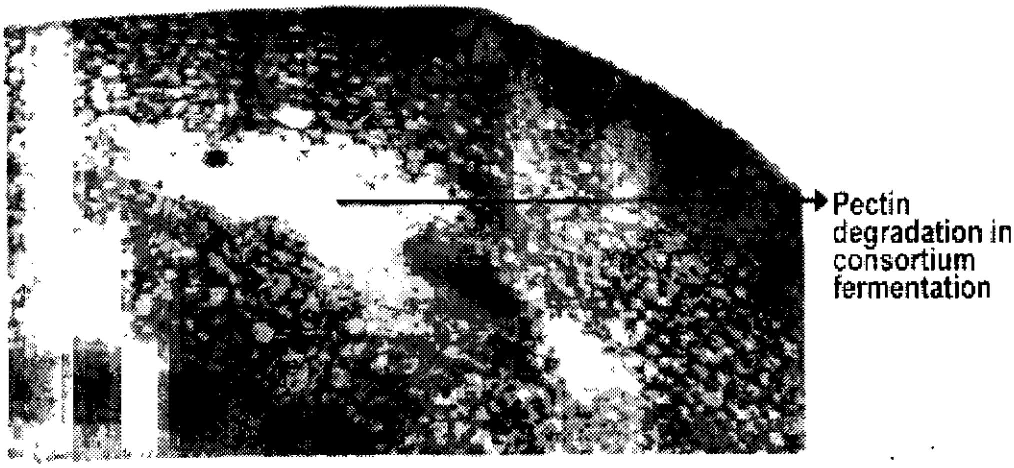

Fig. 2. Degraded tissues of pepper skin bearing pectin on anaerobic treatment (40X)

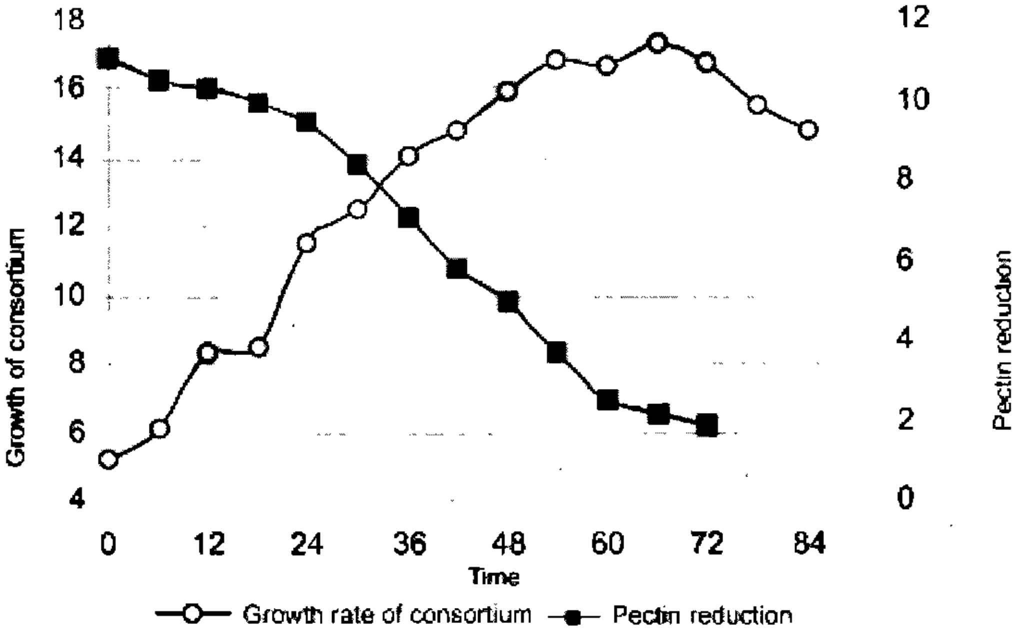

Fig. 3. Degradation of pectin in the pepper skin during anaerobic treatment

Cleaning & drying

The loose skin removal and final cleaning of the pepper after anaerobic treatment is done with the help of a fruit pulping machine and water washing. The decorticated pepper is dried in sunlight or electric hot air drier adjusted at 45°C to bring down the moisture content to <12% (w/w).

White pepper yield

White pepper from mature green pepper gives maximum yield (table 1). The yield is dependent purely on raw material quality. The light berries and damaged berries are rejected either during the process or on white pepper grading and thus affect the total yield. The yield of white pepper is higher from MG-1 (Malabar Garbled) compared to TGEB (Tellicherry Garbled Extra Bold). The white pepper yield from ungarbled black pepper of local markets is the lowest, 60-65 % against 67-72 % of the garbled black pepper.

Quality aspects

The white pepper obtained from green pepper is brilliant creamy white and, has less than 1 % residual black pepper and no extraneous matters. The white pepper from black pepper also has grayish cream colour (table 2). The cleaning and removal of light berries from fresh and black pepper before anaerobic treatment could result in white pepper of uniform size and superior quality. Complete removal of the skin by the process also guarantees elimination of topical contaminations, if any.

Table 1. Yield of white pepper from fresh and different grades of black pepper

Variety	Light berry rejects % (w/w)	Yield in % (w/w)
Fresh pepper	10-17	27.2-32.5
TGEB	12-14	68-70
TGSEB	10-14	67-71
MG-1	9.7-13	68-72
Local	25-35	60-65

The ICMSF (International Commission on Microbiological Specifications for Food) specifies less than 10^6 colony forming unit (cfu)/g. The residual microbial load of white pepper obtained from fresh and black pepper is on the safer range of 1.2×10^4 to 8.4×10^5. The contamination of *Salmonella* or *E. coli* in the white pepper is totally eliminated by the process.

Comparison of principal substances for the spicy quality of white pepper obtained after the anaerobic decortication is given in table 2. During decortication there is a slight decrease of volatile oil content in the pepper as has been reported earlier (Govindarajan,1977; Purseglove *et al.* 1981; Verghese 1989). This is because of the loss of volatile oil bearing cells located in the outer skin layers of pepper berries (Purseglove *et al.* 1981; Mangalakumari 1983; and Gopalam *et al.* 1991).

Table 2. Quality of white pepper prepared from fresh and black pepper

Quality parameter	White pepper from clean processing	
	From fresh pepper	From black pepper
Colour	Creamy white	Grayish Cream
Size (mm)	3 – 6	3 – 6
Extraneous matter (%)	< 0.5	0.5 – 1
Volatile oil (%)	2 – 3.6	2 – 3.1
Piperine (%)	3.5 – 4.6	3.6 – 4.5
Rcsidual black pepper* (%)	0.5– 1 %	1 – 2 %
Yield* (%)	27 – 33	65 – 72

* depends on quality of raw material

Because of the limitations in white pepper production, India's contribution to the white pepper market is negligible despite of its demand and higher price. This cleaner method of white pepper processing provides better scope and can fetch higher value to our pepper. Moreover this processing technology can set new standards to white pepper in the market. Commercial production of white pepper based on the clean processing is under operation in Kerala (Fig. 4) and Karnataka.

Fig. 4. White pepper plant (2.5 ton) at Mananthavady, Wayanad, Kerala

References

Furia T E & Bellanca N 1970 Feranolies hand book of flavour ingredients 2nd Ed., pp. 432-434. Vol. 1, CRC Press, Cleveland, Ohio, U.S.A.

Gopalam A, Zachariah J T, Babu N K, Sadanandan A K & Ramadasan A 1991 Chemical quality of black and white pepper. Spice India 4: 8-10.

Gopinathan K M & Manilal V B 2003 Fermentative degradation of pectin in pepper skin (*Piper nigrum* L.) for white pepper preparation. Proceed Kerala. Sci. Cong., Trivandrum, India, pp. 621- 624.

Gopinathan K M & V B Manilal 2004 Pectinolytic decortication of pepper (*Piper nigrum L.*). J. Food Sci. Technol. 41: 74-77.

Gopinathan K M & V B Manilal 2005 White pepper preparation through bacterial fermentation. Spice India 18: 10-18.

Govindarajan V S 1977 Pepper - chemistry, technology and quality evaluation CRC Crit. Rev. Food Sci. Nutri. 9(2): 115-225.

Joshi D G 1962 White pepper production. Indian patent no 70: 439.

Kachru K P, Patil R T & Srivastava P K 1990 'Post harvest technology of pepper' (*Piper nigrum* L.). Spice India 3(8): 12-16.

Krishnamurthy A 1969 The wealth of India: Raw materials, Vol.8. pp. 60-64 Krishnamurthy, A., (Ed.) Publishing and Information Directorate, CSIR, New Delhi, India.

Lewis Y S, Neelakantan S, Philip T & Nambudiri E S 1968 Production of white pepper in India Spices Bull. 5(6): 6-8.

Lewis Y S, Nambudiri E S, Krishnamurthy N & Natarajan C P 1969a White pepper. Perfum. Essent. Oil Rec. 60: 53-56.

Lewis Y S, Nambuiri E S, Krishnamurthy N 1969b Composition of pepper oil. Perfum Essent. Oil. Rec. 60: 259-262.

Lewis Y S 1982 Important spices from south East Asia. Cultivation and technology. Ind. Food Pack. 36(1): 62-71.

Madhusoodanan K J, Radhakrishnan V, Priyadarshan P M., Kuruvilla K M & Naidu R 1990 A cost effective method for the production of white pepper. Ind. Spices, 3(2): 5-7.

Chemistry and quality standards of black pepper and its products

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Black pepper (*Piper nigrum*) belongs to the family Piperaceae. It is cultivated for its fruit, which is usually dried and used as a spice and seasoning. The same fruit is also used to produce white pepper and green pepper. Black pepper is native to South India where it is extensively cultivated besides some other tropical regions. The fruit, known as peppercorn when dried, is a small drupe five millimetres in diameter, dark red when fully mature, containing a single seed.

Dried, ground pepper is one of the most common spices in European cuisine and its descendants, having been known and prized since antiquity for both its flavour and its use as a medicine. The spiciness of black pepper is due to the chemical piperine. Ground black peppercorn, usually referred to simply as "pepper", may be found on nearly every dinner table in some parts of the world, often alongside table salt. Black pepper also nick named as black gold and king of spices is the most important and widely consumed spice in the world. Compared to many other spices, properly dried black pepper (~ moisture content 8-10 %) can be stored in air tight containers for many years without losing its taste and aroma. In 2007-08, India exported about 35000 metric tons of black pepper with an export earning of Rs.519.5 crores (129.05 million US dollars)

There are several factors which affect the quality of processed black pepper products. These include pests and micro-organisms which infest the product from the plantation, foreign matter and impurities from materials used in processing which contaminate the products, micro-organisms and dirt which are introduced through unhygienic practices of people who handle the produce, and loss of quality that results from short-comings in storage practices. Thus the quality of the product depends on the quality of raw materials, the methods used in processing, the packaging methods and materials and marketing practices. Therefore, to ensure quality of the product, constant care should be maintained till the time it reaches the consumer.

General composition

There are two main components of black and white pepper: the volatile oil and pungent compounds. The volatile oil level in black pepper is usually higher than in white pepper. The hull of pepper contains fiber and some essential oil. Black pepper contains about 2.0-2.6% volatile oil, and about 6-13% oleoresin. Black pepper oil can be used to help in the treatment of pain relief, rheumatism, chills, flu, colds, increase circulation, exhaustion, muscular aches, physical and emotional coldness, nerve tonic and fevers. It furthermore increases the flow of saliva, stimulates appetite, encourages peristalsis, tones the colon muscles and is a general digestive tonic

The pungency of black pepper (*Piper nigrum* L.) was initially attributed to the presence of piperine only, the structure of which is *trans, trans-5-(3,4-methylenedi-* oxyphenyl)-2,4-pentadienoic acid piperidide. Further investigations into the pungency of this spice by several workers lead to the information that materials other than piperine also contributed to the pungency of black pepper. Zachariah *et al.* (2005) evaluated major black pepper cultivars for oil, oleoresin and piperine and details are given in table 1. The accumulation of these constituents tends to vary during maturation.

Table 1. Levels of oil, oleoresin and piperine content of common black pepper cultivars

Cultivar	Oil (%)	Oleoresin (%)	Piperine (%)
Panniyur -1	3.2	8.9	2.8
Panniyur - 2	4.4	12.7	3.6
Panniyur - 3	4.0	11.2	3.6
Panniyur - 4	2.8	9.7	3.5
Panniyur - 5	2.4	8.2	3.6
Pournami	3.6	10.9	3.6
Panchami	3.2	8.7	3.0
Sreekara	3.2	9.8	3.8
Poonjaranmunda	2.8	10.2	3.5
Kuthiravally	3.2	9.5	3.0
Balankotta	2.4	8.5	3.0

Blackening of pepper

Apart from the major quality attributes such as pungency and aroma, the appearance with respect to its colour (brown/ black) is of importance for use of black pepper as a spice in the whole or ground form. Since phenols are known to contribute to browning / blackening of finished pepper corns, the nature and distribution of phenolic compounds are very important. Blackening of fresh green pepper is due to enzymatic oxidation of (3,4-dihydroxy phenyl) ethanol glycoside by an o-diphenol oxidase (PPO) present in the fresh fruit. Bandyopadhyay *et al.* (1990) reported that conversion of green pepper to black pepper by the drying process was accompanied by a 75% decrease in total phenolic content and a complete loss of o-diphenol oxidase oxidizable phenolic fraction which suggest a major role for enzymatic phenolic oxidation during pepper blackening. They characterized 3,4-dihydroxy-6-(N-ethylamino) benzamide as the substrate for o-diphenol oxidase .

Products from Pepper

Black pepper, matured dehydrated green pepper and tender green pepper are processed for various end products. Various products prepared are as follows.

Green pepper based products: Canned green pepper, Green pepper in brine, Bulk-packaged green pepper in brine, Cured green pepper, Frozen green pepper, Freeze dried green pepper, Dehydrated green pepper, Green pepper pickle, Mixed green pepper pickle, Green pepper sauce and Green pepper-flavoured products.

Black pepper based products: Whole black pepper, Sterilized black pepper, Ground black pepper, Cryoground black pepper powder, Pepper oil, Oleoresin, Microencapsulated spice flavour.

White pepper based products: White pepper whole, White pepper powder.

Miscellaneous products: Curry powder-spice blends, Pepper-flavoured products, Pepper extract preservative, pepper oil, Pepper oleoresin, Lemon pepper, Garlic pepper, Sauces, Paste *etc.*

Pepper byproducts: Light pepper, Pepper hulls, Pepper pin heads.

Pepper flavoured products: Pepper mayonnaise, Pepper tofu, Pepper cookies, candy and perfumes.

Aroma

The aroma of black pepper is mainly contributed by the volatile oil which varies between 2-5% in the berries. Produced by steam distillation, from the black peppercorns, the essential oil is water-white to pale olive in colour with a warm, spicy (peppery), fresh aroma. It has a middle note and blends well with rose, rosemary, marjoram, frankincense, olibanum, sandalwood, and lavender; however it should only be used in small amounts.

Aroma compounds in pepper oil

Jirovetz *et al.* (2002) investigated the aroma compounds of the essential oils of dried fruits of black pepper (*Piper nigrum*) and black and white "Ashanti pepper" (*Piper guineense*) from Cameroon by means of solid-phase microextraction (SPME) to identify the odorous target components responsible for the characteristic odor of these valuable spices and food flavoring products. By means of GC-flame ionization detection (FID) and GC-MS (using different polar columns) the main compounds of the SPME headspace samples of *P. nigrum* (black) and *P. guineense* (black and white) were found to be *P. nigrum* (black) - germacrene D (11.01%), limonene (10.26%), b-pinene (10.02%), phellandrene (8.56%), b-caryophyllene (7.29%), a-pinene (6.40%) and cis- b-ocimene (3.19%); *P. guineense* (black) - b-caryophyllene (57.59%), b-elemene (5.10%), bicyclogermacrene (5.05%) and a-humulene (4.86%); and *P. guineense* (white) - b-caryophyllene (51.75%), cis-b-ocimene (6.61%), limonene (5.88%), b-pinene (4.56%), linalool (3.97%) and a-humulene (3.29%).

Major aroma compounds in black pepper oil

Monoterpene hydrocarbons and oxygenated compounds: The monoterpene hydrocarbons are camphene, d^3-carene, p-cymene, limonene, myrcene, cis-ocimene, a-phellendrene, b-phellendrene and b-pinenes, sabinene, a and g-terpinenes, terpinolene and a-thujene.

About 43 oxygenated compounds of monoterpenoid nature have been characterized. Popular oxygenated monoterpenes are borneol, camphor, carvacrol, cis-carveol, trans-carveol, carvone, carvetanacetone, 1,8-cineole, cryptone, p-cymene-8-ol, p-cymene-8-methyl ether, dihydrocarveol, dihydrocarvone, linalool, *cis*-2-menthadien-2-ol, 3,8 (9)-p-menthadien-1-ol, 1 (7)-p-menthadien-6-ol, 1 (7)-p-menthadien-4-ol, 1,8 (9)-p-menthadien-5-ol, 1,8 (9)-p-menthadien-4-ol, cis-p-2-menthen-1-ol, myrtenal, myrtenol, methyl carvacrol, *trans*-pinocarveol, pinocamphone, *cis*-sabinene hydrate, *trans*-sabinene hydrate, 1-terpinen-4-ol, 1-terpinen-5-ol, a-terpeneol, 1,1,4,trimethylcyclohepta-2,4-dien-6-ol, phellandral, piperitone, citronellal, nerol, geraniol, isopinocamphone, methyl citronellate, methyl geranate, a-terpenyl acetate, terpenolene epoxide and trans-limonene epoxide (Zachariah & Parthasarathy 2008).

Linalool, (+)-a-phellandrene, (-)-limonene, myrcene, (-)-a-pinene, 3-methylbutanal and methylpropanal are found to be the most potent odorants of black pepper. Additionally, 2-isopropyl-3-methoxypyrazine and 2,3-diethyl-5-methylpyrazine were detected as important odorants of the black pepper sample from Malaysia which had a mouldy, musty off-flavour (Jagella & Grosch 1999a, b).

Sesquiterpene hydrocarbons and oxygenated compounds: b-carophyllene is the major sesquiterpene hydrocarbon present in pepper oil. Other sesquiterpene hydrocarbons are also reported from black pepper oil. They are a-cis-bergamotene, a-trans-bergamotene, b-bisabolene, ä and g-cadinenes, calamenene, a-copaene, a- and b-cubebenes, ar-curcumene, b- and ä-elemenes, b-farnesene, a-guaiene, a- and g-humulenes, isocaryophyllene, g-muurolene, a-santalene, a- and b-selinenes, ledene, sesquisabinene and zingiberene.

About 20 oxygenated sesquiterpenes have been identified from pepper oil. They are 5,10 (15)-cadinen-4-ol, caryophylla-3(12), 7(15)-dien-4-b-ol, caryophylla-2,7(15)-dien-4-b-ol, caryophylla-2,7(15)-dien-4-ol, b-caryophellene alcohol, caryophyllene ketone, caryophellene oxide, epoxy-dihydrocaryophellene, cis-nerolidol, 4,10,10-trimethyl-7-methylene bicycle-(6.2.0) decane-4-carboxaldehyde, cubenol, epi-cubenol, viridiflorol, a- and b-bisabolols, cubebol, elemol and g-eudesmol (Zachariah & Parthasarathy 2008).

Miscellaneous compounds: Eugenol, methyl eugenol, myristicin, safrole, benzaldehyde, trans-anethole, piperonal, m-methyl acetophenone, p-methyl acetophenone, n-butyrophenone, benzoic acid, phenyl acetic acid, cinnamic acid and piperonic acid are some of the aromatic compounds characterized in pepper oil. Methyl heptenone, pinol, butyric acid, 3-methyl butyric aicd, hexanoic acid, 2-methyl pentanoic acid, methyl heptanoate, methyl octanoate, 2-undecanone, n-nonane, n-tridecane, n-nonadecane and piperidine are the other compounds identified (Narayanan 2000). The major monoterpene hydrocarbons present in pepper oil are a and b-pinenes, sabinene and limonene.

Variability in essential oil constituents

Kerala state of India is known for the many popular cultivars in black pepper. These cultivars exhibit wide variation in the percentage composition of major volatiles. By adopting GC and GC-MS techniques researchers identified over 55 compounds from the volatile oil of these pepper cultivars. Major compounds identified were a and b-pinene, sabinene, limonene, b-caryophyllene, myrcene, p-cymene and caryophellene oxide (Gopalakrishnan *et al.* 1993; Menon *et al.* 2000; Menon *et al.* 2002; Menon *et al.* 2003; Menon & Padmakumari 2005). Table 2 illustrates this variability among different popular cultivars.

Gopalakrishnan *et al.* (1993) analyzed four new genotypes of pepper (Panniyur-1, Panniyur-2, Panniyur-3 and Panniyur-4) by a combination of GC-MS and Kovats indices on a methyl silicone capillary column. The oils from the three Panniyur genotypes contained pinene in the range of 5.07-6.18%, b-pinene 9.16-11.08%, sabinene 8.50-17.16%, and limonene 21.06-22.71% and b-caryophyllene 21.57-27.70%. The oil from Panniyur-4 contained a-pinene 5.32%, b-pinene 6.40%, sabinene 1.94%, myrcene 8.40%, p-cymene 9.70%, limonene 16.74% and caryophyllene 21.19%.

Zachariah *et al.* (2005) conducted a study on the effect of grafting *P. nigrum* on *P. colubrinum* as rootstock. The cultivars used for grafting are Panniyur-1, 2, 3, 4 and 5, Malligesara, Pournami, Sreekara, Poonjaranmunda, Kuthiravally, and Balankotta. The major essential oil constituents in grafts and non-grafts of pepper cultivars were pinene, sabinene and b-caryophyllene. Caryophyllene content varied from 12 to 27% in graft and 7 to 29% in non-graft. Limonene content varied from 13 to 24% in graft and 13 to 22% in non-graft.

Essential oils obtained by hydrodistillation of green and black berries of Indian origin (cv. Thevan Mundi) were analyzed by GC and GC-MS methods and compared with reported constituents of Sri Lankan green and black pepper oils. The monoterpene hydrocarbons of Indian oils were similar to those of corresponding Sri Lankan oils but the oils differed with regard to their sesquiterpene and oxygenated components. â-Pinene and caryophyllene occurred in all oils, sabinene in Sri Lankan oils only and car-3-ene in none of the oils.

Oleoresins

Oleoresins are natural isolates obtained by extracting the comminuted spice with suitable solvents and recovering the solvent mostly by evaporation. The residue is called oleoresin. The type of solvents used to extract oleoresin includes hydrocarbons, chlorinated hydrocarbons, alcohols, ethers, ketones and carbon dioxide. Oleoresin is a blend of volatile and non-volatile components that are soluble in the solvent. The volatile components that is soluble in the solvent. The volatile part, known as essential oil consists of several compounds with varying boiling points. This essential oil imparts flavour and aroma to the product.

The non-volatile part of oleoresin consists of several groups of chemical compounds such as carotenoids, steroids, alkaloids, anthocyanins, glycosides *etc.* The non-volatile part contributes towards taste, colour, pungency, texture and antioxidative properties of the product. Oleoresins are commercially important because of the consistency in flavour, taste, antioxidant properties, increased shelf life and less storage space as it is a highly concentrated product.

Among the organic solvents benzene is prohibited for use in food products. Only 25 ppm residual solvent is allowed for halogenated solvents. Yield of oleoresin after removal of solvents is always much higher than the essential oil recovery and it also depends on the solvent used. Since there is a chance of loss of essential oil during the extraction process, oil is extracted separately and then it is blend to the oleoresin as per the standard requirement. This is called 'standardizing' of the oleoresin. Essential oil content of oleoresin is very critical for the organoleptic quality of the material.

As mentioned earlier, oleoresins consist of volatile and non-volatile parts. The concentration of volatile part ranges between 10 and 20%. The general standard of black pepper oleoresin is 25% volatile oil and 35% non- volatile piperine and other alkaloids. The volatile part *i.e.*, the essential oil, consists of aliphatic compounds, isoprenoids, benzenoids, and miscellaneous compounds.

Pungency of black pepper

Piperine is the major constituent of pepper oleoresin. The pungency of black pepper *(Piper nigrum* L.) was attributed to the presence of piperine, the structure of which was later proven to be *trans, trans-5-(3, 4-methylenedi-* oxyphenyl)-2, 4-pentadienoic acid piperidide. Further investigations into the pungency of this spice revealed that unidentified materials other than piperine also contributed to the pungency of black pepper (Zachariah & Parthasarathy 2008).

The pungency of black pepper has been the subject of investigations since the early nineteenth century. In 1819 Oersted isolated piperine, the most abundant alkaloid in pepper, as a yellow crystalline substance, and its structure was later identified as the trans form of piperoyl piperidine (Narayanan 2000). The pungent dark oily resin obtained after removal of piperine from the oleoresin was named as chavicine (Govindarajan *et al.* 1977). Chavicine was claimed to possess a far greater bite on the tongue than crystalline piperine, but later workers demonstrated that piperine in solution is very pungent. The controversy over which compound *viz.,* piperine, its cis-cis isomer chavicine or other possible isomers-isopiperine (cis-trans) and isochavicine (trans-cis)-is more pungent lasted almost a century. However, later investigations have demonstrated, that piperine is the major pungent principle and chavicine is a mixture of piperine and several minor alkaloids. The presence of chavicine and isopiperine has not been confirmed in pepper extracts while isochavicine is shown to occur as an artifact of photolytic transformation of piperine. Five new minor alkaloids possessing a degree of pungency have been identified in pepper extracts. They are piperettine, piperylin, piperolein A and B and piperanine. Three trace constituents *viz.* peepuloïdin, guineesine and pipericide showing insecticidal properties have recently been identified.

Table 2. Percentage composition of major volatiles in common black pepper varieties

Variety/ Compound	Limonene	β-pinene	β-caryophyllene	Sabinene	Caryophyllene oxide	δ-3-carene	α-pinene	Myrcene	p-cymene	Elemol
Aimpiriyan	19.8-22.5	9.3-23.9	20.3-34.7	-	-	-	-	-	-	-
Narayakodi	9.5-19.5	4.8-15.6	29.8-52.9	4.4-24.6	2.3-3.9	-	-	-	-	-
Neelamundi	12.9-18.6	7.8-11.3	17-31.0	23.2-27.3	-	-	4.7-6.5	-	-	-
Uthirankotta	13.3-19.5	9.3-12.5	25.1-37.8	-	0.6-2.7	6.7-8.5	9.1-14.6	-	-	-
Panniyur-1,2,3	21.0-22.7	9.16-11.0	21.57-27.7	8.5-17.16	-	-	5-6.18	-	-	-
Panniyur-4	16.7	6.4	21.19	1.94	-	-	5.32	8.4	9.7	-
Karimunda	9.4-21.9	2.0-15.2	19.8-45.3	-	-	0.1-21.0	2.4-11.4	-	-	-
Kalluvally	9.4-21.9	2.0-15.2	19.8-45.3	-	-	0.1-21.0	2.4-11.4	-	-	-
Arakulam munda	9.4-21.9	2.0-15.2	19.8-45.3	-	-	0.1-21.0	2.4-11.4	-	-	-
Thommankodi	9.4-21.9	2.0-15.2	19.8-45.3	-	-	0.1-21.0	2.4-11.4	-	-	-
Kottanadan	12.7-23.8	7.5-15.4	8.9-24.1	11.2-22.6	-	-	-	-	-	-
Ottaplackal	15.5-21.7	3.8-11.7	15.5-21.7	0.1-26.8	-	-	-	0-18.6	-	-
Kuthiravally	9.0-16.9	3.8-10.9	29.0-46	-	-	-	-	-	-	-
Cheriya kaniyakadan		14.7-17.8	7.7-11.2	17.4-23.1	9.7-22.3	-	-	-	-	- -
Thevanmundi	8.3-18.0	3.7-8.7	20.3-34.7	4.5-16.2	-	-	-	-	-	-
Poonjaranmunda	14.9-15.8	6.0-11.7	24.4-30.8	-	-	-	-	-	-	1.2-6.8
Valiakaniyakadan	12.9-18.6	-	23.0-38.4	12.9-17.3	-	0-10.5	2.9-6.3	-	-	-
KS-27	18.3-22.7	7.6-9.6	7.6-21.3	-	0.4-6 %	19.0-23.4	3.2-7.0	-	-	-

Source: Menon *et al.* (2000); Menon *et al.* (2002); Menon *et al.* (2003); Gopalakrishnan *et al.* (1993); Menon & Padmakumari (2005)

The acetone extract of pepper showed the presence of 18 components accounting for 75.59% of the total quantity. Piperine (33.53%), piperolein B (13.73%), piperamide (3.43%) and guineensine (3.23%) were the major components.

Variation of piperine in relation to cultivars

Seven black pepper cultivars, namely Panniyur-2, Panniyur-3, Panniyur-4, Sreekara, Subhakara, KS-88 and Neelamundi were evaluated for piperine, oleoresin and essential oil contents. Panniyur-4 recorded the lowest oleoresin (9.2%) and essential oil contents (2.1%) and relatively medium piperine content (4.4%). Panniyur-2 had poor yield but recorded the highest piperine content (6.6%). Neelamundi, KS-88 and Sreekara gave the highest oleoresin contents (13.9, 13.1 and 13.0%, respectively), while Sreekara and Subhakara gave the highest essential oil content (7.0 and 6.0% respectively). HP-813 ('IISR Malabar Excel') had reportedly high oleoresin and piperine content compared to other recently released black pepper cultivars (Sasikumar *et al.* 2004). Varietal variation of black pepper (*Piper nigrum* L.) for oleoresin and piperine was reported in black pepper grown at Idukki District, Kerala. Mathew & Bhattacharyya (1990) showed that a slightly immature grade of 'half pepper' was economically advantageous and contained the highest levels of piperine (6.8%). Five different grades of four (*Piper nigrum*) cultivars were analyzed for their percentage piperine, oleoresin and volatile oil content. The garbled light special (GL special) grade of each cultivar had the highest piperine percentage. The Tellicherry Garbled (TG) grade of Kalluvally had the highest volatile oil content of 3.4%.

Properties, synthesis and estimation of piperine

The alkaloid piperine is generally accepted as the active "bite" component in black pepper. Piperine is a yellow crystalline substance having a melting point of 128-130°C. Piperine, $C_{17}H_{19}O_3N$, was shown to be a weak base which on hydrolysis with aqueous alkali or nitric acid yielded a volatile base $C_5H_{11}N$, later identified as piperidine. The acidic product of hydrolysis, piperine acid ($C_{12}H_{19}O_4$, m.p. 216-217°C), was shown to be 5-(3,4-methylene dioxy phenyl)-2,4, pentadienoic acid.

Geisler & Gross (1990) isolated an acyltransferase from shoots of black pepper which catalysed the synthesis of piperine in the presence of piperoyl-coenzyme A and piperidine. The enzyme is classified as 'piperoyl-CoA: piperidine N-piperoyltransferase' (piperidine piperoyltransferase; EC 2.3.1).

Wood *et al.* (1988) developed the reversed-phase high-performance liquid chromatographic method for piperine determination in black pepper and its oleoresins. It employs bonded C18 stationary phase (ODS-2) and acetonitrile-aqueous acetic acid mobile phase with UV detection. As the spectrophotometric method which invariably yields higher results because of the contributions from other alkaloids such as. piperyline and piperettine, the HPLC method relate more to piperine.

International specifications and desirable limits

Major requirements for international acceptance of black pepper and its products were identified by various agencies. Specifications for whole black pepper, white pepper, and powders are listed in tables 3-6.

Table 3. Whole black pepper: chemical and physical specifications

Specification	Suggested limits
ASTA cleanliness specifications:	
Whole dead insects, by count	2
Mammalian excreta, by mg/lb	1
Other excreta, by mg/lb	5
Mold, % by weight	1
Insect defiled/infested, % by weight	1
Extraneous, % by weight	1
General ISO specifications:	
Insect infested and/or moldy pieces by weight	Ave of 1 %
Mammalian excreta	Ave of 1 %
Foreign matter pickings and siftings by weight	
Volatile oil	2.0 % min.
Moisture	12.0 % max.
Ash	5.0 % max
Acid insoluble ash	0.5 % max
Average bulk index (mg/100 g)	165

Table 4. Ground black pepper: chemical and physical specifications

Specification	Suggested limits
Insect fragment	Ave of 475 or more/50 g
Rodent hair fragments	Ave of 2 or more/50 g
Volatile oil	1.5 % min.
Moisture	12 % max.
Total ash	5 % max
Acid insoluble ash	0.5 % max
Crude fibre	12.5 % max
Nonvolatile methylene chloride extract	7.5 % min
Starch	30.0 % max
Granulation	70 %

Table 5. Whole white pepper: chemical and physical specifications

Specification	Suggested limits
ASTA cleanliness specifications:	
Whole dead insects, by count	2
Mammalian excreta, by mg/lb	1
Other excreta, by mg/lb	1
Mold, % by weight	1
Insect defiled/infested, % by weight	1
Extraneous, % by weight	0.50
FDA DALs	
Insect infested and/or moldy pieces by weight	Ave of 1%
Mammalian excreta	Ave of 1mg per lb
Foreign matter pickings and siftings by weight	Ave of 1%
Volatile oil	1.5 % min
Moisture	14.0 % max
Ash	1.5 % max
Acid insoluble ash	0.3 % max
Average bulk index (mg/100g)	150

Table 6. Ground white pepper: chemical and physical specification

Specification	Suggested limits
Insect fragments	Ave of 475 or more/50 g
Rodent hair fragments	Ave of 2 or more/50 g
Volatile oil	1.5 % min
Moisture	14.0 % max
Total ash	1.5 % max
Acid insoluble ash	0.3 % max
Military specifications	
Volatile oil (ml/100 g)	1.0 min
Moisture	15.0 % max
Total ash	3.0 % max
Acid insoluble ash	0.3 % max
Crude fibre	5.0 % max
Starch	52.0 % max
Nonvolatile methylene chloride extract	7.5 % min
Granulation	95 % min through a U.S.S.
Bulk index (ml/100 g)	180

References

Bandyopadhyay C, Narayan V S & Variyar P S 1990 Phenolics of green pepper berries (*Piper nigrum* L.). J. Agric. & Food Chem. 38(8): 1696-1699.

Geisler J G & Gross G G 1990 The biosynthesis of piperine in *Piper nigrum*. Phytochemistry 29(2): 489-492.

Gopalakrishnan M, Nirmala Menon, Padmakumari K P, Jayalekshmy A, Narayanan C S & Menon N 1993 G C analysis and odor profiles of four new Indian genotypes of *Piper nigrum* L. J. Essent. Oil Res. 5(3): 247-253.

Govindarajan V S 1977 Pepper Chemistry, technology and quality evaluation. Critical Reviews in Food Science and Nutrition 9: 115-225.

Jagella T & Grosch W 1999a Flavour and off flavour compounds of black and white pepper (*Piper nigrum* L.) I. Evaluation of potent odorants of black pepper by dilution and concentration techniques. European Food Research and Technology 209(1): 16-21.

Jagella T & Grosch W 1999b Flavour and off flavour compounds of black and white pepper (*Piper nigrum* L.) II. Odour activity values of desirable and undesirable odorants of black pepper. European Food Research and Technology 209(1): 22-26.

Jirovetz L, Buchbauer G, Ngassoum M B & Geissler M 2002 Aroma compound analysis of *Piper nigrum* and *Piper guineense* essential oils from Cameroon using solid phase microextraction gas chromatography, solid phase microextraction gas chromatography mass spectrometry and olfactometry. J. Chromatography 976(1/2): 265-275.

Menon A N 2000 The aromatic compounds of pepper. J. Medicinal and Aromatic Plant Sciences 22(2/3): 185-190.

Menon A N, Padmakumari K P & Jayalekshmy A 2003 Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.) III. J. Essent. Oil Res. 15(3): 155-157.

Menon A N, Padmakumari K P & Jayalekshmy A J 2002 Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.). J. Essent. Oil Res. 14(2): 84-86.

Menon A N, Padmakumari K P, Jayalekshmy A, Gopalakrishnan M & Narayanan C S 2000. Essential oil composition of four popular Indian cultivars of black pepper (*Piper nigrum* L.). J. Essent. Oil Res. 12(4): 431-434.

Menon A N & Padmakumari K P 2005 Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.) IV. J. Essent. Oil Res. 17: 206-208.

Narayanan C S 2000 Chemistry of black pepper. In: P N Ravindran (Ed.) Black pepper (*Piper nigrum* L.). Harwood Academic Publ., Amsterdam, The Netherlands, pp. 143-162.

Ravindran P N 2000 Introduction on black pepper. In: P N Ravindran (Ed.), Black Pepper (*Piper nigrum* L.) Harwood Academic Publ., Amsterdam, The Neteherlands, pp 1-22

Sasikumar B, Haridas P, George K J, Saji K V, Zachariah T J, Ravindran P N, Babu K N, Krishnamoorthy B, Mathew P A & Parthasarathy V A 2004 'IISR Thevam', 'IISR Malabar Excel' and 'IISR Girimunda' three new black pepper (*Piper nigrum* L.) clones. J. Spices and Aromatic Crops 13(1): 1-5.

Wood A B, Barrow M L & James D J 1988 Piperine determination in pepper (*Piper nigrum* L.) and its oleoresins through a reversed phase high performance liquid chromatographic method. Flavour and Fragrance J. 3(2): 55-64.

Zachariah T J, Mathew P A & Gobinath P 2005 Chemical quality of berries from black pepper varieties grafted on *Piper colubrinum*. J. Medicinal and Aromatic Plant Sciences 27(1), 39-42.

Zachariah T J & Parthasarathy V A 2008 'Black pepper' In: Chemistry of Spices. V A Parthasarathy, B Chempakam & T John Zachariah (Eds.) CABI, UK, pp.21-40.

Crop protection in black pepper-an overview

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Introduction

The productivity of black pepper (*Piper nigrum*) is considerably low in India due to various factors among which infestation by pests and diseases is a major factor. The major pests and diseases affecting black pepper in India include *Phytophthora* foot rot and slow decline diseases, *pollu* beetle, scale insects, root knot nematode and burrowing nematode. The pests and diseases which are emerging as serious threats to black pepper in recent years include stunt and anthracnose diseases, spike shedding and root mealybugs and *Erythrina* gall wasp on *Erythrina* standards. Adoption of integrated pest management schedules is important in black pepper since the spice is high-value and export-oriented in nature and excessive use of pesticides could lead to pesticide residues in the produce and other ecological hazards. The advances in protection of the crop from pests and diseases involving cultural and biological means, use of resistant varieties and plant products and need-based application of pesticides are highlighted.

Diseases

Phytophthora foot rot

Phytophthora foot rot caused by *P. capsici* is the most devastating disease of black pepper in India and is reported to cause a crop loss of over 1000 tonnes annually at Kozhikode and Kannur districts in Kerala. The disease which is common during the monsoon period is characterized by black spots on the leaves which have typical fimbriations at the margins. The tender leaves and shoot tips of freshly emerging runner shoots trailing on the soil turn black when infected. When the main stem at the ground level or at the collar region is infected, the entire vine wilts followed by shedding of leaves and spikes. The branches break up at nodes and the entire vine collapses in a month. When the damage is confined to the feeder roots, the expression of symptoms is delayed till the cessation of rain and the vine shows symptoms such as yellowing, wilting, defoliation and drying up during the post monsoon period. These vines may recover after the onset of rains and survive for more than two seasons till the root infection culminates in collar rot and death of the vine. High soil moisture, rainfall and humidity are conducive for multiplication of the fungus and spread of the disease.

Management

The strategies recommended for the management of the disease include:

Phytosanitation, which is removal and destruction of dead vines along with the root system from the plantation which reduces the build-up of pathogen inoculum in the field.

Cultural practices, like providing adequate drainage to prevent water logging especially during the monsoon season and shade regulation with the receipt of pre-monsoon showers helps in reducing the spread of the disease. Digging the soil and undertaking other cultural operations which damage the roots should be avoided. The emerging runner shoots should also be pruned to prevent the infection spreading to the main stem of the vine. In severely disease affected areas IISR-Shakthi which is resistant to the disease may be planted.

Biological control, including application of antagonistic micro organisms such as *Trichoderma harzianum* at the onset of the monsoon around the base of the vine @ 50 g/ vine (containing 10^8 cfu/g of formulation). A second application of *T. harzianum* has to be done during August-September. *Pseudomonas fluorescens* @ 50 g/vine (10^8 cfu /g of formulation) may also be applied be along with *T. harzianum.* Addition of organic mulches and oil cakes in the basins improves the texture of the soil and enhances the growth of antagonistic microorganisms.

Chemical control, including spraying Bordeaux mixture 1% with the onset of south west monsoon during June-July and drenching the plant basins with copper oxychloride 0.2% . The spraying and drenching is to be repeated during August-September and if the monsoon is prolonged, a third round of drenching may be given during October. Alternatively, after the receipt of pre-monsoon showers the vines are to be sprayed and drenched with potassium phosphonate @ 3 g/l or metalaxyl-mancozeb @ 1.25 g/l. The second and third round of spraying and drenching may be repeated if required. In case biocontrol agents are applied, only spraying is to be resorted to and drenching may be avoided.

Since *Phytophthora* foot rot is a serious concern in black pepper production, research on management of the disease is a major focus mainly at Indian Institute of Spices Research (IISR), Calicut and Kerala Agricultural University (KAU), Vellanikkara. This includes managing the soil borne infection by disinfesting the soil, addition of organic amendments, biological control, identification of resistant sources, chemical control using fungicides, and biotechnological approaches to develop disease resistant lines.

Soil solarization: Experiments conducted to explore the possibility of soil disinfestation by solarization of potting mixture for reducing *Phytophthora* infection in nurseries indicated that raising black pepper cuttings in potting mixture solarized for 30 to 45 days is effective in minimizing the infection in the nursery.

Organic amendments: Addition of organic amendments such as, farmyard manure, bone meal, chicken manure, neem cake, and extracts of garlic and mustard suppressed populations of *P. capsici*. Application of vermicompost along with *T. harzianum* also resulted in low incidence of root rot.

Resistance: Efforts were made to locate resistance to *P. capsici* in the germplasm collections of IISR, Calicut, and a large number of cultivars, hybrids, related *Piper* species and Karimunda accessions were screened and promising lines identified. A *Phytophthora* tolerant line namely, IISR Shakthi, was released based on screening open pollinated seedling progenies of various cultivars and evaluation in the field. Another open pollinated progeny (P 24-04-1) was identified as resistant and is under field evaluation. Efforts were made to graft *P. nigrum* on the resistant rootstock *P. colubrinum* and their evaluation in the field indicated that the grafts remained healthy even 7 years after planting. Recently *R. sylvaticum* was also identified to be resistant to the pathogen. An inter-specific hybrid (*P. nigrum* x *P. colubrinum*) partially resistant to *Phytophthora* foot rot has also been developed at Pepper Research Station (KAU), Panniyur.

Biological control: Several strains of biocontrol agents effective in protecting the crop against *P. capsici* have been isolated, screened, mass multiplied and evaluated in the field. Promising isolates of VAM such as *Glomus mossae, G fasciculatum, G etunicatum, Acaulospora laevis* and *Gigaspora margarita* can be incorporated in the nursery soil mixture for better establishment and production of disease-free planting material. Various isolates of fluorescent pseudomonads and *Trichoderma* spp. were isolated from black pepper roots and rhizosphere soils from South India among which *Pseudomonas fluorescens, T. harzianum* and *T. viride* were efficient in protecting black pepper from root rot caused by *P. capsici*. Mass multiplication techniques were also standardized using coconut water, sorghum meal, coffee husk and pulp, tea waste and decomposed coir pith. A bioconsortium was also developed with potential rhizoosphere bacteria namely, IISR-6, 8, 13, 51, 151 and PB-21C and found effective under field conditions. Recently, promising endophytic bacteria such as *P. aeruginosa, P. putida* and *Bacillus megaterium* were identified from black pepper and proved effective against the disease in greenhouse studies. Pesticides such as metalaxyl, potassium phosphonate, mancozeb, copper, phorate and chlorpyriphos were compatible with *T. harzianum*.

Chemical control: Based on epidemiological studies, the practice of pasting the collar region with Bordeaux mixture that was suggested earlier was discouraged and instead use of systemic fungicides such as metalaxyl and potassium phosphonate was recommended for the control of the disease.

Biotechnological approaches: Biotechnological approaches to develop disease resistant lines is being undertaken at IISR, Calicut, and KAU, Vellanikkara. Attempts were made to induce variability in somaclones and a few somaclones tolerant to *P. capsici* were identified that are being evaluated for their tolerance to the disease in the field. A mapping population involving Panniyur 1 x Subhakara was developed and the inheritance pattern of *Phytophthora* resistance in the mapping population was studied. Successful *Agrobacterium* mediated transformation with osmotin gene was also achieved for disease resistance in black pepper. The enzyme chitinase involved in disease resistance was identified in *P. colubrinum* and the gene was cloned which showed similarity to known chitinase gene from plants.

Emerging diseases

A. Stunt disease

Stunt disease caused by caused by *Cucumber mosaic virus* (CMV) and *Piper yellow mottle virus* (PYMoV) are becoming serious in recent years in Kerala and Karnataka especially at higher altitudes.

The diseased vines exhibit shortening of internodes and the leaves become small and narrow with varying degrees of deformation and appear leathery, puckered and crinkled. Chlorotic spots and streaks also appear on the leaves. The incidence of the disease was higher (45.4%) in Wayanad District in Kerala; in Karnataka the highest disease incidence (4.9%) was recorded in Kodagu District. The yield loss due to stunt disease in infested vines, varied from 16%-85%.

Two viruses namely, CMV and PYMoV virus were associated with the disease. The mealybugs *Ferrisia virgata* and *Planococcus citri*, commonly found associated with black pepper were found to transmit PYMoV. DAS-ELISA based methodology was developed for the detection of both the viruses in nursery and plants. A protocol for isolation and simultaneous detection of both the viruses infecting black pepper based on multiplex RT-PCR method was also developed.

Management

Since black pepper is vegetatively propagated, infected planting materials are the major mode of disease spread. Adequate care should also be taken to plant virus-free cuttings especially in new areas where the incidence of the disease is not observed in the field. The most viable method to control the disease would be identification and use of virus-free cuttings for propagation. Once a good virus-free plant is identified, they must be maintained virus-free under insect-proof conditions and used for propagation. Regular inspection and removal of infected plants and replanting with healthy plants should be resorted to in the field. Other potential weed and crop hosts, which might act as reservoirs for the virus need to be removed, burnt or buried deep in the soil. Regular monitoring of the nursery and field for insect vectors such as aphids and mealybugs is important and should be controlled with a spray of dimethoate 0.05%.

B. Anthracnose

Anthracnose disease caused by *Colletotrichum gloeosporiodes* is also referred to as *pollu* disease indicating the hollow nature of infested berries. The disease is increasingly becoming serious at higher attitudes in Kerala and Karnataka. The symptoms of the disease include appearance of small, black spots surrounded by a halo on the leaves, crinkling of leaf lamina and formation of cross splitting on the berries. The disease when combined with predominance of female flowers, lack of pollination in rainfed areas, heavy shade and delayed emergence of spikes results in large scale spike shedding. The crop loss due to anthracnose was reported to be up to 67% in Kerala when the berries were infected at an early stage; the crop loss was higher when the spikes were affected.

Trials conducted at Kodagu District (Karnataka) revealed that irrigation of vines 4-5 times at an interval of 5-7 days commencing from the third week of March, followed by shade regulation of support trees was optimum for managing spike shedding. Phytosanitory, prophylactic sprays with Bordeaux mixture 1% and nutrition management practices are also necessary for holistic management of the disease. Trials conducted in Idukki District (Kerala) indicated that vines treated with carbendazim and mancozeb 0.1% or mancozeb 0.1% alone was effective for the management of the disease.

Plant parasitic nematodes

Slow decline

Several plant parasitic nematodes belonging to different groups are associated with black pepper in India among which *Meloidogyne* spp., *Radopholus similis*, *Trophotylenchulus piperis*, *Helicotylenchulus* sp. and *Rotylenchulus reniformis* are predominant. In Kerala and Karnataka, 69.8% and 53.8% of the vines respectively, were found infested with *M. incognita*. *T. piperis* is also wide spread in all major black pepper areas in Kerala and Karnataka.

Slow decline (slow wilt/pepper yellows) is caused by the association of *M. incognita* and *R. similis* and also *P. capsici*. The affected vines exhibit mild to moderate foliar yellowing initially and with depletion of soil moisture during the post monsoon season, they show defoliation and die-back leading to loss of vigour, yield and finally death of the vine. Plants infested with *M. incognita* exhibit inter veinal chlorosis and galling in roots. Root penetration by *R. similis* causes necrotic lesions on white feeder roots which merge and encircle the root cortex leading to disintegration of distal portion of the roots. Experiments conducted under simulated field conditions showed that *R. similis* and *P. capsici* alone or in association and *M. incognita* in association with either *R. similis* or *P. capsici* or both resulted in root rotting leading to typical slow decline disease. Though the disease is prevalent in all major black pepper growing areas in India, exact crop loss estimates are not available. Yield losses ranging from 39% to 65 % have been reported when black pepper vines were inoculated with *R. similis* and *M. incognita* under simulated field conditions.

Management

Nematode management in black pepper warrants a sustainable approach integrating several strategies to bring down nematode populations below economic injury levels.

Preventive measures: Use of nematode-free planting material and soil-less growing media in nurseries, and phytosanitation can reduce nematode spread to a greater extent. Uprooting and destruction of diseased vines along with root mass and replanting after 9-12 months have to be undertaken in nematode infested plantations. Denematization of nursery mixture either through solarization or fumigation with chemicals is highly effective in reducing the nematode load for production of healthy rooted cuttings. The potting mixture should also be fortified with biological control agents after sterilization.

Cropping practices: Exclusion of nematode susceptible intercrops and supports or standards can minimise nematode infestations in the field. Support trees such as *Ailanthes malabarica*, *Artocarpus heterophyllus*, *Garuga pinnata*, *Macaranga indica* and *Erythrina indica* are not susceptible to root knot nematodes and can be grown as support trees. Several inter crops like banana, ginger and turmeric and a large number of weeds are susceptible to these nematodes and may be avoided in black pepper plantations.

Soil amendments: Application of neem cake @ 2 kg/vine is highly effective against *M. incognita*. Addition of chopped leaves of *Gliricidia maculata* (10 g/kg soil) as green manure reduced populations of *R. similis* and increased plant growth.

Resistant lines: A number of black pepper germplasm accessions, including wild types, were screened against *M. incognita* and *R. similis* by several workers at IISR, Calicut and KAU, Vellanikkara. A cultivar, CLT-P-812, which was resistant to *M. incognita* was released as 'Pournami' for cultivation in root knot infested areas. *Piper hymenophyllum, P. colubrinum, P. attenuatum* and accessions like HP-39 and C-820 were resistant to *R. similis*. *P. colubrinum* is now widely used as a root-stock to graft cultivated pepper plants.

Biological control: Biological control initiatives to manage nematode pests of black pepper have been undertaken by several workers. Promising isolates of VAM such as *Glomus mossae, G fasciculatum, G etunicatum, Acaulospora laevis* and *Gigaspora margarita,* which are suppressive nematodes can be incorporated with the nursery soil mixture for better establishment and production of nematode free planting materials.

A number of antagonistic fungi, have been identified and evaluated in the greenhouse and field *Paecilomyces lilacinus* suppressed nematode infestation in black pepper and increased the production of root mass. *Pochonia chlamydosporia (=V. chlamydosporium)* promising against nematodes was isolated from black pepper gardens. Several *Pseudomonas* isolates were isolated and screened against root knot nematodes infesting black pepper. *Bacillus pumilis, B. macerans* and *B. circulans* significantly reduced *M. incognita* population and improved the growth of black pepper plants. *Pasteuria penetrans* was also reported to inhibit root knot nematodes infesting black pepper.

There are only very few successful attempts to control *R. similis* by using fungal bioagents, probably due to the migratory endoparasitic nature of this nematode. Mycorrhizal fungi were reported to suppress *R. similis* infestation on black pepper. Recently, rhizobacteria that suppressed both *R. similis* and *M. incognita* were identified in greenhouse studies. Two promising endophytic bacteria namely, *Bacillus megaterium* and *Curtobacterium luteum* suppressing *R. similis* have been identified recently.

Chemical control: As a preventive measure, black pepper planting materials can be treated with granular nematicides like phorate or carbofuran @ 0.1g a.i./plant. In plantations, application of carbofuran or phorate @ 3 g a.i./vine in May/June and again in September/October resulted in remission of foliar yellowing and reduction in nematode populations.

Insect pests

Pollu beetle

The *pollu* beetle (*Lanka ramakrishnae=Longitarsus nigripennis*) is the most destructive insect pest of black pepper in India. The pest infestation is higher in the plains and midlands in Kerala and in endemic areas up to 40% of the crop is lost due to the pest infestation.

Bioecology: The adult *pollu* beetle feeds on tender shoots, leaves and spikes resulting in black patches on tender shoots and spikes and small irregular circular holes on tender leaves. Severely infested leaves and spikes often rot and drop due to invasion of secondary microorganisms. The damage caused by the larva (grub) is more serious and they bore into tender spikes and berries and feed on the internal contents. The infested spikes develop necrotic patches and the berries turn black and crumble when pressed (the hollow nature of the infested berries is termed as pollu in Malayalam). The adults are seen on black pepper vines throughout the year in the field though their population is higher during September-October.

Management: An integrated strategy involving regulation of shade and spraying of insecticide and neem-based product is to be adopted for the management of *pollu* beetle. Regulation of shade in the plantation by pruning branches of support and shade trees before the onset of the monsoon helps in reducing the build up of pest population. The management schedule to be adopted includes spraying the vines during July and October with quinalphos (0.05% each) or spraying quinalphos (0.05% each) during July followed by Neemgold (0.6%) (neem-based insecticide) during August, September and October.

Resistance: Black pepper cultivars show wide variation in their reaction towards *pollu* beetle in the field. Forty four cultivars of black pepper maintained at Pepper Research Station (KAU), Panniyur (Kerala) were screened against *pollu* beetle among which, Kalluvally Type II was less susceptible to the pest. Four cultivars resistant to the pest under field conditions were identified from the germplasm collections of IISR, Calicut. Six wild species of *Piper*, namely, *P. colubrinum*, *P. chaba*, *P. longum* , *P. attenuatum*, *P. barberi* and P. *hymenophyllum* have also been identified to be resistant to the pest. Interspecifc hybrids of black pepper such as *P. nigrum* x *P. attenuatum* and *P. nigrum* x *P. barberi*, were less preferred for feeding by adult *pollu* beetle. These resistant lines are being utilized in breeding programmes for developing resistant varieties against the pest.

Natural enemies: Very few natural enemies have been recorded on *pollu* beetle in the field and they include an entomophagous nematode (Mermithidae), predatory spider (Araneae) and *Oecophylla smaragdina* Fabr. (Fomicidae). However, the level of parasitization/predation by these natural enemies is quite low and they may not have a major role in the regulation of the pest population in the field.

Plant products: Extracts of various plant species have been screened for antifeedant activity, among which leaf extracts of *Chromolaena odorata*, *Azadirachta indica* and *Strychnos nux-vomica*, root bark extracts of *Uvaria narum* and *U. hookeri*, neem oil, neem seed kernel extract and custard apple (*Annona squamosa*) seed extract were promising indicating their potential in utilizing them in IPM schedules.

Scale insects

Scale insects are major insect pests of black pepper at higher altitudes in Kerala, Karnataka and Tamil Nadu. Among the various species of scale insects recorded on the crop, the mussel scale (*Lepidosaphes piperis*) and coconut scale (*Aspidiotus destructor*) are the most common.

Bioecology: The mussel scale encrusts main stems, lateral branches, mature leaves and berries resulting in chlorotic patches, yellowing and drying of leaves. Younger vines often succumb to the pest during the course of 1-2 years when the infestation occurs on the main stem. On older vines the infested lateral branches wilt and dry resulting in vacant spaces in the canopy. The coconut scale infests mature leaves resulting in chlorotic patches on them and sometimes also infest berries). Scale insects are observed in the field throughout the year, but their population is higher during the post monsoon and summer months. *A. destructor* is highly polyphagous and infests more than 20 economically important plants in India. *L. piperis* occasionally infest cassava (*Manihot esculenta*) stems in the field and storage.

Management: Spraying dimethoate 0.1% may be undertaken selectively on affected vines after clipping off severely infested branches after harvest of berries; the spraying may have be repeated after 21 days if the infestation persists.

Natural enemies: Various predators and parasites have been recorded on scale insects in the field among which predatory beetles such as *Chilocorus* spp. and *Pseudoscymnus* spp. (Coccinellidae), and hymenopterous parasitoids such as *Aphytis* sp. and *Encarsia* spp. (Aphelinidae) were identified as major natural enemies. Methods have been standardized for mass rearing of *C. nigrita* and *C. circumdatus* in the laboratory. Evaluation of these predators in the field indicated that their release brought down the population of *L. piperis* and *A. destructor*.

Plant products: Neem products such as neem oil 0.3% or Neemgold 0.3% or natural products such as fish oil rosin 3% are also promising for the management of scale insects and are safer to the coccinellid predators.

Emerging insect pests

The emerging insect pests which are becoming serious especially at higher altitudes include root mealybugs on black pepper and *Erythrina* gall wasp on *Erythrina* standards. Colonies of root mealybugs (*Planococcus* spp.) are observed at the basal portion of the stem under the soil and on roots causing yellowing, wilting and mortality of younger vines. The pest infestation is more common at higher altitudes in Wayanad (Kerala) and Kodagu (Karnataka) districts and is more severe on vines affected with *Phytophthora* sp. and nematodes. Root mealybugs can be managed by planting pest-free cuttings, removal of weeds in the interspaces of black pepper vines during summer and drenching chlorpyriphos 0.075% and also by undertaking management schedules against *Phytophthora* and nematodes.

The *Erythrina* gall wasp (*Quadrastichus erythrinae*) is a new invasive pest infesting *Erythrina* spp. in all black pepper areas. The pest infestation results in the formation of galls on tender shoots and leaves leading to stunting and death of standards. Short-term strategies for the management of the pest include application of phorate 10G at the basins of young trees and spraying monocrotophos 0.05% or imidacloprid 0.006% on tender flushes of older trees. A viable long-term strategy would be planting other standards such as *Ailanthes malabaricus*, *Garuga pinnata*, *Grevillea robusta*, *Gliricidia sepium* for trailing black pepper.

Pests and diseases in the nursery

Various pests and diseases occur in the nursery resulting in poor establishment in the field and also causing spread of pests and diseases to newer areas. The important diseases affecting nursery plants include *Phytophthora* infections, anthracnose, leaf rot, basal wilt and viral diseases. *Phytophthora* infections can be managed by raising the plants in sterilized soil, spraying Bordeaux mixture 1% and drenching copper oxychloride 0.2% at monthly intervals. Alternatively, metalaxyl 0.01% or potassium phosphonate 0.3% could also be used. Biocontrol agents such as VAM @ 100cc/kg of soil and *T. harzianum* @ 1g/kg of soil and *P. fluorescens* (IISR-6) @ 1 g/kg of soil may be added to the nursery mixture. Anthracnose, root rot and basal wilt infections can be managed by phytosanitation and spraying Bordeaux mixture 1% or carbendazim 0.1%. Selection of virus-free healthy mother plants, regular inspection and removal of infected plants and monitoring of the nursery for insects and spraying with dimethoate 0.05% helps in prevention of spread of viral diseases.

Infestations of plant parasitic nematodes such as *M. incognita* and *R. similis* are common in nurseries. For management of nematode infestation, the nursery mixture should be sterilized by solarization and fortified with biocontrol agents such as *Pochonia chlamydosporia* or *T. harzianum* @ 1-2g/kg of soil. A prophylactic application of phorate 10 G @ 1g/bag or carbofuran 3 G @ 3g/bag is also necessary to check the nematode infestation if serious.

Insect pests such as leaf gall thrips, scale insects, gall midge and mealybugs are common in the nursery and can be managed by spraying dimethoate 0.05%. Colonies of root mealybugs occur at the basal portion of the stem under the soil and on roots causing yellowing, wilting and mortality of cuttings. The pest infestation can be controlled by drenching chlorpyriphos 0.075% and by undertaking control measures against *Phytophthora* and nematodes.

Future thrusts

Though considerable advancements have been made and technologies developed for the management of pests and diseases, they continue to affect the productivity of the crop in the country. Hence, emphasis should be given on the following aspects for a holistic management of pests and diseases.

- Development and utilization of diagnostics for management of pests and diseases
- Characterization and conservation of pathogens and biocontrol agents of pests and diseases
- Breeding varieties with resistance to *pollu* beetle, *Phytophthora*, nematodes and viruses by conventional and biotechnological approaches

- Development of sustainable IPM strategies including cultural methods, resistant lines, biocontrol agents, botanicals, microbial metabolites and need-based application of pesticides
- Developing strategies to manage new and invasive insect pests and diseases

Selected References

Anandaraj M 2000 Diseases of black pepper In: Ravindran P N (Ed.) Black Pepper *Piper nigrum* (pp. 239–268). Harwood Academic Publishers, Amsterdam

Anandaraj M 2006 Disease management in *Phytophthora* foot rot (quick wilt) affected black pepper plantations. Final report of research project, Indian Institute of Spices Research, Calicut.

Anandaraj M & Eapen S J 2006 Achievements in biological control of diseases of spice crops with antagonistic organisms at Indian Institute of Spices Research, Calicut. In: Ramanujam B & Rabindra R J (Eds.) Current Status of Biological Control of Plant Diseases Using Antagonistic Organisms in India (pp. 189–215). Project Directorate of Biological Control, Bangalore.

Anandaraj M & Sarma Y R 2003 The potential of PGPR in disease management of spice crops in Indian Institute of Spices Research, Calicut, Kerala, India. In: Reddy M S, Anandaraj M, Eapen S J, Sarma Y R & Kloepper J W (Eds.) Oral Presentations, 6th International PGPR Workshop (pp. 27-39). Indian Institute of Spices Research, Calicut.

Bhai R S 2007 Screening germplasm of spice crops for reaction to diseases. Final report of research project, Indian Institute of Spices Research, Calicut.

Bhat A I 2008 Viral diseases of some important spice crops. In: Rao G P, Myrta A & Ling K S (Eds.). Characterization, Diagnosis and Management of Plant Viruses, Vol 2, Horticultural Crops (pp 223-248). Studium press, USA.

Devasahayam S 1996 Biological control of insect pests of spices. In: Anandaraj M & Peter K V (Eds.) Biological Control in Spices (pp. 33–45). Indian Institute of Spices Research, Calicut.

Devasahayam S 1998 Biological control of scale insects infesting black pepper. Final report, ICAR Ad-hoc research scheme, Indian Institute of Spices Research, Calicut.

Devasahayam S 2000 Insect pests of black pepper. In: Ravindran P N (Ed.) Black Pepper *Piper nigrum* (pp. 309–334). Harwood Academic Publishers, Amsterdam.

Devasahayam S 2005 Potential use of plant products for the management of insect pests of spices. Pestology 29(11):14-16.

Devasahayam S & Koya K M A 1994a Natural enemies of major insect pests of black pepper (*Piper nigrum* L) in India. J. Spices Arom. Crops 3: 50–55.

Devasahayam S & Koya K M A 1999 Integrated management of insect pests of spices. *Indian J.* Arecanut Spices Med. Plants 1: 19–23.

Eapen S J 2006 Screening spice germplasm for reaction to nematodes. Final report of research project. Indian Institute of Spices Research, Calicut.

Eapen S J 2007 Endophytic bacteria for biological system management of *Radopholus similis*, the key nematode pest of black pepper (*Piper nigrum* L.). Final report, DBT project. Indian Institute of Spices Research, Calicut.

Eapen S J & Ramana K V 1996 Biological control of plant parasitic nematodes of spices In: Anandaraj M & Peter K V (Eds.) Biological Control in Spices (pp. 20-32). Indian Institute of Spices Research, Calicut.

Koshy P K, Eapen S J & Rakesh Pandey 2005 Nematode parasites of spices, condiments and medicinal plants. In: Luc M, Sikora R S & Bridge J (Eds.). Plant Parasitic Nematodes in Tropical and Subtropical Agriculture-2 Edition. (pp. 751-791). CAB International, Wallingford.

Koya K M A 1994 Studies on coccids infesting black pepper. Final report of research project. National Research Centre for Spices, Calicut.

Ramana K V & Eapen S J 2000 Nematode induced diseases of black pepper In: Ravindran P N (Ed.) Black Pepper *Piper nigrum* (pp. 269–296). Harwood Academic Publishers, Amsterdam.

Ramana K V, Mohandas C & Eapen S J 1994 Plant parasitic nematodes and slow decline disease of black pepper. Technical Bulletin, National Research Centre for Spices, Calicut.

Sarma Y R, Anandaraj M & Venugopal M N 1996. Biological control of diseases of spices In: Anandaraj M & Peter K V (Eds.) Biological Control in Spices (pp. 1-19), Indian Institute of spices Research, Calicut.

Sarma Y R & Saju.K A 2004 Biological control technology for the management of foot rot and slow decline diseases of black pepper. Focus Pepper 1 (2): 25-51.

Diseases of black pepper

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Black pepper (*Piper nigrum* L.) is one of the key crops, in which India has an inherent strength to dominate the global markets. Recorded history elucidates the extreme fascination of the rest of the world for this fabled wealth of India. In spite of the conducive agroclimatic situations prevailing in our country, it is paradoxical that the productivity of the crop in India is no way near to the world average. Many reasons are attributed for this situation. Diseases continue to be the main production constraints in India. In India, 17 diseases caused by fungi, bacteria, viruses and mycoplasma are known to affect pepper. However, *Phytophthora* foot rot and slow decline diseases are most important because of their severity. Anthracnose and stunted diseases which were of minor importance are on the increase in recent times. In India, major research work is carried out on *Phytophthora* foot rot and slow decline diseases.

A. *Phytophthora* foot rot

This disease was earlier known as quick wilt and later it was renamed as *Phytophthora* foot rot. In India, the disease was known as early as in 1902. But, it was reported that the causal organism of wilt of black pepper as *Phytophthora palmivara var. piperina* during 1966 only. Crop loss of upto 25-30 % in Kerala and a loss of 44.64 - 48.24 % of vines in Karnataka is reported due to the disease. Careful examination of large number of *Phytophthora* isolates from black pepper world wide revealed that a great majority of these isolates produced long pedicellate, caducous sporangia and were identified as *Phytophthora capsici* Leonian, emend. A Alizadeh and P H Tsao.

Symptoms

Phytophthora capsici infect all parts of the plant and cause severe economic damage. First visible symptom on leaf and stem is noticed 24 to 48 hours and two to five days respectively after the inoculation. Fully developed lesion has a dark brown necrotic centre, plesionecrotic boarder surrounded by yellow halo. The yellow halo is not noticed during prolonged wet and humid conditions. Under these conditions the lesion is uniformly brown in colour. Infection occurs on younger leaves than matured leaves. Development of flaccidity, drooping, yellowing and defoliation of leaves are the marked symptoms during the progress of the disease when the pathogen is infected on stem and branches.

Infection on runner shoots (stolons) leads to the stem and collar infection and cause the sudden wilting of the vine. Infection on spikes causes blackening of developing fruits and peduncle leading to spike shedding. Initial infection on roots and collar regions are same as that noticed on leaves and branches. Infection on roots and collar is fatal. Infection on fine roots slowly progress to feeder roots, causes their rotting and degenerations resulting in flaccidity, yellowing, defoliation and the entire vines will be dried within short period, depending upon the age and health of the vines. If the infection reaches the collar, either through the runner shoots or through roots closer to the soil level, plants show only wilting symptoms, whereas infection reaching the collar through roots of the lower nodes leads to yellowing and defoliation before succumbing to the infection. Such plants may remain alive for 2-3 years.

Epidemiology

Intensity of the disease incidence was maximum in July (39.08%) when rainfall, number of rainy days and relative humidity were high. Increase in amount of rainfall, number of rainy days and relative humidity and lower temperatures had significant positive correlation with the disease and were conducive for higher incidence of the disease as these factors favour disease initiation, development and spread.

Studies in an arecanut-pepper mixed cropping system showed that a combination factors such as daily rainfall of 15.8 – 23.0 mm, temperature range of 22.7 – 29.6°C, relative humidity of 81-99 per cent and sunshine of 2.8 –3.5 h /day favour the spread of aerial infection. The pathogen activity in the soil is confined to the wet monsoon period and depends on availability of soil moisture. The weather conditions during monsoon along with high soil moisture (>25%), temperature ranging from 22-29°C and relative humidity >80 per cent are favourable for rapid multiplication of the fungus. Growth of the host indirectly influences the pathogen by the increased root exudation and availability of more susceptible tissues for colonization. Arecanut, rubber, cocoa, coconut and cardamom can serve as collateral hosts of *Phytophthora* sp. infecting black pepper.

Survival

Contaminated soil is the main source of inoculum. The inoculum survives in the soil upto 19 months in the absence of host plant. The pathogen is concentrated on the surface (0-30 cm) and it gets reduced as the distance and depth increases from the source of diseased plant. The survival structures of *P. capsici* in the soil are chlamydospores and thickened mycelium. Addition of organic amendments to the soil promote growth of saprophytic organisms which in turn reduce the population of *P. capsici*. Both initial occurrence and subsequent spread of the disease followed strictly a nonrandom pattern and the infection clustered around the previously infected plants. The foliar infection spreads within the bush through rain splashes from the lower portions to upper portions whereas, spread to the adjacent plants is through both rain splashes and also through wind blown water droplets.

Disease resistance

Identifying the source of resistance becomes imperative for the effective and long term control of the disease. Black pepper accessions P 24 and P 1352 were found to be field tolerant to *P. capsici*. Study conducted at IISR, Calicut showed that *P. colubrinum* is highly resistant to *P. capsici*. Several O.P. progenies of Perambramundi, Kalluvally, Cholamundi and hybrids involving Panniyur 1 x Karimunda and Narayakodi x Neelamundi have recorded tolerant reaction. Narayakodi, Kalluvally, Balankotta, Neelamundi and Cholamundi were also tolerant. Screening of genotypes at KAU revealed that Kalluvally II and Panniyur 5 had minimum infection.

Among the biochemical parameters studied, *P. colubrinum* the tolerant type, registered highest content of total phenol, reducing sugars, total free amino acids and higher activities of peroxidase and polyphenol oxidase enzymes. The susceptible genotype Panniyur 1 was marked by low OD phenols, reducing sugars, total free amino acids, peroxidase and polyphenol oxidase activities and high glucanase and IAA oxidase activities. The tolerant genotype Kalluvally registered medium values for total phenols, reducing and non-reducing sugars, total free amino acids and enzymes like peroxidase, glucanase and polyphenyl oxinase. However, the content of OD phenol was high and IAA oxidase activity was low in Kalluvally. Activities of peroxidase, catalase and esterase were also high in tolerant cultivars. Tolerant types expressed higher content of defense related enzymes like phenylalanine ammonia lyase and PR proteins. Anatomical differences were also noticed between tolerant and susceptible genotypes.

Disease management

Chemical control

Studies conducted at Pepper Research Station, Panniyur on the efficacy of different methods of application of Bordeaux mixture (BM) indicated that premonsoon pasting with 10 % BM coupled with 1 % BM spray during May – June, July- August and September- October are required for managing foot rot of black pepper. Evaluation of eleven fungicides against foot rot by KAU revealed that, Redomil, Cuman, Kitazin, Thiride, Bayer 5072 and Emisan were effective at concentrations of 1000 and 2000 ppm. However treatments with BM were most effective.

With the advent of highly effective systemic fungicides in the seventies, the chemical control of diseases caused by oomycetous fungi has taken a new turn. Among five systemic fungicides evaluated, *i.e.*, metalaxyl, fesetyl- Al, ethazole, propamocarb and oxadixyl, ethazole and metalaxyl were the most toxic to mycelial growth of the fungus. Ethazole followed by metalaxyl, fesetyl- Al, and oxadixyl were effective in inhibiting the sporangiogenesis. Though fesetyl- Al was less toxic to mycelial phase of the pathogen, it showed good ability on sporangial production and also on spore germination. Metalaxyl was readily taken up by the pepper plants and its systemic activity was noticed even one hour after the application. Its inhibitory effect persisted in the plants for 50 days. Several formulations of metalaxyl such as Ridomil granules and Ridomil- Ziram have been reported to be effective against foot rot of pepper. Studies conducted at IISR indicated the efficacy of potassium phosphonate (Akomin) both as foliar spray and soil drench in checking the *Phytophthora* infection. Maximum reduction of foliar infection was noticed four days after the treatment with Akomin. Treatment schedule *i.e.*, spraying and drenching of BM, Ridomil (0.1%) and Akomin (0.2%) was suggested for managing the disease effectively. Efficacy of metalaxyl gold and Akomin in managing *Phytophthora* foot rot in black pepper is also reported.

Cultural Control

Provision of good drainage

Provision of good drainage condition would reduce the severity of infection since the pathogen is spreading through water. Population build up of *P. capsici* is dependant on weather and is positively correlated with soil moisture.

Growing cover crops

Cover crops are generally recommended to reduce the spread of *Phytophthora* diseases. Cover crops reduced the movement or spread of contaminated soil in a garden through surface water and rain splashes and might increase the activity of antagonistic microflora which reduced the rot in black pepper gardens. But increased population of *P. capsici* with weed than without weed calls for clean cultivation.

Phytosanitation and eradication

Use of disease free planting material is the first step towards the establishment of healthy crop. So utmost care should be exercised while collecting source material for nursery. The infected tissues produce profuse sporulation of the fungus which forms dangerous source of inoculum for further spread of disease. Hence their removal would help in arresting and at least reducing the rate of spread of infection.

Shade regulation

Canopies of live standards may generate ideal climatic situation for multiplication of *P. capsici*. So lopping of branches during rainy season is essential to facilitate better sunlight and reduction of relative humidity in the garden which in turn reduces the leaf wetness besides increasing the temperature within the garden.

Use of beneficial microorganisms

Incorporation of *Azospirillum* enhanced rooting and growth of black pepper. VAM inoculation has been found to enhance rooting, growth and suppress the root damage caused by *P. capsici*. Different isolates of VAM tested against *P. capsici* isolates Is-6, Pi-11, Pi-9, *G. fasciculatum* and *Gigaspora nagarita* were very effective in stimulating the growth and nutrient (P, K, Ca, Mg, Cu. Fe, Mn and Zn) uptake of black pepper. *Glomus fasciculatum* recorded the lowest mortality and foot rot index (53.35% and 62.50%) as against 100 per cent mortality and 98.50 per cent rot index noticed in control.

Biological control

Trichoderma species and *Gliocladium virens* were the best among the several isolates of antagonistic fungi tried against *P. capsici*. Isolation and identification of microorganisms, antagonistic/hypersensitive to *P. capsici* in black pepper plantations of Kerala and Karnataka showed the predominance of *T. viride, T. harzianum. T. hamatum and Gliocladium virens*. Combined application of *T. harzianum* and *Alcaligenes* sp. are effective in reducing the incidence of *P. capsici* and enhancing the plant growth.

Integrated disease management (IDM)

Since any single method would be of little effect to control the disease, an integrated approach would be an ideal strategy to tackle the complex and serious soil borne plant pathogens in many of the economically important crops like black pepper. Nursery hygiene, phytosanitation and other cultural practices, chemical and biocontrol measures coupled with host resistance are important components of IDM, that would reduce the cost and pesticide/fungicide load to the environment.

Use of disease free planting materials, resistant cultivars, cultural practices and timely use of fungicides is very essential for reducing the *Phytophthora* infection in black pepper. Fungicidal application against *P. capsici* coupled with the addition of neemcake @ 1kg/vine and AMF propagule boosted the plant growth and suppressed the root infection. Spraying of 1 % Bordeaux mixture and drenching with copper oxychloride 0.2 per cent and foliar spray and Ridomil Mz/Akomin 40 (0.3%) and application of biocontrol agents prevent the build up of *P. capsici* in black pepper. Spraying and drenching metalaxyl (2.5 g/l) and application of *Trichoderma* sp. registered more than 75% control of *Phytophthora* foot rot in black pepper.

Both nematodes and foot rot diseases can be effectively managed by neemcake and phorate application in soil, drenching and pasting Bordeaux mixture before the onset of monsoon and Akomin (0.04%) & Ridomil Mz (100ppm) as spray and drench during the second week of July and September.

A study carried out to assess the level of adoption, diffusion and impact of IDM of *Phytophthora* foot rot diseases of black pepper in Wynad District indicated that after the intervention by IISR, 75 % of the farmers adopted application of bio control agents and other integrated management practices for the control of the disease. They reported lower crop loss than those who did not adopt the technology.

B. Anthracnose (fungal *pollu*)

Anthracnose in pepper is referred as *'pollu'* disease in India. Later, the disease was named as fungal *'pollu'* caused by *Colletotrichum necator*. Later, it was reported that malformation of berries of black pepper was associated with *C. gloeosporioides* (Penz.) Penz. Sacc.

The initial symptom on leaves, tender shoots and berries is chlorotic specks and only physiologically active leaves are infected. A well developed circular leaf spot is noticed under dry condition. Pedicel infection causes the shedding of spike. The infected berries become dried, shriveled, dark in colour and light in weight. Infection on matured berries causes cracking of the rind.

The intensity of leaf infection was positively correlated with number of rainy days and total rainfall. The berry infection commences during the later part of the South-West monsoon period. Mature berries get more infection than immature berries. The severity of the disease vary causing 1.93 – 9.54 per cent spike shedding. Highest incidence of fungal *pollu* was recorded in Panniyur 1 followed by Balankotta. Vellanamban II showed no infection.

Disease management

Pre-monsoon prophylactic Bordeaux mixture spray against *Phytophthora* check this disease also. Two rounds of Bordeaux mixture (1% spray) prior to flowering and one after berry formation was effective in checking fungal 'pollu'. Difoltan, Boyleton and Kavach were also found suitable to control the disease.

Nursery diseases

Black pepper is propagated vegetatively through cuttings. Nursery diseases act as the major constraint in the production of quality rooted cuttings. Further, the conditions provided in the nursery for better growth and establishment of cuttings are ideal for the development of nursery diseases. Another alarming factor is that if cuttings from infected nurseries are planted in the main field, the diseases are also carried to the field resulting in their wide spread occurrence.

***Phytophthora* foot rot :** The symptom on leaf branch, stem and root was same as described in the main field.

***Colletotrichum* rot :** The symptom and rotting in nursery is similar to that of leaf and stem rots in the main field. Stem infection due to *colletotrichum* was very rare. The symptoms usually develop near the nodal region of the newly formed tender shoots. Severe infection results in yellowing of newly formed leaves which later defoliate and such infected stem may sometimes get detached at the nodal region.

***Rhizoctonia* rot** : The pathogen produced symptoms both on leaves and stem. Fungal growth and also blackening of the bark and brownish exudation near collar region, drooping and drying of leaves 10-12 days after inoculation are the symptoms. Heavy shade and high frequency of irrigation in pepper nurseries were favourable for infection by *R. solani*

***Sclerotium* rot :** In nursery, *Sclerotium rolfsii* was found to infect both leaves and stem of pepper cuttings. On stem, infection was more at the collar region. The main detectable sign of this disease was the appearance of whitish mycelial growth and the infected ones collapsed within 5 days.

Survey conducted on nursery diseases in Kerala for four years revealed four major diseases *i.e.*, *Phytophthora* foot rot (*P. capsici*), *Colletotrichum* rot (*Colletotrichum gloeosporioides*), *Rhizoctonia* rot (*R. solani*) and *Sclerotium* rot (*S. rolfsii*). Incidence of diseases varied with different locations during different seasons. Among the diseases, *Phytophthora* foot rot was most predominant. Pepper nursery raised under HDPE sheet was free from all the diseases during the survey. Vellanamban II, a local cultivar, did not take up the infection of *C. gloeosporioides*. Cuttings planted during February-March had better sprouting and growth, in addition to less disease incidence.

Disease control

Pepper being the perennial crop, production of disease free planting material is the first step in disease management. The disease management strategy include collection of disease free planting material, disinfection of nursery mixture and an integrated control measures. Dipping the cuttings in fungicides before planting, shade regulation in nurseries, disinfection of potting mixture by using fungicides or through solarization before planting, use of methyl bromide fumigated soil *etc.* are reported in managing the nursery diseases.

Nursery diseases caused by *R. Solani, Pythium* species, *C. gloeosporioides* and *S. rolfsii*, could be controlled by timely application of Bordeaux mixture. Copper oxychloride (0.2%) or spraying with Ridomil MZ at monthly intervals also gave good control of these diseases.

Solarization of nursery mixture for 30-45 days was effective in managing the diseases in pepper nursery. Studies revealed that solarization reduced pre sprouting mortality and and reduced the incidence of disease in pepper nursery.

Bordeaux mixture one per cent, drenching copper oxychloride 0.2 per cent, and foliar spray of Ridomil MZ/Akomin 40 (0.3%) and application of bio control agents to prevent the disease build up are recommended. Solarization of nursery mixture with addition of neemcake and timely application of fungicide under 50 per cent shade reduced the disease incidence in black pepper nursery. Solarized soil (30 days solarized), *Trichoderma viride* incorporated and Fytolan drenched treatments were highly effective in managing the *Phytophthora* foot rot in black pepper. Maximum sprouting per cent of cuttings and minimum disease incidence was noticed in treatments of soil solarization for 30 days, *T. harzianum* alone followed by the treatment as per package of practices of Kerala Agricultural University. To sum up, nursery hygiene, phytosanitation and other control practices, chemical and bio control measures coupled with host resistance are important in managing the nursery diseases.

Viral diseases

Stunted disease

This disease is also termed as little leaf disease. This disease is found in all pepper growing tracts of Kerala and Karnataka. Up to 100 per cent incidence of this disease was recorded in certain plantations of Kozhikode and Wynad districts. ELISA tests indicated the disease is caused by cucumber mosaic virus (CMV). The association of badna virus with disease affected black pepper was established. The virus was transmitted from diseased to healthy black pepper plants by grafting and mealy bug (*Ferrisia virgata*). Citrus mealy bug (*Planococcus citri*) commonly found associated with black pepper was shown to transmit badna virus. The disease is characterized by vein clearing, scattered chlorotic flecks followed by chlorotic mottling along veins leading to intervenal chlorosis and curling of leaves. In few cultivars, vein banding, vein thickening and green island –like symptoms are also seen. Incidence was more severe in Karimunda. Yield loss due to the disease varied from 16- 85 % in Kodagu District of Karnataka. Disease can be managed by rouging of infected vines.

Phyllody disease

First recorded in Wynad District of Kerala, the etiology is yet to be understood. The spikes and flowers of the affected vines are malformed into leaf like structures instead of normal flowers. The stock of the affected spikes are elongate, the leaves become smaller and show chlorosis. Removal of the disease affected vines to check further spread is the only way to manage the disease.

Bacterial leaf spot (*Xanthomonas compestris pv betilicola*, red rust (*Cephaleuras mycoidea*), thread blight (*Pellicularia filamentosa*), stump rot (*Rosellina bunodes*), velvet blight (*Septobasidium spp*) are some of the other diseases found in pepper gardens.

Selected references

Abraham K, Shaju K V, Nybe E V & Nandakumar A 2003 Management of *Phytophthora* rot in black pepper. National Seminar on integrated plant disease management for sustainable agriculture (IPDMSA). March 20-21, 2003, Department of Plant Pathology, Annamalai University, Annamalai Nagar, Tamil Nadu. Abstract: 126

Anandaraj M, Ramachandran N & Sarma Y R 1991 Epidemiology of foot rot disease of black pepper (*Piper nigrum* L.) in India. Diseases of black pepper. Sarma Y R & Premkumar T (Eds.). Proceedings of the international pepper community workshop on black pepper diseases. October, 27-29, 1988, Goa, India. National Research Centre for Spices, Calicut, Kerala, pp.114-135

Anandaraj M, Sarma Y R & Ramachandran 1994 *Phytophthora* root rot of black pepper in relation to the age of the host and its culmination in foot rot. Indian Phytopath. 47: 203-206

Anandaraj M & Sarma Y R 1995 Diseases of black pepper (*Piper nigrum* L.) and their management. J. Spices Arom. Crops 4: 17-23

Anandaraj M, Ramana K V & Sarma Y R 1996 Sequential inoculation of *Phytophthora capsici, Radopholus similis* and *Meloidogyne incognita* in causing slow decline of black pepper. Indian Phytopath. 49: 297-299

Bhat A I, Devasahayam S, Sarma Y R & Pant R P.2003 Association of badnavirus in black pepper (*Piper nigrum* L.) transmitted by mealy bug (*Ferrisia virgata*) in India. Current science 84 (12):1547-1550

Malebennur N S, Gangadharappa P M & Hegde H G 1991 Chemical control of foot rot of black pepper caused by *Phytophthora capsici* (*P. palmivora* - MF4). Indian Cocoa, Arecanut Spice J. 14: 148-149

Mammootty K P 1978 Symptomatological studies on quick wilt disease of pepper. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur, Kerala. p.87

Mammootty K P, Sasikumaran S & Pillai V S 1992. Management of nursery diseases of black pepper. Indian Cocoa, Arecanut Spice J. 15: 65-67

Mammootty K P, Sivakumar G, Neema V P & Vanaja T 2003 Integrated disease management of foot rot of black pepper (*Piper nigrum* L.). National Seminar on integrated disease management for sustainable agriculture, March 20-21, 2003, Department of Plant Pathology, Annamalai University, Annamalai Nagar, Tamil Nadu. Abstract: 126

Mammootty K P 2004 Nursery diseases of black pepper (*Piper nigrum* L.) in Kerala with special reference to the management of *Phytophthora capsici* Leonian, emend. Alizadeh and Tsao. Ph.D. thesis, Kerala Agricultural University, Trichur.

Nair P K U. & Sasikumaran S. 1991 Effect of some fungicides on quick wilt (foot rot) disease of black pepper. Indian Cocoa, Arecanut Spice J. 17: 1-2

Nair P K U, Mammootty K P, Sasikumaran S & Pillai V S 1993 *Phytophthora* foot rot of black pepper (*Piper nigrum* L.) - A management study with organic soil amendments. Indian Cocoa, Arecanut Spice J. 19: 1-2

Nambiar P K V, Pillai V S, Sasikumaran S & Chandy K C 1978 Pepper research at Panniyur - a resume, Fungal *pollu*. J. Plantn. Crop 6: 4-11

Nambiar K K N & Sarma Y R 1982 Some aspects of epidemiology of foot rot of black pepper. In: Nambiar K K N (Ed.), *Phytophthora* Diseases of Tropical Cultivated Plants. Central Plantation Crops Research Institute, Kasaragod, pp.225-232

Ramachandran N, Sarma Y R. & Anandaraj M 1991 Management of *Phytophthora* infections in black pepper. Sarma Y R & Premkumar T (Eds.). Diseases of black pepper - Proceedings of the international pepper community workshop on joint research for the control of black pepper diseases. October 20-27, 1988, Goa, India. National Research Centre for Spices, Calicut, pp.158-174

Ramachandran N & Sarma Y R 1990 Bioefficiency of systemic fungicides against *Phytophthora* in black pepper (*Piper nigrum* L.). J. Plantn. Crop (supplement) 20: 78-84

Sarma Y R, Ramachandran N & Nambiar K K N 1982 Morphology of black pepper *Phytophthora* isolates from India. In : Nambiar K K N (Ed.), Phytophthora Diseases of Tropical Cultivated Plants. Central Plantation Crops Research Institute, Kasaragod, pp.233-236

Sarma Y R & Nambiar K K N 1982 Foot rot disease of black pepper (*Piper nigrum* L.). In Nambiar K K N (Ed.), Phytophthora Diseases of Tropical Cultivated Plants. Central Plantation Crops Research Institute, Kasaragod, pp.209-224

Sarma Y R, Premkumar T, Ramana K V, Ramachandran N & Anandaraj M 1987 Diseases and pest management in black pepper nurseries. Indian Cocoa, Arecanut and Spices J. 11: 45-49

Sarma Y R, Ramachandran N & Anandaraj M 1988 Integrated disease management of quick wilt of black pepper (*Piper nigrum* L.) caused by *Phytophthora palmivora* MF4 (*P. capsici*) J. Coffee Res. 18: 61-67

Sarma Y R, Anandaraj M & Ramachandran N 1992 Recent advances in *Phytophthora* foot rot research in India and need for holistic approach. Wahid P, Sitepu D, Daciyanto S & Supran V (Eds.) Proceedings of international workshop on black pepper diseases. Bander Lampung, Indonesia. Agency for Agric. Res. and Devpt. Res. Inst. for Spice and Medicinal Crops. Bogor, Indonesia, pp.133-143

Sarma Y R, Anandaraj M & Ramachandran N 1994 Strategies of disease management in *Phytophthora* caused plant diseases. National group meeting on Phytophthora diseases of horticultural crops. September 1994, Calicut, Kerala. Abstract: 21-23

Sarma Y R, Anandaraj M & Venugopal M N 1996 Biological control of diseases of spices.In: Biological Control on Spices. Anandaraj M & Peter K V (Eds.). Indian Institute of Spices Research, Calicut, p.42

Sarma Y R & Anandaraj M 1997 *Phytophthora* foot rot of black pepper. Agnihotri V P, Sarbhoy A K & Singh D V (Eds.) Management of threatening diseases of national importance. Malhotra Publishing House. pp 237-248.

Towards sustainable management of black pepper nematodes

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Introduction

Most of the black pepper growers of the country are smallholder farmers using traditional methods. In traditional agriculture, practices have evolved that can reduce the incidence and damage caused by pests and diseases. The occurrence of a serious nematode problem is often one of the first indications that a farming system has become unsustainable. However, nematodes are rarely perceived to be pests by many agricultural scientists or developmental personnel and, therefore, not surprising to find that the farmer's perception of nematodes or other unseen organisms as pests is also very limited.

Nematode problems in black pepper

Though, plant parasitic nematodes belonging to 30 genera and 54 species were reported on black pepper all over the world, only 14 genera were found in association with the crop in the major pepper growing areas in India. Among these, only a few species like *Meloidogyne incognita, Radopholus similis, Trophotylenchulus piperis, Rotylenchulus reniformis* and *Helicotylenchus* spp. are predominantly associated with the crop in India. *Meloidogyne* spp. and *R. similis* assumed greater economic importance since these nematodes are responsible for slow decline or yellows disease, a major threat to black pepper cultivation.

Root knot nematode infestation and the incidence of slow wilt disease of black pepper were reported by Barber as early as in 1902 from Wayanad, Kerala, India. Butler (1906) in his further investigations on the disease in Wayanad also reported the association of root-knot nematodes with the diseased vines. But the mortality due to the disease during those days was less than 10%. However, the association of *R. similis* with black pepper in India was first reported by D'Souza *et al.* in 1970. Surveys conducted during the 80s clearly showed the wide spread distribution of many of the above nematodes in all the pepper growing tracts of the country. Interestingly, both apparently healthy and slow decline affected vines harboured high populations of nematodes. In India, a minimum population of 250 nematodes/g roots was consistently recorded with slow decline affected pepper vines.

Symptoms and economic importance

Mild to moderate foliar yellowing at different regions of the affected vine is the initial aerial symptom of slow decline disease. With the advancement of the disease and with the depletion of soil moisture in summer season, the infected vines show defoliation and die back leading to loss of vigour, yield and finally death of the vine. Plants with root knot nematode infestation exhibit dense, yellowish discolouration in inter veinal areas of leaves (inter-veinal chlorosis) and varying degrees of galling in roots. Root penetration by *R. similis* causes necrotic lesions on white feeder roots of black pepper which merge and encircle the root cortex leading to disintegration of distal portion of the roots. Pathogenicity tests with both the nematodes showed that they have the potential to cause significant reduction in the growth and yield of black pepper vines. Yield losses ranged from 39 to 65 % when pepper vines were inoculated with *R. similes or M. incognita* alone or in combinations under simulated field conditions. Interaction of nematodes with other pathogens like *Phytophthora capsici*, *Fusarium* sp. *etc.* leads to damages far greater than the sum of the damages, either of the pathogens can produce individually.

Nematode management in black pepper

Perennial crops such as black pepper pose a greater challenge since nonchemical tactics to suppress the rate of reproduction or disease progress are not yet available. Most of the present day recommendations for nematode management are good for reducing their initial population density which may not be ideal for perennial crops. However, the management of nematodes and some other pests can be achieved in sustainable and subsistence agricultural systems by the integration of different farming practices. Integrating compatible or complementary tactics, such as host resistance/tolerance and nematicides with biological control, should minimize potential problems associated with the loss of efficacy of specific nematicides or the appearance of nematode biotypes that attack resistant cultivars.

Preventing nematode introduction and spread

Worldwide dissemination of *R. similis* is mainly through commercial crops like banana. They are disseminated on vegetative propagating material such as rooted cuttings, rootstocks, tubers, and corms. Planting material infested with the nematode is probably one of the main sources of inoculum in new land.

Use of nematode-free planting material

Using planting materials from known, nematode free sources and selecting healthy propagating materials without symptoms of nematode infestation are important for successful management of nematodes. The farmer can select nematode-free planting material, or can remove the nematodes from the material before planting. Farmers producing their own planting materials will import fewer nematode problems into their lands than those who buy them. The improvised methods like bamboo method and serpentine method are very congenial for nematodes than the conventional three-noded cuttings. Stem cuttings of black pepper can be guaranteed free of root parasitic nematodes provided they are kept separate from all soil before planting. Tissue culture is another excellent option in a nematology perspective.

Studies have shown that many of the commercial black pepper nurseries, be it under private or public sector, are ravaged by nematode problems. Farmers recognizing nematode induced symptoms such as surface cracking, surface galls, watery lesions, necrotic spots, blackened roots, galls as signs of disease or abnormality generally refrain from using the material for planting. In lightly or moderately infested material, nematode infested roots can be removed from planting material by cutting away roots, soil, and diseased tissues.

Potting soil to be used in black pepper nurseries can be made nematode free by inexpensive methods like simple heating or drying under the sun during hot dry seasons for a minimum of two weeks. Steam sterilization and solarization are also recommended for this purpose. The nematode-free potting mixture can be fortified with some of the biocontrol agents like *Trichoderma*, *Pochonia chlamydosporia*, *Pseudomonas fluorescens* or any other promising antagonistic bacteria.

Cultural and physical methods

Crop cultivars resistant to nematodes can be the most useful and cheapest means of nematode control for small-scale farmers. 'IISR Pournami' is a root knot nematode resistant black pepper variety recommended for cultivation. Recently some lines have been identified as resistant to *R. similis*. Although nematode resistant cultivars of crops have been developed for commercial production, relatively few of these cultivars are readily available for farmers in India because of flaws in planning and development. If genetic diversity of crops is present, farmers will select for resistance or tolerance to locally occurring pests, including nematodes. Exclusion of nematode susceptible intercrops, supports or standards and weeds can also minimise the nematode infestation.

Uprooting and burning infected root systems kills nematodes present in the soil and reduces the carry-over populations. Destroying crop residues including roots or lifting roots onto the soil surface is traditional in many parts of India. Grafting of black pepper high yielding varieties to nematode resistant-root stocks such as *Piper colubrinum* is another promising technology to keep at bay the nematode problems. The use of organic matter as soil additives is a well-established and ancient agricultural practice used by small-scale and large-scale farmers alike. Amendments alone improve the nutrients and water-holding capacity of the soil, thereby improving plant growth and hence increasing tolerance to nematodes. Higher organic content in soils also stimulates microbial activity and increases the presence and activity of beneficial soil microorganisms antagonistic to nematodes. Furthermore, the decomposition of residues results in the accumulation in the soils of specific compounds that may be nematicidal. Sustainable agricultural systems would be expected to have soils with a high organic content. A very extensive range of amendments using bioproducts and wastes from agricultural and other activities helps to control nematodes.

Biological control

Traditional farming systems have built-in biodiversity in the soil as well as in crops, and they usually enjoy a high degree of natural pest control. Several naturally occurring organisms like nematophagous fungi, endoparasitic fungal parasites, vesicular arbuscular mycorrhizal fungi, the obligate parasite, *Pasteuria penetrans*, and predaceous organisms are antagonistic to nematodes. A number of such antagonistic fungi, which parasitize or prey on nematodes, have been identified from spice based cropping systems and further evaluated in greenhouse and field trials for managing nematode pests of spices. Promising among these are mycorrhizal fungi, *Paecilomyces lilacinus*, *Pochonia chlamydosporia*, *Pasteuria penetrans*, *Bacillus* spp. and *Pseudomonas fluorescens*. Unfortunately, many of these are effective against root knot nematodes and not burrowing nematodes.

A number of endophytic bacteria that inhibit *R. similis* under greenhouse conditions have been isolated recently from black pepper itself. A few of the prominent isolates are *Curtobacterium luteum* and *Bacillus megaterium*. Plant growth promoting bacteria (PGPR) including endophytes, besides offering protection against phytopathogens, are also good growth promoters, an added advantage for any practical agriculture system. These bacterial strains may be useful in multi-crop, multi-pathogen management programmes to augment genetic resistance to plant diseases. It is evident that rhizobacteria could possibly serve as ecofriendly and sustainable alternative to the hazardous chemicals used for growth promotion and management of crop diseases.

Microbial agents occurring naturally in agricultural soils and that can be encouraged to proliferate hold the greatest potential for nematode control, especially by sustainable practices. Natural biological control in farm soils can also be encouraged by reduced tillage, generally more effective in conserving beneficial antagonists of nematodes than is intensive cultivation. Maintaining soil moisture and improving the supply of nutrients increases root growth, which partly compensates for damage by nematodes. Mulching with some of the leaf residues of *Glyricidia* and agricultural wastes also helps to maintain nematode population under the threshold levels.

Depleting biodiversity

The reduction in crop diversity and the trend towards genetic uniformity invariably increase problems associated with nematodes, soil degradation, and food insecurity. Large scale introduction of high yielding lines like Panniyur 1 has resulted in irrecoverable loss of traditional local cultivars that had better resistance to nematodes. Long-term stability derives partly from a multiple cropping system and partly from the cultivation of mixed cultivars to minimize risk. The tendency to raise black pepper as a monocrop or sole companion crop of coffee or arecanut also should be checked as a long term strategy to deal with nematodes.

Multiple cropping systems are still the norm for traditional and subsistence farmers in the tropics. Although sometimes regarded as primitive, most tropical crop combinations are more productive and efficient than the related pure stands. Multiple cropping systems can reduce nematode populations and the damage caused to various crops. Traditional and sustainable agricultural systems have considerably greater genetic diversity because of the availability a large number of cultivars of domestic crop species.

Conclusion

Black pepper cultivation is seriously threatened by damage by plant parasitic nematodes. The growers are not aware of the gravity of the situation. Large scale distribution of infested planting materials, changing cultivation practices and ultimately the climate change are favouring the nematodes and not the crop. In this context, there needs to be drastic change in our approach towards nematode management. A sustainable model for managing this menace in black pepper nurseries and plantations is proposed based on the experimental leads of last three decades (Figs. 1 & 2). However, managing them in an existing garden is a difficult proposition and nematicides may be the only option. The proposed model is ecologically sound, environment friendly and should be economically feasible. It calls for some strategic deviation from the currently advocated practices in black pepper cultivation.

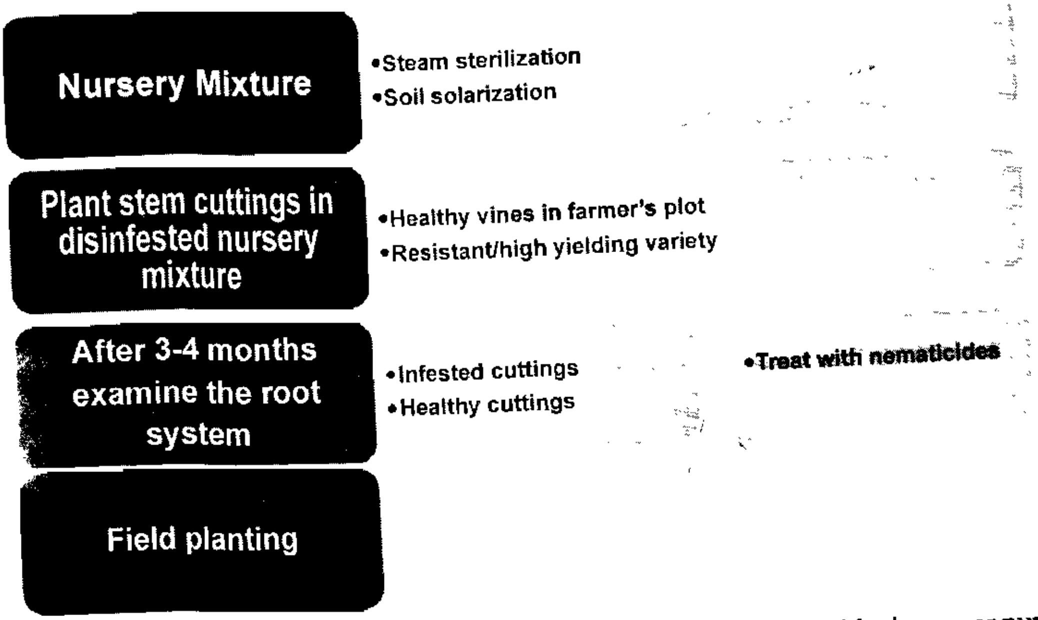

Fig. 1. Schematic model for management of plant parasitic nematodes in a black pepper nursery

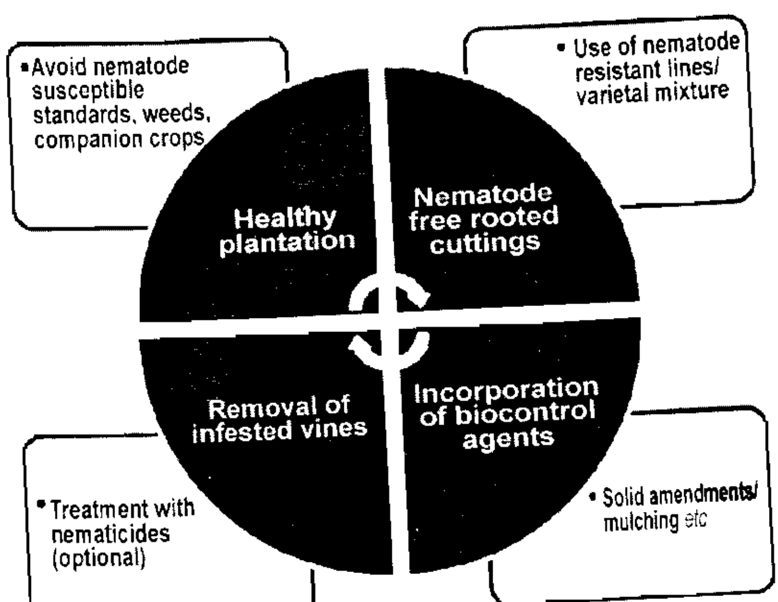

Fig. 2. Management of plant parasitic nematodes in a black pepper plantation (new planting)

Selected references

Anandaraj M, Ramana K V & Sarma Y R 1996 Sequential inoculation of *Phytophthora capsici, Radopholus similis* and *Meloidogyne incognita* in causing slow decline of black pepper. Indian Phytopathology 49: 297-299.

Bridge J 1996 Nematode management in sustainable and subsistence agriculture. Annual Review of Phytopathology 34:201–25.

D' Souza G I, Kumar A C, Viswanathan P R K & Shamanna H V 1970 Relative distribution and prevalence of plant parasitic nematodes in coffee tracts of South Western India. Indian Coffee 34: 329-330, 342.

Eapen S J, Beena B & Ramana KV 2005 Tropical soil microflora of spice-based cropping systems as potential antagonists of root-knot nematodes. J. of Invertebrate Pathology 88: 218-225.

Koshy P K, Eapen S J & Rakesh Pandey 2005 Nematode parasites of spices, condiments and medicinal plants Pp. 751-791. In: Plant parasitic nematodes in tropical and subtropical agriculture -2 edition. Luc M , Sikora R S & Bridge J (Eds.) CAB International, Wallingford, U.K.

Krishna Menon K 1949 The survey of pollu and root diseases of pepper. Indian J. of agricultural Science 19: 89-136.

Mohandas C & Ramana K V 1987 Plant parasitic nematodes associated with black pepper (*Piper nigrum* L.) in Kerala. Indian J. of Nematology 17: 62-66.

Mohandas C & Ramana K V 1991 Pathogenicity of *Meloidogyne incognita* and *Radopholus similis* on black pepper (*Piper nigrum* L.). J. of Plantation Crops 19: 41-53.

Ramana KV 1992 Role of nematodes in the incidence of slow decline (slow wilt disease) of black pepper and screening pepper germplasm against nematodes. Final Report. National Research Centre for Spices, Calicut, Kerala, India. 149p.

Ramana K V, Mohandas C & Balakrishnan R 1987 Role of plant parasitic nematodes in the slow-wilt disease complex of black pepper (*Piper nigrum* L.) in Kerala. Indian J. of Nematology 17: 225-230.

Ramana KV, Sarma Y R & Mohandas C 1992 Slow decline disease of black pepper (*Piper nigrum* L.) and role of plant parasitic nematodes and *Phytophthora capsici* in the disease complex. J. of Plantation Crops 20 (suppl.): 65-68.

Sundararaju P, Koshy P K & Sosamma V K 1979 Plant parasitic nematodes associated with spices. J. of Plantation Crops 7: 15-26.

Venkitesan T S 1976 Studies on the burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne 1949 on pepper (*Piper nigrum* L.) and its role in slow wilt disease. Ph. D. thesis, Department of Plant Pathology, University of Agricultural Sciences, Bangalore, India. 122p.

Insect pests of black pepper and their management

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Black pepper is one of the major spices of India, especially in the southern states, with Kerala being the prime state in area and production (www.indianspices.com). Legend has it that when Vasco de Gama's disciples took pepper vines on board their ships for planting, the erstwhile Zamorin of Calicut remarked to his minister Mangattachan, that without the torrential rains of thiruvathira, commercial production of pepper was impossible. Today, however, insects attacking pepper have a limiting role in pepper production. Both the pepper nursery and the main field are affected by insect pests. Black pepper being a much exported produce, does not allow heavy insecticidal management in the main field. However, the nursery can have the liberty of some pesticidal control. Hence the pests of main field and nursery are being described separately.

Major insect pests in the main field

The *pollu* beetle: *Longitarsus nigripennis* Mots. (Chrysomelidae: Coleoptera)

This flea beetle is probably the most destructive pest of pepper berries, limiting its production. Pollu in Malayalam means hollow, and the beetle derives its name by its habit of making the berries hollow. Incidence of the pest has been recorded at a lower level (5- 10 per cent) in the higher altitude of Wynad or above 900 m above MSL (Devasahayam 1992a) and higher (20-32 per cent) in the plains (Premkumar & Nair 1984). Estimates of losses due to the pest range from 6-40 per cent (Prabhakaran 1994). Though the adult beetles can feed on the spikes, leaves and tender shoots, damage by them is only marginal and intended only for survival. They cause holes on the leaves and scraped and dried black patches on the plant parts. Significant yield loss however is due to the grubs.

The minute adult beetles measuring approximately 3x2mm are black or bluish black on the elytra and with a yellowish head. The legs and abdomen are brown with the hind femur enlarged. Description of the species, biology and morphology are given by Maulik (1926); Premkumar (1980); Babu (1994). The adult females lay single eggs or rarely 2-3 eggs on the developing berries or spikes in a hole scraped by the female. After an incubation period of 3-8 days, the eggs hatch into creamy white or yellow grubs that typically eat away the internal contents of individual berries. There are three larval instars during which the grubs finish off 3-4 berries, coming out of the berry when the contents are fully eaten up. This causes the drying up of 3-4 adjacent berries to become hollowed. Consequent to the attack the berries turn yellowish, then brown to black and later fully dry up, while the whole spike is still maturing. In some cases, when the grubs bore into the central rachis of the spike, the whole spike distal to this point dries up. All affected berries will crumble when pressed. This type of feeding causes a high percent of yield loss than when individual berries are eaten up. The insect prefers shaded conditions for its development and hence the damage is more in areas of higher shade in the plantation and in plantations with standard trees producing higher amount of foliage and shade. When the grubs are fully grown, within a period of 20-40 days, they fall to the ground and pupate in the soil for 6-8 days (Nair & Visalakshi 1999). Emergence occurs periodically, depending upon successful completion of the different broods. A generation may be completed in 30-60 days, depending on the ambient weather, availability of food and the susceptibility or resistance regime of the variety being attacked. Consequently, during the berry maturing season from May to December, there can be 3-4 overlapping generations. During the period December to May when no berries are available for feeding, there is a reduced adult population that survives by nibbling on the leaves and other soft plant parts. Stray egg laying and perpetration of the species might occur on other parts of the plant during this period. Population build up starts with the commencement of the pre-monsoon showers in April -May and the consequent emergence of spikes on the plant. Food ambience during the rainy period causes development of further broods and population dwindle after the cessation of the monsoon rains and increase in temperature. The correlations of population build up with weather have been described by Premkumar & Nair (1984).

Management practices for *pollu* beetle

Before recommending management practices for *pollu* beetle in pepper, it is desirable to consider the plantation health in totality and visualize IPM for the plantation rather than individual pest control. A comprehensive IPM treatment is suggested at the end of this paper encompassing all the pests rather than treating individual pests in isolation.

Management of *pollu* beetle warrants chemical control when the beetle attains pest status. Three rounds of spray during May, July and September is recommended by Nandakumar *et al.* (1987). The Kerala Agricultural University suggests a two spray schedule, one at spike initiation and the second one month later, with a third need based spray in the third month (KAU 2007).

Top shoot borer: *Cydia hemidoxa* Meyr. (Tortricidae, Lepidoptera)

The top shoot borer is a pest in the nursery and young plantations in the initial years. It is debatable whether this pest is a blessing in disguise, at least in low infestation levels, since attack by the pest initiates development of new shoots from axillary buds.

The adult is a small beautiful moth with a wing span up to 15mm. The basal region of the wing is yellowish and the distal half crimson red with black wavy markings, the forewing being folded rooflike in the resting posture. The hindwings are grey. The caterpillar when full fed is 12-14 mm long and is grayish green (Nair & Visalakshi 1999). The larvae bore into the terminal shoots and eat up the internal contents. The larva is capable of completing its life cycle within a single internode. There are five larval instars lasting upto 14 days. Pupation is in the larval tunnel extending about 8-10 days. The attack causes the affected terminal tips to dry up. Infestations are heavy during the main flushing season commencing with the onset of monsoon and continues until no more top shoots or terminal shoots are produced. The larvae are parasitized by *Apanletes sp., Euderus sp., and Goniozus sp. Apanteles cypris* and a mermithid *Hexameris sp.* (Devasahayam & Koya 1993b; 1994b).

Management

The pest is not managed by chemicals in isolation, since sprays against *pollu* beetle would manage this pest also. Another reason is its low occurrence and ability to induce axillary shoots in the attacked vines.

Marginal gall thrips: *Liothrips karnyii*(Bagn.) (Thripidae, Thysanoptera)

This pest has been described as a serious problem in high altitudes with a significant positive correlation of pest incidence with altitude (Devasahayam 1992b). Thrips attack on the leaf, however is omnipresent in all pepper tracts in the plains also. The attack is initiated on the tender leaves and heavy occurrence coincides with the pre-monsoon and monsoon periods, when large number of new leaves is put up. The leaf margins curl downwards and inwards, allowing a concealed feeding site for the thrips. Egg laying of the first brood is on the margins which causes hypertrophy and aided probably by the thrips secretions, folds to the underside, causing the galls. This allows further concealed feeding sites for colony development. Eggs hatch in 6-8 days, into light brownish thrips that pass through one more nymphal, pre-pupal and pupal instars spanning 13-18 days to become black thrips. The folded margins initially show yellowing, and later blackening and crinkling. The margin becomes malformed, chlorotic and galled. Only in the case of very young vines and even there, only in severe infestations, the pest causes serious concern. Studies correlating infestation with direct yield loss does not seem to be available. As such, even though this is a pest in all pepper tracts, it is not a significant one, since only the leaf is affected and that too only at the margins.

Management

There are many natural enemies including *Montandoniola moraguesi*, an anthrocorid bug and a predatory thrips *Androthrips flavipes,* a member of Phalaeothripidae that prey upon the juveniles of the thrips. However, insecticidal management specifically for thrips is not necessary. Application of dimethoate 0.05% on new flushes or malathion 0.1% or fenvalarate (Devasahayam 1989; 1990; Vivekanandan *et al*. 1981) is recommended, but any of these for pollu beetle and /or top shoot borer as the first spray would manage thrips also.

Scale insects

Mussel scale: *Lepidosaphes piperis* Green (Diaspididae)

Soft scale: *Marsipococcus* (Lecanium) marsupialis (Green) (Coccidae)

Coconut scale: *Aspidiotus destructor* Sign (Diaspididae)

Scale insects, especially the mussel scale, has become serious pests in pepper nurseries and small plants as in bush pepper. The pest is more serious since their infestation is not easily recognized by the farmer due to the sedentary nature and also because of their camouflaging colour.

L. piperis, the mussel scale almost fully covers the main stem of young vines and lateral branches. They are also seen on the undersurface of mature leaves and also cover the berries fully. The main damage to the crops is by the sap sucking by the pests which causes devitalizing of the young vines. As a consequence, they dry up. The scales also infest the undersurface of leaves, but is limited to a few leaves only. In high altitudes, they also attack the berries. These berries are ugly to look at close range and of low or little market value. When the berries mature, they can be seen as oval dark grey scales sticking on the berries in large numbers. Initially they cause yellowing of the berries, but even after drying the berries are crinkled and malformed. This scale can also attack cassava and *P. attenuatum* (Pillai 1994).

Aspidiotus destructor, the coconut scale, is also seen attacking the leaves in large numbers, causing yellowing and chlorotic patches on the leaves. This is highly polyphagous and attacks more than 20 economically important crops.

Management

This assumes importance for mussel scale control especially in nurseries. Here, there is no alternative to chemical control, since drying up of cuttings cannot be allowed. Chlorpyriphos 0.075% or dimethoate 0.05-0.1% depending on the intensity of attack can be sprayed. It is necessary to apply the insecticide along with teepol or sandovit @ 5 ml per litre for easy penetration of the waxy layer of the scales, even when systemic insecticides are used, since many of these has an added contact and/ or stomach action also. For managing *A. destructor*, which is mostly on the leaves, the normal sprays against other pests may be sufficient.

Mealy bugs

Planococcus sp. (Pseudococcidae)

Ferrisia virgata Ckll. (Pseudococcidae)

These are pests of pepper that have assumed importance recently. Both the species attack the leaves, shoot and berries. *Planococcus* is also the root mealy bug, which causes yellowing and drying up of the vines in nursery and in young plantations. The root mealy bug is not easily detected and is hence not easy to manage. Colonies of the root mealy bug infest the basal portion of the stem under the soil and also the roots and extensively desap from the tissues. They do not move actively, even though they are not entirely sedentary. Desapping leads to yellowing of the plants initially and later cause wilting and mortality of vines. Nine species of the mealy bugs have been reported to infest pepper (Koya *et al.* 1996)

During recent years, mealy bug infestation has become widespread on the berries also causing reduction in quality of the produce. Even during harvest, the body parts remain on the berries, which contaminate the dried produce.

Management

The root mealy bug is a pest that is difficult to manage, since it is below the soil and usually undetected until the vines dry up. When the vines start yellowing, drenching with 0.075% chlorpyriphos should be done. It is most essential to drench sufficient spray fluid. Addition of surfactants like teepol or *Sandovit* or soap solution @ 5ml / per litre drastically improves efficiency of control.

For berry attack, the addition of soap/surfactant to the third round of spraying directed against the *pollu* beetle, during September takes care of the mealy bug also.

Vine borers

Diboma procera (Cerambycidae: Coleoptera)

Pterolophia griseovaria (Breuning Cerambycidae: Coleoptera)

P. annulata Chevr. (Cerambycidae: Coleoptera)

These infest the vines and feed on the central core. Thc faecal matter and frass is seen as chewed up tissues inside the dried vincs. The attack is severe during the summer months, but initiated during the post monsoon itself. The grubs pupate inside the vines and come out, making an exit hole on the vines (Ranjith *et al.* 1991).

Field sanitation by systematic collection and destruction of the vines is necessary against the pest. Since the grubs are semi saprophytic, leaving the collected vines in the field without burning them does not cause death of the grubs. Trash burning of the dried vines is thus very important.

Gall midges: *Cecidomyia malabarensis* Felt. (Cecidomyiidae: Diptera)

This is an emerging pest both on the leaves and vines. The leaves are damaged in characteristic pattern initially in spots and later yellowing. The vines show galling. The galling of vines can cause reduction in growth of the vines and also reduction in yield. At present levels of infestation, chemicals directed against other pests could be sufficient against this gall fly also.

Minor pests

There are many minor pests in pepper which are not economically important but are potential pests. But on very scarce occasions they become important, producing a scare and media coverage in mass media. For a complete and more comprehensive review, refer Devasahayam (2000); Devasahayam (2006).

Grasshoppers: Feed on the leaf lamina causing irregular large feeding holes and patches.

Whiteflies: The spiraling whitefly *Aleurodicus dispersus* Russel and the tobacco whitefly *Bemisia tabaci* (Genn.) accumulate in large numbers on the underside of fresh leaves, without causing any appreciable damage.

Bugs: The stink bugs *Cyclopelta siccifolia* westw has been described on pepper (Mathew & Sudheendrakumar 1991), but are usually pests over wintering beneath the vines on the shade trees like *Erythrina* (Ranjith *et al.* 1992), but can interfere in the harvest by causing nuisance.

Root Grubs: *Holotrichia fissa* Brenske and *Leucopholis burmeisteri* Burm. can feed on the rootlets in the nursery and young plants causing yellowing and drying up of plants.

Flea Beetles other than *pollu* beetle: There are many flea beetles, the adults of which feed on the young leaves usually in the dark, that leave small holes on the leaf.

Leaf feeding caterpillars: Caterpillars are rare on pepper, except stray incidence of *Spodoptera litura* F., *Synegia* sp., *Latoia lepida* Cram. and *Cricula trifenestrata* Helf. (Gautam 1980; Fletcher 1914; Ayyar 1940)

Insect pests in the nursery

Root mealy bug: *Planococcus* sp. (Pseudococcidae)

The nymphs and adults of this pest desap from the roots causing yellowing, wilting and drying of the plants. Management is possible by drenching the soil with sufficient quantity of chlorpyriphos 0.075 %, with teepol or soap at 0.05% added to penetrate the waxy layer of the insect.

Leaf gall thrips: *Liothrips karnyi* (Thripidae)

The nymphs and adults of this thrips suck the sap from the margins of the leaves causing crinkling and malformation. The pest is managed by a scheduled spray of dimethoate 0.05 % on the tender leaves. Repetition of the spray may be necessary every 21 days.

Scale Insects: *Lepidosaphes piperis* (Diaspididae)

Attack by the scales cause yellowing and drying of infected leaves and shoots of older cuttings. Here, there is no alternative to chemical control, since drying up of cuttings cannot be allowed. Chlorpyriphos 0.075% or dimethoate 0.05-0.1% depending on the intensity of attack can be sprayed. It is necessary to apply the insecticide along with teepol or sandovit @ 5 ml per litre for easy penetration of the waxy layer of the scales, even when systematic insecticides are used, since many of these has an added contact and/ or stomach action also. For managing *A. destructor,* which is mostly on the leaves, the normal sprays against other pests may be sufficient.

Root knot nematode: *Meloidogyne incognita*

The nematode infested cuttings show stunted growth and foliar yellowing. The roots become swollen and galled. Profuse galling with egg masses can be seen on the roots.

Burrowing nematode: *Radopholus similis*

They cause root necrosis and rot. Roots show characteristic lesions. Use nematode free cuttings, apply two doses of phorate /carbofuran @ one g a.i. / vine, and *Bacillus macerans*@10 g / vine (KAU 2007). Application of nematicides like methyl bromide (fumigation) @ 500 g / ton of nursery soil mixture under polythene cover for 48 hours can check the nematode problem. This has to be carried out 2-3 weeks before planting the cuttings.

IPM in black pepper

IPM in pepper plantation should consider the reproductive period starting from the pre-monsoon showers till the harvest time as the first activity period and the non-reproductive period as the second activity (or inactivity) period in the plantation. A total package for IPM in black pepper would encompass the following

- Collection and removal of dried up plant parts, dead vines and leaves from the plantation. Heap these on the borders and burn during the evenings to destroy the over wintering life stages of the insects. This will considerably reduce the initial populations during the berry season. Trash collection and burning should be completed just before the onset of pre monsoon showers. Since the build up of heavy population follow a geometric progression, low initial loads cause longer periods to attain pest loads due to higher success of natural biological control, extended life cycle for the initial broods and phenological asynchrony of host tissues and pest biology.
- Regulation of shade in the plantation by lopping of branches is to be done just after the pre monsoon showers, but before initiation of flushing in pepper . This increases the temperature in the microclimate, reduces humidity build up and increase sunlight and photosynthesis for the vines rather than the shade trees. Pest build up reduces for pollu beetle and also reduces disease build up.
- Supplementary planting of damaged or weak stands with vines of resistant or tolerant sources.
- Scales and mealy bugs cause heavy devitalisation of the plants, especially in the nursery and during the summer months or non-reproductive phase. Higher temperatures prevalent in Kerala cause loss of vigour for the plants and higher vitality for the pests. Management strategy would involve the last spray against *pollu* beetle or an additional spray in endemic areas to be beefed up by addition of a surfactant like teepol or soap solution for enhancing the effectiveness of the insecticide spray.
- It is not necessary to spray different chemicals against *pollu* beetle and top shoot borer. A single spray during the flushing and spike emergence would normally suppress *pollu* beetle, top shoot

borer and also thrips. Selection of a chemical like dimethoate with higher residual action and lower LD 50 for the first spray increases efficiency of management.

- Quinalphos is another good option since this insecticide has also proven to have fungicidal effect (Bhavani 2004)
- The second spray can be with endosulfan or a synthetic pyrethroid like fenvalerate. Endosulfan may help in lower damage to parasitoids or other natural enemies.
- Cassava, coconut and banana harbour many scales and mealy bugs which also attack pepper, but when these plants are well cared for, the incidence is low. Removal of left over crop residues and trash from such intercrops or companion crops should also be strictly followed.
- The third spray when warranted can be with a neem based product, to reduce the residues in the harvested product.

References

Ayyar T V R 1940 Handbook of Economic Entomology for South India. Government Press, Madras, India.

Babu S 1994 Some aspects of biology of *Longitarsus nigripennis* Mots (Coleoptera: Chrysomelidae), a serious pest on black pepper *Piper nigrum* L. Entomon. 19: 159-161.

Bhavani R 2004 Biological management of *Phytophthora* pod rot of cocoa. M Sc. (Ag.) thesis, College of Horticulture, Kerala Agricultural University, Trichur.

Devasahayam S 1989 Residual toxicity of certain insecticides to leaf gall thrips (*Liothrips karnyi* Bagnall) on black pepper, Entomon. 14: 79-80

Devasahayam S 1990 Field evaluation of insecticides for the control of leaf gall thrips *(Liothrips karnyi* Bagnall) on black pepper. Entomon. 15: 137-138.

Devasahayam S 1992a Management of insect pests of black pepper: problems and prospects. In: Sarma Y R, Devasahayam S & Anadaraj M (Eds.) Black Pepper and Cardamom: Problems and Prospects, Indian Society for Spices, Calicut, pp. 48-50.

Devasahayam S 1992b Bioecology and control of leaf gall thrips *(Liothrips karnyi* Bagnall) infesting black pepper. Final report of Research Project. National Research Centre for Spices, Calicut.

Devashayam S 2000 Insect pests of black pepper In: Ravindran P N (Ed.) Black Pepper (Piper nigrum), CRC press, pp. 309-334.

Devasahayam S 2006 Insect pests of major spices and their management In: Ravindran P N, Nirmal Babu K, Shiva K N & Johny A Kallupurackal (Eds.) Advances in Spices Research: History and Achievements of Spices Research in India Since Independence, Vedam books, Jodhpur.

Fletcher T B (1914) Some South Indian Insects and other Animals of Importance. Government Press, Madras.

Gautam S S S (1980) *Spodoptera litura* Fabr. and *Toxoptera aurantii* (B.de F.) – two new pests of black pepper. Indian J. Ent. 42: 330.

Kerala Agricultural University 2007 Package of Practices Recommendations: crops 13 th edition. Kerala Agricultural University, Thrissur, P 334.

Koya K M A, Devasahayam S, Selvakumaran S & Kallil M 1996 Distribution and damage caused by scale insects and mealy bugs associated with black pepper *(Piper nigrum* Linnaeus) in India J. Ent. Res. 20: 129-136.

Mathew G & Sudheendrakumar V V 1991 Unusual outbreak of a pentatomid bug in Wynad. Evergreen, Newsletter of Kerala Forest Research Institute, Peechi, Kerala, India, No. 27, p 5.

Maulik S 1926 The Fauna of British India Including Ceylon and Burma. Coleoptera: Chrysomelidae (Chrysomelinae and Halticinae). Taylor and Francis, London.

Nair M R G K & Visalakshi A 1999 A monograph on crop pests of Kerala and their control. Kerala Agricultural University, Mannuthy, pp. 93-96.

Nandakumar C, Ragunath P, Visalakshi A & Mohandas N 1987 Management of *pollu* beetle on pepper by adjusting the spray schedules. Abst. Natn. Symp. Integral Pest Control-Progress and Perspectives, Trivandrum, p 50.

Pillai K S 1994 Pests of cassava. In: Chanda K L & Nayar G G (Eds.) Advances in Horticulture Vol. 8 – Tuber Crops. Malhotra Publishing House, New Delhi, pp. 429-456

Premkumar T 1980 Ecology and control of peppr Pollu beetle, *Longitarsus nigripennis* Motschulsky (Chrysomelidae: Coleoptera). Ph.D. thesis, Kerala Agricultural University, Vellayani, Trivandrum.

Premkumar T & Nair M R G K 1984 Seasonal fluctuations of population and habits of adults of *Longitarsus nigripennis* Mots. on black pepper. J. Plantation Crops 13: 138-141.

Ranjith A M, Pillay V S, Sasikumaran S & Mammootty K P 1991 Record of *Pterolophia griseovaria* Breuning as a pest on pepper *(Piper nigrum* L.*)*. Entomon 16: 323-325

Ranjith A M, Mammootty K P, Sasikumaran S & Pillay V S 1992 Biology of *Cyclopelta siccifolia* Westwood (Dinidoridae: Hemiptera) on *Erythrina* standards in pepper gardens. Spice India 5(2): 9-10.

Vivekanandan P, Regupathy A, Habeebullah B, Balasubramaniam M & Irulappan I 1981 Dissipation of insecticides in black pepper applied to control leaf gall thrips *Liothrips karnyi* Bagnall. Indian spices 18(2-4): 25-29.

www.indianspices.com/html/s1930 pac.htm accessed 02-09-08

Erythrina gall wasp *(Quadrastichus erythrinae* Kim) – an emerging threat to *Erythrina* spp. in South India

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Introduction

The Indian coral tree *Erythrina* spp. (Family: Fabaceae) is native to India and Malaysia. There are about 110 species in the genus *Erythrina* which have been introduced to various parts of the world as a shade, ornamental and avenue tree, living fence, wind break and support tree for crops like black pepper, vanilla, betel vine, *etc. Erythrina* spp. are also used as fodder and green manure, and for timber, pulpwood, fibre and dyes. In India, the tree is widely used as a standard for black pepper vines (*Piper nigrum*) and as a shade tree in coffee plantations.

The number of insect pests reported on *Erythrina* spp. in India is less. The tree is attacked by a cermabycid borer, *Remphan* sp. which bores into the basal portion of the stem and roots. The psyllid *Terastia meticulosalis* is an important pest of foliage. The larvae of the citrus fruit sucking moth *Othreis fullonica* also occasionally feed on the leaves. Recently, a new invasive pest, the *Erythrina* gall wasp (EGW), *Quadrastichus erythrinae* (Hymenoptera: Eulophidae) has become a serious threat to *Erythrina* trees in the country.

Distribution

The EGW is reported to attack 24 species of *Erythrina* in many parts of the world. The EGW was first reported damaging *Erythrina* sp. in Taiwan in 2003 and Kim *et al.* (2004) described the wasp as new species. The presence of closely related species in Africa suggests that the EGW might have originated in that region. Wasps of the family Eulophidae are parasitoids on many arthropods with a few phytophagous species. *Q. erythrinae* is the only phytophagous member of the genus. The EGW is now present in Thailand, American Samoa, Guam, Hawaii, Mauritius, Philippines, Reunion, China, Hong Kong, Japan, Taiwan, Singapore and India. In India, the pest was first recorded on *Erythrina* spp. in Thiruvananthapuram District of Kerala (Faizal *et al.* 2006; Isaac & Pillai 2006).

Damage

The female EGW inserts the eggs into tender leaf and stem tissues of the tree. The larvae, which develop within the plant tissue, induce the formation of galls in leaflets and petioles. As the infestation progresses, the leaves curl and appear deformed while the petioles and shoots become swollen, forming many thick-walled globular galls. The larvae pupate within the leaf and stem tissues. Adult wasps emerge after cutting exit holes through the galls to the outside. Heavily galled leaves and stems result in a loss of growth and vigour of the tree. Severe gall wasp infestations may cause defoliation and tree death (Yang *et al.* 2004).

Biology

The adults of EGW are sexually dimorphic. The female is 1.4–1.6 mm long and dark brown with yellow markings. The male is smaller than the female, 1.0–1.2 mm long and pale-white to pale yellow. Studies conducted by the Hawaii Department of Agriculture indicate a life cycle (egg to adult) of about 20 days. A female wasp can carry approximately 320 eggs (Yang *et al.* 2004). The adult female wasp exhibit a preference for depositing the eggs in very young terminal leaves and stems, but not on mature leaves. The larvae are apodous and creamy white. They develop individually in chambers formed inside the meristematic tissue. The adults survive for 2-3 days without food while those provided with honey live for 6-10 days. The sex ratio is about 7 males to 1 female (Heu *et al.* 2006).

Incidence of EGW in India

In India, the EGW was first recorded on *Erythrina* spp. in Thiruvananthapuram District of Kerala (Faizal *et al.* 2006; Isaac & Pillai 2006). Kore (2006) observed symptoms of the pest infestation on *E. indica* in Pune, Satara, Sangli and Kollapur districts in Maharashtra and Belgaum and Dharwad districts in Karnataka. Rajkumar *et al.* (2007) reported severe attack of the pest on black thorned *Erythrina* sp. in Idukki District of Kerala. The incidence of EGW and its extent of damage on *Erythrina* spp. in major black pepper growing districts of Kerala and Karnataka has been studied recently (Jacob & Devasahayam 2008). The surveys were conducted in 4 districts and 13 taluks in Kerala and 1 district and 3 taluks in Karnataka. The total number of locations and farmers fields covered during the survey include 97 and 273 in Kerala and 39 and 63, in Karnataka, respectively.

The EGW was present in all the districts surveyed (Idukki, Kozhikode, Kannur and Wayanad districts in Kerala and Kodagu District in Karnataka) damaging the trees to various levels. *E. stricta* was free from EGW infestation through this species was cultivated to a limited extent. The pest infestation on *E. variegata* (white form) was very serious, and resulted in malformation of almost all the new shoots. Death of trees was also very common and the farmers also opined that the attack was more severe on the white form. Among the districts, highest EGW infestation on trees (59.6%) and branches (41.4%) was recorded in Wayanad District. Kozhikode and Kannur districts recorded the lowest EGW infestation on trees (31.7%) and branches (15.6%), respectively. Among the taluks, the pest incidence on the trees was highest in Virajpet (Kodagu District) (73.8%) and lowest in Vadakara (Kozhikode District) (8.6%). Branch infestation was highest in Mananthavady (Wayanad District) (48.6%) and lowest in Madikeri (Kodagu District) (5.4%).

Management

Pruning the trees failed to control the EGW in Hawaii. After trimming off the infested materials, all the new growth exhibited severe infestation. Trimming or anything that promotes new growth in the tree, like using fertilizers, appeared to intensify the problem. Application of systemic pesticides was tried as a short-term emergency measure in Hawaii. Bark injection of the systemic pesticide imidacloprid had some effect in protecting new growth.

Sustainable control of EGW can probably be achieved by classical biological control and a few parasitic wasps belonging to Encyrtidae, Eupelmidae and Pteromalidae were reared from galled *Erythrina* twigs in Taiwan.

Short-term strategies for the management of EGW in black pepper tracts in India include, application of phorate 10G in the basins of young trees and spraying imidacloprid (0.006%) on tender flushes of older trees. These strategies would be more successful if undertaken on a community basis in a large area. A long-term strategy would be planting other standards such as *Ailanthes malabaricus, Garuga pinnata, Grevillea roubusta, Gliricidia sepium, etc.* for trailing black pepper.

References

Faizal M H, Prathapan K D, Anith K N, Mary C A, Lekha M & Rini C R 2006 *Erythrina* gall wasp *Quadrastichus erythrinae*, yet another invasive pest new to India. Curr. Sci. 90: 1061-1062.

Heu R A, Tsuda D M, Nagamine W T, Yalemar J A & Suh T H 2006 Erythrina gall wasp, *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae). New Pest Advisory No. 05-03, Department of Agriculture, State of Hawaii.

Issac S R & Pillai S 2006 The pepper standards under threat. Spice India 19: 15-17.

Jacob T K & Devasahayam S 2008 Report on the incidence of *Erythrina* gall wasp on *Erythrina* spp. in South India. Indian Institute of Spices Research, Calicut.

Kim I K, Delvare G & La Salle J 2004 A new species of *Quadrastichus* (Hymenoptera: Eulophidae): A gall-inducing pest on *Erythrina* spp. (Fabaceae). J. Hym. Res. 13: 243-249.

Kore B 2006 *Erythrina* gall wasp *Quadraslichus erythrinae*. Curr. Sci. 91: 8.

Rajkumar A J, Sivakumar G & Backiyarani S 2007 *Erythrina* gall wasp - a potential threat to black pepper standards in high ranges of Idukki District. Spice India 20: 4-7.

Yang M M, Tung G S, La Salle J & Wu M L 2004 Outbreak of *Erythrina* gall wasp on *Erythrina* spp. (Fabaceae) in Taiwan. Plant Prot. Bull. 46: 391-396.

Global pepper economy - trends and forecast

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Introduction

Pepper is a smallholder crop in almost all producing countries. An estimated 1.3 million farmers are engaged in the cultivation of pepper in countries like Brazil, India, Indonesia, Malaysia, Sri Lanka and Vietnam. As is typical for any smallholder crop, the pepper growers in these countries have limited options for their survival strategies. Fluctuating prices, limited opportunities to add value, problems of pests and diseases and difficulties in producing pepper of consistent quality are some of the concerns of growers. Buyers on the other hand, are concerned with the quality of the pepper they obtain, in terms of consistency, uniformity and reliability. In addition to physical characteristics, authorities in consuming countries have specific concerns regarding the safety aspects of the pepper imported, including microbial contamination and pesticide residues.

The first half of this decade witnessed a sharp increase in production which was not in tune with the export demand resulting in stock accumulation. This excess supply brought down the prices to yet another trough affecting the pepper growers in the producing countries. However, in the second half, the acceleration in production has been contained, export has been stabilized at a higher level and prices moved upwards much to the relief of the pepper growers. In this context it would be interesting to analyze the pepper economy from the supply as well as demand side.
This paper attempts to analyze:

- Production trends in traditional as well as comparatively new producing countries
- Growth pattern in the export of pepper and its value added products
- Consumption pattern of the major importing countries and the changes in their per capita consumption
- Domestic consumption of the producing countries

World production

World pepper production has increased from 191,690 tones in 1997 to 362,160 tons in 2003, at a growth rate of 11.19% per annum. It is significant to note that production from the traditional producing countries such as Brazil, India, Indonesia, Malaysia and Sri Lanka has increased by only 7.96 % during the period whereas production from Vietnam has increased by 22.63%. Production from other producing countries such as China, Ecuador and Cambodia has increased by 13.30% in the same period.

Thereafter, the production from Malaysia and Sri Lanka has remained stagnant but India's production has declined.from 70,000 tons to 50,000 tons. World pepper production is shown in table 1

Table 1. World production of pepper

Year	Brazil	India	Indonesia	Malaysia	Sri Lanka	Vietnam	Others	Total
1997	18,000	60,000	43,290	18,000	4,470	25,000	22,930	191,690
2000	26,385	58,000	77,500	24,000	10,670	36,000	27,535	260,090
2001	43,000	79,000	59,000	27,000	7,800	56,000	36,395	308,195
2002	45,000	80,000	66,000	24,000	12,600	75,000	38,460	341,060
2003	50,000	65,000	80,000	21,000	12,660	85,000	48,500	362,160
2004	*45000*	*62,000*	*55,000*	*20,000*	*12,820*	*100,000*	*51,659*	*346,479*
2005	35,000	70,000	35,000	19,000	14,000	90,000	31,720	294,770
2006	44,500	55,000	20,000	19,000	14,330	1,00,000	36,400	289,230
2007	35,000	50,000	25,000	20,000	14,640	90,000	36,400	271,040
2008	33,000	50,000	20,500	23,000	14,900	80,000	41,500	262,900

*Preliminary estimates

Note: Under others, China has a share of 15,000 to 35,000 tons, Thailand 9,500 tons, Cambodia 5,000 tons, Ecuador 3500 tons and Madagascar 2,500 tons. .

Fertile basalt soils, gently slopping hills and generally suitable weather conditions encourage pepper cultivation in the Northern Central highlands of Vietnam. Pepper is also cultivated in South East area and Central highlands. High productivity, less cost of production, almost negligible domestic consumptions are the major features of Vietnam pepper industry. The productivity in areas like Northern Central highlands and Phu Quoc Islands are as high as 3.8 tons per hectare. The traditional producing countries, on the other hand, due to limited resources and low prices not succeeded much in either the area expansion or the productivity increase.

White pepper constitutes nearly 20% of the total pepper production. However, in the last few years, significant decline in production has been reported from the island of Bangka in Indonesia, which is the major producer of white pepper. The emergence of Vietnam and China as a major producer of white pepper filled this gap to a certain extent. Total white pepper production in recent years is around 40,000 tons.

World exports

Pepper exports increased from 141,767 tons in 1997 to 194,942 tons in 2003 showing an annual average growth rate of 5.45%. Exports from the traditional pepper producing countries during this period remained almost stagnant whereas exports from Vietnam has shown a growth rate of 17.81%. Large production base, low cost of production and the negligible domestic demand enabled Vietnam to offer pepper at a comparatively low price and absorbed whatever increase in the demand. The emergence of Vietnam as a cheaper source of pepper encouraged low income countries like Syria, Iran, Turkey, Philippines *etc.* to increase their import and per capita consumption. The maximum export of the review period has been recorded in 2006. Early estimate for 2007 is again not very promising. Exports from pepper producing countries are shown in table 2.

Table 2. Export of pepper from the producing countries

Year	Brazil	India	Indonesia	Malaysia	Sri Lanka	Vietnam	Others	Total
1997	13,961	37,816	33,011	24,808	3,279	23,500	5,392	141,767
2000	19,173	22,388	29,682	20,359	4,855	36,465	2,261	135,183
2001	35,799	22,618	23,656	23,095	3,161	56,509	2,144	166,982
2002	37,188	24,225	21,019	19,793	8,225	78,155	8,609	197,214
2003	37,213	19,423	32,867	14,567	8,240	74,035	8,597	194,942
2004	39,394	14,049	29,826	15,655	4,853	98,504	8,734	211,015
2005	32,740	15,800	18,435	13,807	7,981	109,565	5,269	203,597
2006	38,542	26,377	17,045	10,179	8,190	116,670	6,000	223,003
2007	36,000	30,000	16,300	19,000	8,500	83,000	8900	201,700

(Source: Government agencies of the respective countries)

Pepper products

Value added forms like ground pepper, green pepper, pepper oils and oleoresins are also exported by some of the producing countries like India and Malaysia. Pepper based products such as pepper sauces, pepper candy, pepper flavored cheese, pepper cookies, *etc* are also produced and exported by Malaysia and Indonesia. Export performance of these products are given below.

Ground pepper

Among pepper producing countries, India, Malaysia and China are the leading exporters of ground pepper. According to official statistics available from these countries, in 2007 they have exported a total of almost 10,618 tons of ground pepper. Exports of ground pepper by these countries for the last three years are shown in table 4.

Table 4. Exports of ground pepper (tons)

Source	2000	2007
India	1211	7789
Brazil	-	1470
Malaysia	1052	241
China	976	281
Vietnam	312	412
Indonesia	1239	425
Total	4790	10618

This is only a portion of the world trade in ground pepper, as countries such as Germany, Netherlands and Singapore import whole pepper and re-export ground pepper. Germany exports 6500 tons of ground pepper, Netherlands 3200 tons and Singapore around 500 tons. Thus the world import demand for ground pepper may be estimated to be about 21,000 tons.

Green pepper: India, Malaysia and Madagascar are the major sources for green pepper. India exported 1686 tons of green pepper in 2007, while Malaysia exported 573 tons. Even though official statistics are not available, it is understood from trade sources that Madagascar exports around 600 tons to 700 tons of green pepper annually. Thus the demand for green pepper could be in the region of 3000 tons.

Pepper oil and pleoresins: India is the major producer and exporter of pepper oil and oleoresin. In 2007, India exported 1294 tons of pepper oils and oleoresin against 1015 tons exported in the year 2000 recording an annual growth of 6%. Pepper oil constitutes around 7% of the total exports. Sri Lanka exports 1.5 to 2 tons of pepper oil and oleoresin annually.

Other pepper based products: Pepper sauces, pepper cookies, pepper candy, pepper cheese, etc are some of the pepper-based products available from the pepper producing countries. Some of these products are even exported to other countries. However no statistics are available on the quantum of production or export of these items.

Import of pepper by consuming countries

Since pepper has got shelf life, the import of a particular year need not reflect the actual consumption of that country. Therefore, in order to arrive at a more realistic estimate of the consumption, three years average import is considered for analysis. Thus the pepper consumption of a particular country for the year 2000 refers to the average import for the years 1999, 2000 and 2001.

During the last seven-year period, 2000 to 2006, total world imports of pepper increased from 268,826 to 303,184 tons, registering a CAGR of 2.09%. (These import figures include the import by re-exporting countries also). Based on the volume of imports, 46 countries have been identified for a detailed study. Net import by these countries, their per capita consumption and changes in the consumption pattern have been taken into account for the study. The analysis shows that imports to some of them have increased spectacularly during this period whereas some other countries have shown moderate or marginal growth. In few countries, pepper imports have remained almost stagnant causing great concern for the future. A review of the performance of these countries may be important in formulating a strategy to increase the import/consumption of pepper in these countries. Based on the percentage variation in the import volume, these countries are categorized as follows.

- High growth (HG), areas with Compound Annual Growth Rate (CAGR) of more than 10%,
- Medium Growth (MG), areas with CAGR between 5% to 10%,
- Low Growth (LG), areas with CAGR between 2% to 5%,
- Stagnant (SG), areas with CAGR between 0% to 1% and
- Negative Growth (NG) with CAGR less than -1%.

High growth markets

Turkey, Iran, Philippines, Syria, Ireland, Senegal and Gambia are high growth markets and their annual imports have grown by more than 10%. Turkey, the most important among these countries, in terms of growth in imports, per capita consumption and population has increased its imports from 907 tons in 2000 to 3446 tons in 2006. The per capita consumption has also increased from 13 gm to 46 gm during this period. Iran, Philippines and Syria are other major market where both the total imports as well as per capita consumption has increased significantly. These countries with a total population of around 273 million and a population growth of around 2% per annum needs to be treated as high potential markets for the future.

In Ireland, nearly 60% of spices including pepper are consumed by the industrial sector with the retail sector accounting for around 35%. The relatively higher usage by the industrial sector reflects the growing popularity of ready to use spice mixtures. Another reason for the shift towards higher usage by the industrial sector is the increasing consumption of processed foods and ready to eat dishes, which often rely on spices and herbs to retain and enhance food flavor. Import of pepper and per capita consumption of these two countries are given in table 5.

Table 5. High growth in imports and per capita consumption of pepper

Country	Total imports (Net) (t)			Per-capita consumption (g)	
	2000	2006	CAGR	2000	2006
Turkey	907	3446	21%	13	46
Iran Rep.	611	1984	18%	9	28
Philippines	736	2365	18%	10	27
Syria	667	1818	15%	40	91
Ireland	273	557	11%	72	130
Senegal	353	2118	29%	34	171
Gambia	243	646	15%	176	378

Medium growth markets

Morocco, South Africa, Poland, Russia, Romania, Saudi Arabia, Egypt, Belgium, Ukraine and Austria are the countries coming in this group. Imports of pepper into these countries have gone up by 5 to 10 % per annum during the period. The future growth in the demand for pepper mainly depends on these countries which have a population of around 450 million but per capita pepper consumption is comparatively low. Promotional activities need to be focused on these countries to increase the per capita consumption of pepper. Imports and per capita consumption of pepper by the countries under this group is shown in table 6.

Table 6. Medium growth in imports and per capita consumption of pepper

Country	Total imports (Net) (t)			Per-capita consumption (g)	
	2000	2006	CAGR	2000	2006
Morocco	666	1298	10%	23	42
South Africa	1296	2431	9%	29	50
Poland	3235	5671	8%	84	149
Russia	5524	9023	7%	37	63
Romania	1049	1639	7%	47	76
Saudi Arabia	2518	3892	6%	121	157
Austria	1684	2573	6%	208	308
Egypt	4909	7492	6%	74	99
Ukraine	2208	3297	6%	45	71
Belgium	2679	3926	6%	258	375

Marginal growth markets

Pepper imports into USA, Germany, Japan, Spain, U.K., Korea, Australia, Algeria, Greece, Czech, Bulgaria, Norway, *etc.* have shown a marginal growth of 2% to 5% per annum during the period under the study.

Import of pepper to USA has increased from 56,030 tons to 67,126 tons during the period, recording a growth of 3% per annum. Per capita consumption of pepper in the USA has increased from 194 grams to 217 grams between 2000 and 2006. American palates are learning to adapt to a wide range of ethnic foods, including hot dishes that are really hot. Supermarket spice sections are growing almost exponentially, with tins and jars of exotic flavors muscling in among the basic condiments of yesterday. The American Spice Trade Association (ASTA) reports that the most popular herbs are oregano, basil and sage; while the leading spices, in order of volume of sales, were dried mustard, sesame seeds, pepper, cinnamon and the capsicums (chili powder, cayenne pepper, crushed red pepper flakes and paprika). A recent study noted that at least half of U.S. households have a minimum of 26 varieties of spices and herbs on hand.

USA re-exports a small portion of the pepper imported by them and the re-exports during this period have increased from 2500 tons to 5000 tons.

The market study published by the CBI Netherlands in March 2007 shows that the net import of spices and herbs in the EU is growing at 4% per annum which supports the present study. In countries like Germany, UK, Greece, Spain and Czech Republic, the pepper imports grown by 2 to 5%. Germany is the largest market for spices and herbs in the EU, with a share of 26% of total imports. Pepper is the leading spice imported by Germany and in 2006 the total volume of pepper imports was 19,741 tons. Compared to the imports of 14,081 tons imported in 2000, a growth 4% per annum has been achieved by 2006. According to the market of CBI Netherlands, Germany has the highest per capita consumption of spices and herbs among the EU countries, as high as 850 grams per year.

The increasing popularity of dishes from other European countries such as Italy and Spain, its large foreign population and the tendency of the Germans to travel abroad have influenced their preferences for spicy foods. The Germans travel to South and South East Asian countries have created a greater demand for ethnic foods, with a corresponding increase in the use of spices.

Germany is also a significant re-exporter of pepper, normally adding value to the whole pepper imported. In recent years exports of ground pepper from Germany have shown substantial increase. Re-exports from Germany, including ground pepper, have almost tripled, from 2,524 tons to 7,802 tons.

UK is considered to be the second largest market for spices and herbs among member countries of the European Union, with a share of 21%. Import of pepper to UK has shown a growth of 3% and the per capita consumption increased marginally from 92 grams to 107 grams. Spain is another important market for pepper, where imports have increased from 6,783 tons in 2000 to 8,053 tons in 2006, reflecting an annual growth rate of 2%. The per capita consumption in this market has gone up from 169 grams to 182 grams. The per capita consumption of spices and herbs in Spain is reported to be around 300 grams. Growth in foreign tourist arrivals, a growing immigrant population and the diverse ethnic mix offer excellent opportunities for spices and herbs, including pepper. Imports and per capita consumption of pepper by the countries under this group is shown in table 7.

Table 7. Marginal growth in imports and per capita consumption of pepper

Country	Total imports (Net) (t)			Per-capita consumption (g)	
	2000	2006	CAGR	2000	2006
Czech	868	1240	5%	85	122
Germany	14,081	19741	5%	171	239
Australia	2100	2851	4%	110	137
Norway	473	604	4%	105	129
Korea	3278	3990	3%	143	168
U. K	5410	6550	3%	92	107
United States	56030	67126	3%	194	217
Algeria	1615	1921	3%	53	57
Spain	6783	8053	2%	169	182
Bulgaria	615	715	2%	77	94
Greece	1250	1418	2%	114	127
Japan	8028	9103	2%	63	71

In the EU countries, there is a silver lining, which may increase the uses of spices including pepper. One of the recent research study published by Market Research and Consumer Intelligence (Mintel) shows that more people in Britain are becoming conscious of the risks in high intake of salt with the food they eat. The study reports that "increasingly people are turning to black pepper, herbs and spices, instead of salt to add flavor to their food". Hopefully, this trend will help to increase the consumption of pepper, along with other spices, in the UK and other EU markets.

Stagnant markets

Pepper imports into countries such as France, Argentina, Italy, Sweden, Canada, Hungary, Switzerland and Mexico have almost stagnant during this period. These countries together constitute nearly 14% of total world pepper imports and hence these markets need more attention.

The per-capita pepper consumption in Canada, Hungary, Switzerland and Mexico have declined marginally during the period, which is a matter of concern. Per capita consumption of pepper and imports of the countries under this group is given in table 8.

Table 8. Stagnant markets - Imports and per capita consumption of pepper

Country	Total imports (Net) (t)			Per-capita consumption (g)	
	2000	2006	CAGR	2000	2006
France	8496	9297	1%	139	146
Argentina	1347	1453	1%	37	37
Italy	3612	3820	1%	63	65
Sweden	1511	1583	1%	170	174
Canada	5794	5925	0%	189	180
Hungary	1113	1082	0%	109	108
Switzerland	849	825	0%	116	110
Mexico	2992	2904	0%	30	27

Negative growth markets

Denmark has shown a negative growth both in imports and per capita consumption of pepper. Pepper imports into Denmark have come down from 1,444 tons in 2000 to 1,233 tons in 2007 (-2% CAGR). Per capita consumption has also shown a significant decline, *ie*. 271 grams to 227 grams.

The aging population could be one of the major reasons for the decline in the pepper consumption in Denmark. The median age in Denmark is estimated as 40.9 year and this is going to have serious impact in the economy of Denmark. It is reported that their consumption pattern is undergoing a significant change, from spicy food to less spicy food, less coffee *etc.*

Imports by producing countries

Another significant development during the decade is the growth in imports of pepper by some of the producing countries. India is the largest importer in this group, followed by Malaysia and Thailand. India, traditionally a pepper producer and exporter, has become a major pepper importer during this decade. India's pepper imports have gone up from 6,045 tons in 2000 to 16,876 tons in 2007. A major portion of these imports is used for value addition and re-exported as ground pepper or pepper oil and pepper oleoresins. Malaysia has also increased their imports significantly during this period. However, it is notable that China has slowed their Imports since it meets their demand by increasing their production. Import of pepper by producing countries is given in table 9.

Table 9. Imports of pepper by producing countries

Countries	Total pepper imports (t)	
	2000	2007
India	6,045	16,876
Malaysia	2,806	7,175
China	6,387	1,500
Indonesia	707	1,000
Thailand	538	NA

Imports by major re-exporting countries

The role of re-exporters of pepper was found to have declined in the last decade, as most of the importing countries preferred direct dealing with the producing countries. This is evident from the decline in imports by countries such as Singapore, Netherlands, and United Arab Emirates.

From the import statistics of these countries, it can be seen that their import volume has been declining over the years, indicating the preference of the consuming countries to obtain supplies directly from origins. Import of pepper by intermediate countries is shown in table 10.

Table 10. Imports of pepper by re-exporting countries

Country	2000	2003	2007
Singapore	45,491	29,415	12,999
Netherlands	17,517	17,399	14,585
United Arab Emirates	14,268	10,500	10,000

Challenges and opportunities for the future

Price elasticity of demand (PED) measures the responsiveness of the quantity demanded to a change in price, with all others factors held constant. PED for pepper is found to be between 0.28 and 0.36. This implies that the decline in prices will not result in a matching increase in export demand. Thus stabilization of prices at reasonable levels can not be expected to take place unless the demand is increased by extraneous factors such as promotion, innovation, new uses/new users.

In the last few decades, USA and Europe were considered as the major markets for spices and most of the promotional efforts were concentrated in these markets. This has actually increased the import and per capita consumption of spices in these countries. But the recent consumption trend in these countries shows that the growth achieved cannot be sustained for a long time. The comparatively increased per capita consumption, slow down in the population growth, aging of people are the factors likely to affect the future consumption of spices in these region. In contrast to this, Asian and Middle East countries are characterized by the low per capita consumption of spices, growing population and younger generations. Thus the area to be focused for increasing the consumption of spices including pepper has to be shifted to countries like Syria, Jordan, Turkey, China, Indonesia, *etc.*

The average population growth in European countries like Germany, Italy, Spain, Denmark, *etc.* is only 0.12 %. The median age size in these countries are reported as 40 plus. The aging population, as per the reports, is shifting to less spicy foods. In the long run this will have a significant impact on the demand for spices. In this context, what is required is to promote the medicinal and nutraceutical properties of spices which will have a positive bearing on the health conditions of the aged people.

However, the high population growth and the younger generations in the Middle East countries like Syria, Jordan, Saudi Arabia, Kuwait and the Asian countries like Iran, Indonesia, China, Thailand, *etc.* will have a direct positive impact on the spice consumption. Massive promotional programmes to be directed to these countries to increase the consumption of spices in the food sector. In brief, what is required is to formulate twin strategies, promotion of medicinal and nutraceutical values of spices in Europe and USA, promote the uses of spices in foods in Asian and Middle East countries, to increase the overall consumption of spices including pepper.

Domestic consumption

Consumption of pepper in the producing countries has increased significantly over the last few years from around 70,180 tons in 2000 to 116,900 tons in 2007, registering an annual growth of 11% per annum. India's domestic consumption of pepper shows the most dramatic increase during this period, from 35,000 tons to 55,000 tons. Domestic consumption figures from other countries are reported to be as follows: Brazil- 6000 tons, Indonesia- 7,000 tons, Malaysia- 3500 tons, Sri Lanka- 6400 tons, Vietnam- 3500 tons, China -23,000 tons, Thailand- 9,000 tons and Madagascar- 1,500 tons. Domestic consumption of pepper as a percentage of production is shown in table11.

Table11. Domestic consumption of pepper as percentage of production

Country	1999	2007
Brazil	18.20%	17.14%
India	40.00%	98.39%
Indonesia	28.20%	28.00%
Malaysia	5.60%	17.50%
Sri Lanka	16.90%	43.72%
Vietnam	5.00%	3.89%

Price situation

A price cycle has been observed in pepper, with ups and downs in a period of 10 to 12 years. As in the case of other agricultural commodities, the attractive prices in a few years motivate the pepper farmers to augment their pepper cultivation both intensively and extensively. The new pepper plants reach the optimum production stage in 7 to 8 years. Then there will be an increased production and accumulation of stocks in the next few years. This pushes down the prices to lower levels. The low prices then detract the farmers attention from pepper gardens and it result in decline in production and the resultant price rise. Substantial increase in the price will also result in the emergence of new producers of pepper. Vietnam is an example to this.

The excess supply over demand brought down the prices from around US $ 1.12/lb in 1977 to US $ 0.73/lb in 1983. The year 1987 witnessed the peak of US $ 2.36/lb. Again the prices have come down to US $ 0.56/lb in 1992 to reach the peak of US $ 2.54/lb in 1999. The year 2005 saw the next bottom line of US $ 0.74/lb. There after the upward trend in prices started and the latest price reported is US $ 1.86/lb in the month of September 2008. The monthly prices of black pepper at New York market is given in table 12.

'able 12. Monthly average prices of black pepper at New York market

1onth	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
ιpril	2.58	2.50	2.62	1.50	1.00	0.85	0.76	0.75	0.78	1.78	1.90
1ay	2.64	2.40	2.63	1.45	1.04	0.83	0.76	0.76	0.80	1.95	1.86
une	2.57	2.50	2.62	1.17	0.93	0.86	0.77	0.77	0.80	1.92	1.78
uly	2.47	2.27	2.60	1.02	0.86	0.90	0.77	0.77	0.90	1.93	1.75
ιugust	2.52	2.47	2.52	0.89	0.88	0.86	0.75	0.77	1.12	1.87	1.72
eptember	2.47	2.60	2.03	0.89	0.88	0.87	0.75	0.78	1.52	1.77	1.63
)ctober	2.47	2.74	1.78	0.88	1.02	0.82	0.74	0.78	1.52	1.78	
1ovember	2.38	3.00	1.47	0.81	1.04	0.80	0.73	0.77	1.40	1.76	
)ecember	2.25	2.67	1.42	0.84	1.02	0.79	0.73	0.78	1.35	1.72	
anuary	2.29	2.60	1.57	0.85	0.94	0.78	0.73	0.78	1.33	1.76	
'ebruary	2.22	2.57	1.46	0.80	0.90	0.77	0.73	0.78	1.36	1.86	
1arch	2.46	2.46	1.42	0.80	0.89	0.76	0.74	0.78	1.37	1.92	
ιverage	2.44	2.57	2.01	0.99	0.95	0.82	0.75	0.77	1.19	1.84	1.77

Conclusion

At present the global pepper production is in the region of 2,70,000 tons, of which more than 70%, *i.e.*, 200,000 tons is being exported to consuming countries, with the balance retained for domestic consumption /stock by producing countries. World import demand is estimated at 200,000 tons including re-exports. In other words, at current price levels, the market in consuming countries is absorbing around 200,000 tons of pepper. With domestic consumption between 116,000 to 120,000 tons, total demand is estimated at 316,000 to 320,000 tons. Built up stock, estimated at around 60,000 tons is keeping prices at this level. Hence any significant drop in supply (production) from this level will lead to liquidation of stocks and in turn, boost the prices to new heights.

From the demand side, even though total pepper imports have grown by 2.09% per annum during the last 7 year period, there is still potential to increase the growth rate. By focusing countries with low per capita consumption and high population growth, overall pepper consumption can be increased.

Promotional activities need to be undertaken in countries such as Argentina, Italy, Sweden, Canada, Hungary, Switzerland, Mexico and Denmark, where the per capita consumption is low or remains stagnant over the last few years. Countries with large populations, such as Turkey, Iran, Philippines, Russia, Pakistan, Morocco, and Mexico also require more attention to increase pepper consumption.

Taking advantage of the current price scenario, the possibility of intensive pepper cultivation by countries like Vietnam, China and Cambodia can't be ruled out. Once this happens, the outcome will be yet another excess supply and low price. Hence what is urgently required is a focused and concerted promotional efforts directed towards specific markets to improve the consumption and stabilize prices received by farmers.

Technologies transferred for augmenting black pepper yield - a success story

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Introduction

Among the spices, black pepper (*Piper nigrum* L.) occupies unique position and hence called the king of spices. Presently it is grown in about 26 countries and occupies 4,67,708 ha with productivity of 790.2 kg/ha (Parthasarathy *et al.* 2008). India with more than 40% share of area contributes about 23% of the total production of the world. As it is mainly grown as mixed crop, the productivity of black pepper in India is around 310 kg/ha. Its cultivation is mainly confined to Kerala, Karnataka and Tamil Nadu. It is also cultivated to a small extent in Andaman and Nicobar Islands, West Bengal, Andhra Pradesh, Goa, North Eastern States, Orissa and Pondichery.

Black pepper in Karnataka

In Karnataka, pepper is grown as a profitable intercrop in almost all the coffee plantations (2,04,482 ha) and in most of the arecanut plantations of Malnad region (1,10,199 ha). The cost benefit ratio of 1:301 and 1:2.29 is reported respectively, in Arabica + pepper and Robusta + pepper mixed crop system (Raghuramulu 2007). The variety grown is predominantly Panniyur-1. Other local varieties like Kalluvalli, Mallisara, Karimallisara, Urutugere, Doddiga, Karimunda, Uddagere, Vadakkan *etc.* are grown in different regions mainly as mixed crop in arecanut plantations. Since, it is grown as mixed crop, it is a general practice of the farmers to under-report/non-report area coverage and production with the intention of avoiding taxes. Because of this, the actual production of black pepper in Karnataka is not reflected in the official estimates released by the Directorate of Economics and Statistics, New Delhi. Tamil Selvan *et al.* (2005) in their report on crop estimates of black pepper for Karnataka reported 30816 and 24742 MT of black pepper respectively for 2004-05 and 2005-06 crop seasons. This report was based on survey of six districts in Karnataka (Kodagu, Hassan, Chikmagalur, North Kanara, Shimoga and South Kanara). In Karnataka, about 75-80 per cent of the black pepper area is covered by the high yielding variety Panniyur-1 and hence the productivity is also high compared to Kerala. Major area is under coffee based mixed crop. The elite coffee growers are adopting recommended package of practices on a large scale. Most of them are fertilizing coffee regularly, in the process pepper vines are also fertilized. Though separate irrigation is not given to pepper vines, blossom and backing irrigation given to robusta coffee also benefit black pepper to some extent. It is also seen that small per centage of farmers are irrigating the pepper vines also. All the Arabica + black pepper mixed crop is rainfed and level of shade is also very high.

Location specific production problems of coffee based mixed crop of black pepper

Based on survey and feed back by the growers the following are identified as the major productions constraints of coffee-black pepper mixed crop of different zones.

Location	Major problems
High rainfall, misty, high elevations	Spike shedding, anthracnose, foot rot (more foliar infection and secondary spread)
High rainfall Robusta coffee + black pepper	Foot rot of pepper
High rainfall, Arabica coffee + black pepper	Foot rot, partial setting and spike shedding
Moderate rainfall, Robusta coffee + black pepper	Foot rot, partial setting, slipping of vines from standard due to termite attack, root mealy bugs and scales
Low rainfall Arabica coffee + black pepper and Robusta coffee + black pepper	Partial setting, moisture stress, yellowing, slipping of vines from standard due to termite attack , foot rot, root mealy bugs and scales

Process of technology transfer

Motivation: On farm trials undertaken by the IISR with close interaction of progressive growers and leads are serving as eye openers for growers and failure as lesson to refine production technologies. Diversification plots established by the Coffee Board research stations have added strength to motivate large number of growers on viable cropping system of coffee and black pepper mixed crop. Voluntarily many progressive coffee growers have adopted integrated practices exclusively for black pepper. These plots are also serving as model to plan location specific production strategies. IISR with active co-operation of many self help groups (Nalkanad Planter Association, Boikeri Self Help Group, women self help groups of Hakathur, Maragod *etc.*). Many progressive growers in Kodagu, Hassan and Chikmagulur conducted many on farm trials like impact of bio control measures in management of foot rot, management of spike shedding and anthracnose diseases, impact of irrigation on pepper production and impact of location specific strategies on black pepper production. The success achieved in the above on-farm studies were passed on to the growers through seminars organized by Coffee Board, Spices Board and Krishi Vignana Kendras (Gonikoppal, Mudigere and Shimoga), Department of Horticulture, Govt of Karnataka and Department of Agriculture, Govt of Karnataka. Besides, above production technologies were demonstrated to corporate sector (TATA Coffee, Pollibetta; BBTC, Siddapur; BCK Thithimathi) Codagu Planters Association and Karnataka Planters Association through special interactive group discussion and on farm visits.

Based on request special training programmes/seminars were arranged to explain the success stories to Codagu Planter Association, TATA Coffee Ltd, Pollibetta and Dharmasthala Rural Development Trust, Dharmasthala and Sullia.

Technology transfer process was based on twelve major principles which are follows

- Planting and maintenance of minimum 225-575 plants per ha
- Raising multiple leader stems
- Planting minimum 3-4 varieties in Arabica + black pepper mixed crop
- Common minimum plant basin and nutrition management methods like slash weeding, de mulching during monsoon, earthing up during May and October, yearly liming/dolomite application, recycling available agro waste and compost application, opening and cleaning of drains to prevent water stagnation
- Nutrition management as per yield levels of different age groups
- Shade regulation during March –April
- Life saving irrigation during March-April
- Basin irrigation in the years of delayed monsoon
- Mandatory spraying of 2-3 rounds of 1% Bordeaux mixture and spot application (drenching 3-5 litre per plant) of 0.2% copper oxy chloride
- Root mealy bug, termite and scales management measures in moderate and low rainfall zones
- Harvesting after 10-15% ripening
- White pepper production only with fully matured, ripened and graded berries

In technology transfer process the production package was implemented on calendar basis which is follows

Month	Agro-practices
April	Shade regulation of support trees, in the absence of premoon showers basin irrigation at 7-10 days intervals, first irrigation @ 80-100 litres per plant and subsequent irrigations @ 50 litres per plant
May	Earthing up, liming and removal of dead vines
June	Training of vines, application of compost and bio control agents, neem oil cake-0.5 to 1 kg/vine, opening/cleaning of drains, spraying with 1% Bordeaux mixture, spot application of 0.2% copper oxy chloride and gap filling with runners/rooted cuttings
July	Spraying of 1% Bordeaux mixture and drenching with 0.2% copper oxy chloride in moderate and low rainfall zones
September	Application of compost, spraying second round of 1% Bordeaux mixture, application of bio control agents, phyto sanitation
October	Earthing up
March / April	Harvesting after noticing 10-15 % ripened spikes

Research leads from on-farm trials

Production potentiality of pepper vines under coffee mix crop system

Silver oak and *Erythrina* are the preferred standards for raising pepper crop and these trees also provide necessary partial shade to coffee. To understand the crop potentiality of black pepper on these standards five estates representing different rainfall zones were selected and trees were grouped as per the canopy height of pepper vines and individual green and dry yield was collected (table 1).

Table 1. Yield levels under integrated production system

Location	Height of canopy (meters)	Dry yield per vine (kg)
Dwaraka estate, Hakathur	< 4	2.8
	4-6	4.3
	>8	12.3
Whoshully division, Pollibetta, TATA Coffee	< 4	3.3
	4-6	7.3
	>8	11.8
Sri laxmi estate, Kandana Colly	< 4	2.6
	4-6	4.8
	>8	13.9
Guntikutty estate, Suntikoppa	< 4	3.0
	4-6	6.6
	>8	10.5
Ashoka Plantations, Boikeri	< 4	1.8
	4-6	7.8
	>8	8.3

The yield obtained varied from 1.8 to 13.9 kg dry berries per vine and yield increase was proportional to the height of canopy. This study helped to target yield with integrated system of management.

Success stories

Devi Poonacha estate, Napoklu

This estate is of 17 ha with Robusta coffee + black pepper and is situated on the bank of Cauvery river, receives rainfall of 3000-3500 mm/year. The planter approached the Cardamom Research Centre, IISR, Appangala for remedial measures to contain foot rot during 1998. Survey revealed 13% mortality, 5% yellowing and 23% leaf infection by *Phytophthora*. As the foliar infection was on higher side, a combination of metalaxyl spray and drenching along with 0.2% copper oxy chloride was recommended.

This was followed by spraying and drenching with prophylactic fungicides (1% Bordeaux mixture and drenching with 0.2% copper oxy chloride). Over a period of 9 years, by following integrated nutrient management and integrated disease management schedule the entire estate is rejuvenated and incidence of foot rot is less than 2% and production level is maintained at 8.5 tonnes to 10 tonnes.

Kalarical estate, Nelliahudikeri, Siddapur

In this estate, 40 ha area is with Robusta coffee + black pepper, Arabica coffee + black pepper and cardamom + black pepper (4ha) and is situated in moderate rainfall area (2000-2100 mm). Black pepper experienced high mortality of foot rot (53%) and sparse setting. This estate was rejuvenated completely over a period of 8 years by following integrated nutrient management and disease management schedule. The production level has also been consistent (8-14 MT) in the last 5 years. During 2005-06, foliar infection of *Phytophthora* foot rot reappeared due to prevalence of disease in adjacent plantations. This problem was controlled in course of 1-2 years and at present mortality is less than 1%. The success obtained in this estate has given greater confidence to rejuvenate foot rot affected plantations in course of 5-7 years.

Ashoka Plantation Pvt. Ltd., Boikeri

Both mono and mixed crop black pepper with coffee are maintained in 63 ha. in this plantation. The Panniyur-1 variety in this estate constantly experienced anthracnose and spike shedding (87%) for more than four successive years. Based on the lessons of some progressive growers of Saklespur (Diwan Gudda estate, Mahesh Kumar estate) and leads obtained through on farm trials conducted in Boikeri zone, a schedule comprising of shade regulation in April, irrigation in March 4th week and prophylactic measures with first spray of 0.2% carbendazim followed by two rounds of 1% Bordeaux mixture were given on strict calendar basis. This was supplemented with adequate nutrition and other basin management methods. There was miraculous improvement in the setting, yield and both spike shedding and anthracnose infection were effectively checked. After the analysis of the situation of whole area, the success were mainly attributed to timely shade regulation and basin irrigation. The cause of spike shedding in the earlier years was due to non pollination and low proportion of bisexual flowers in spikes which emerged after July. The yield levels improved from 2.8 MT to 14.7 MT.

On farm trials on impact of irrigation on spike shedding

Growers participatory trials were conducted in different zones (Sri laxmi estate; Paka estate; Boikeri estate; Sandalkad estate; Fair field estate, Hosakeri; Kalarical estate, Siddapur SLN Plantations, Chettalli; Cowribetta estate, Siddapur; Devi Poonacha estate, Makkandur; Green vally estate, Hebbettageri). The schedule shade regulation, 4-5 round of basin irrigation, 2-3 rounds of 1% Bordauex mixture spray, one round of compost application, recommended fertilizer application, in two splits, liming / dolomite application once in two years, need based micronutrient application were followed in all the estates. The foliar infection of *Phytophthora* was contained by timely spraying of 0.1% metalaxyl + macozeb. The loose setting, spike shedding, anthracnose infection and mortality and yellowing due to foot rot infection were effectively checked in all the plantations. The estates which never yielded in earlier years were were brought to productive level by timely operations listed above. These trials gave leads of transforming unproductive and anthracnose infected pepper vines to productive vines.

Murugarajendra estate, Madapur

This estate comprises 18 ha with Arabica and Robusta coffee and black pepper as mixed crop with coffee at 4.25 m x 4.25 m spacing. In the year 2004-05, severe foot rot incidence was noticed in Madapur zone which ultimately destroyed most of the pepper vines. During the initial stages of the infection, the planter approached our centre for suggestion to contain foot rot. As the planter is knowledgeable and committed, the whole refined production technology was implemented through his active co-operation from 2005 onwards. As a result the foot rot which appeared in five independent spots was effectively checked and anthracnose incidence was also reduced to manageable level. After experiencing the benefits of irrigation in 2007 in small area, planter extended irrigation to 10 ha area in ensuing crop season. Production of 22-25 tonnes is expected in the present crop season because of early pre monsoon showers, five rounds of basin irrigation and integrated nutrient and disease management measures. This is the model plot which can enthuse coffee growers to take up profitable cultivation of black pepper as mixed crop. This estate became pilgrimage centre for interested planter and till date over 500 growers have already visited to see the impact of improved production technologies.

Large scale transfer of technology in plantations

IISR, Cardamom Research Centre, Appangala offers technical help and consultancy support to interested growers based on their request. Several group companies and individual planters availed advisory service and implemented package. The service was limited to only technical help, formulation of location specific strategies and monitoring during crucial months. Total area covered under advisory service is presented in table 2. The sequence of technology transfer process implemented in large and small plantations are as follows.

Large plantations / corporate group

Short listing of location specific problem

↓

Identification of core group with skilled field staff- Explaining the importance of all mandatory need based management methods.

↓

Preparing inventory of crop census in different plantations/blocks

↓

Formulation of location specific management/rejuvenation strategy

↓

Implementation package on strict calendar basis

↓

Monitoring through Spot field visit, replanting process, nutrition methods, plant protection methods

↓

Reminding crucial operations through telephonic conservation/random field visit

↓

Appraisal of success obtained in previous years and identifying gaps/shortcomings

↓

Preparing fresh inventory of crop census in different plantations/blocks and refinement of management strategy for the proceeding year.

Medium and small holdings

Preparing inventory of crop census in different blocks

↓

Short listing production problems of different blocks

↓

Formulation of integrated management strategy

↓

Direct monitoring through field visits during crucial months (April-Oct)

↓

Implementation package on strict calendar basis

↓

Monitoring different operations like shade regulation, irrigation, replanting process, nutrition and plant protection methods.

↓

Appraisal of success obtained in previous years and identifying gaps/shortcomings

↓

Preparing fresh inventory of crop census in different plantations/blocks and refinement of management strategy for proceeding year.

Table 2. Area and production of black pepper under technology transfer of IISR Calicut

Category	No of plantations	Area (ha)	Production range (MT)	Foot rot incidence (%)	
				Initial	After adoption
Corporate sector	25	9202	970-1448	13-32	2-6.3
Dwaraka estate (integrated bio control system)	1	65	8-14	23	5.6
Large holdings (>20 ha)	8	518	120-158.5	8-52	3.0
Medium holding (<20 ha)	3	67	24-32	1-17	2.0
Small holding (<10 ha)	5	21	27.72-38.3	1-12	1.2
Total	42	9873	1149.7-1688.8		

Intensive foot rot disease management strategies

Foot rot management is the point of concern to the majority of the planters. The general recommendations are not adequate to prevent the introduction, secondary spread and rejuvenation of plantations. With in the affected plantations the fresh crop census and mortality was collected. Areas were grouped to different categories based on disease intensity and specific intensive management strategies were formulated which are as follows.

Prioritization of foot rot management measures

Location	Priority	Important agro practices
Uninfected area	Preventing introduction of disease	Moderate shade regulation to maintain staggered umbrella canopy of shade trees, prophylactic foliar spray during early and mid monsoon period, integrated basin management measures.
Infected area with less than 5 % mortality	Preventing rapid secondary spread of disease	Gap filling after 1-2 years of phyto- sanitation, avoidance of excess shade regulation, spot drenching with 0.2% COC 2-3 rounds spraying with 1% Bordeaux mixture, spot application of metalaxyl to check secondary spread of foliar infection.
Infected area with wide spread incidence of foot rot and yellowing	Protecting healthy vines with in infected area. Prevention of secondary spread	Avoidance of excess shade regulation, two rounds drenching of all the vines with 0.2% COC, 2-3 rounds spraying with 1% Bordeaux mixture, spot application of metalaxyl to check secondary spread of foliar infection.
Heavily infected area with more than 50% death of vines	Protecting healthy vines with in infected area. Prevention of secondary spread. Suppression of soil born spread. Rejuvenation	Avoidance of excess shade regulation, replanting with 8-10 runners/ rooted cuttings per standard after 1-2 years in infected spot,two round drenching of all the vines with 0.2% COC, 2-3 rounds spraying with 1% Bordeaux mixture, spot application of metalaxyl to check secondary spread of foliar infection.

Rejuvenation of foot rot affected blocks, progressive reduction of diseases, improvement of canopy architecture, sustenance of productivity and production achieved in misty hilly region are the major lessons obtained through large scale extension programmes. Two decades back many grower friends out of frustration used to tell that pepper will disappear from Kodagu in next 10 years time. Through adoption of improved production packages same estates are rejuvenated, production has increased and foot rot incidence has come down to less than 2 per cent. Another important lesson obtained in above implementation programme is strategies works only with sustained concentrated efforts and any lapse during heavy monsoon period can revert the most productive plantation to distress within three months time.

Conclusion

Disseminating the technology across coffee and arecanut growers is need of the hour and if the transfer of technology is implemented effectively in all suitable coffee and areca based black pepper mix cropped area, the countries production and productivity can be double in next 6-8 years time. KVK's under UAS, ICAR, Spices Board, Coffee Board and Department of Horticulture, Government of Karnataka has to work cohesively to achieve to higher goals in black pepper production.

Increased prices in 2006 – 2007 and 2007 – 2008, itself is an incentive to growers to focus on black pepper. Most of the growers are practicing nutrition and disease management methods. However, paucity of skilled workers due to overlapping of robusta coffee harvesting and pepper harvesting they are loosing 10 – 20 % of the crop mainly due to delayed harvest. Delayed harvests also affects the crop of proceeding season. By correcting this crucial agro-practice, growers can aim at 15 – 20 % more yield.

Crop damage due to rapid spread of foot rot during heavy monsoon period of 2006 and 2007 season was reported from several areas like Pollibetta, Ammathi, Hakathur, Kakkabe, Shanivarasanthe and Kodlipet in Kodagu District and several pockets in Chickmagalur and Hassan districts. After experiencing heavy casualty, planters are paying attention to prophylactic and estate rejuvenation methods. Timely adoption of prophylactic measures is the only answer to prevent further damage. IISR in close co-operation with Spices Board, Coffee Board, State Horticulture Department and Planter's Association is offering technical guidance to improve knowledge and adoption level of improved technologies. Through adoption of specific technologies for spike shedding, anthracnose management even the chronic production problems of black pepper grown in misty high elevation and highly shaded arabica plantations can be resolved.

Only small section of growers has realized the advantages of irrigation in sustainable production of pepper. Strengthening the irrigation infrastructure and crop management practices is the only answer to solve production problems in rainfed areas.

Adoption level of minimum plant protection practices is on the increased level with over 92 % of the growers taking up spraying with 1 % Bordeaux mixture. However, minor adjustments in scheduling of spraying are to be taken up on need based manner.

Though Panniyur- 1 is the best yielder under integrated system, area under other released selections like Panniyur – 4, Panniyur – 5, Panniyur – 6, Panniyur – 7, IISR Girimunda, IISR Thevam, IISR Malabar Excel and traditional high yielders like Karimunda, Chomala, Neelamundi and Kalluvalli are to be increased in the rainfed areas which are prone to anthracnose infection and spike shedding. Planting material production units in low and moderate rainfall zones are to be strengthened to cater the paucity of healthy material requirement of other varieties.

References

Anonymous 2005 Coffee Guide. Coffee Board Research Department, Coffee Board, India, p.130 - 131

Horticultural Crop Statistics of Karnataka State at a Glance 2002 – 2003 Directorate of Horticulture, Lalbagh, Bangalore - 560 004

Raghuramulu Y 2007 Impact of diversification initiatives in Indian coffee. Indian Coffee LXXI (1) : 22 - 29.

Reddy D R B, Raghuramulu Y & Naidu R 2004 Impact of diversification in Indian coffee plantations - A sustainable approach. In: Proceedings of 20th International Conference on Coffee Science (ASIC). 2004, Bangalore, India, pp. 1129 – 1135.

Sainamole Kurien P, Backiyarani S, Joseph Rajkumar A & Murugan M 2002 Varietal evaluation of black pepper (*Piper nigrum* L.) for yield, quality and anthracnose disease resistance in Idukki district Kerala. J. Spices and Aromatic Crops 11: 122 – 124.

Parthasarathy V A, Bhat A I, Kandiannan K & Zachariah T J 2008 Black pepper. In: Spices: vol I Parthasarathy V A, Bhat A I & Utpala Parthasarathy (Eds.). Today and Tomorrow's Printers and Publications, India, pp. 19 - 140.

Tamilselvan M, Premaja P & Manojkumar K 2005 Pepper production prospects during 2005 – 06. Indian J. Arecanut, Spices and Medicinal Plants 7(4): 149 – 155.

Traditional knowledge and farmer innovations in black pepper cultivation

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Introduction

Black pepper, the king of spices that changed world history, originated in the West coast of India. Initially it might have been collected from the wild but demand prompted the local people to seek strategies to cultivate the spice and several practices and associated wisdom evolved over the centuries. It is interesting to delve into this store house of knowledge and is worth pursuing even today. These practices were more closer to nature in a sustainable manner. Till recently, these innovations of farmers were not recognized or rewarded properly. Nowadays, such information is brought to the lime light for the benefit of public through NGO's and specifically the National Innovation Foundation, Ahmedabad. Very recently, the Krishi Vigyan Kendra, Kannur, Kerala under the Kerala Agricultural University organised a Farmer's Science Congress in February, 2008 in which several innovations were highlighted not only in pepper but also in other crops.

Sir Francis Buchanan in his travelogue "A journey from Madras through the countries of Mysore, Canara and Malabar" written in 19th century gives an impressive narration of pepper cultivation in South India. In this paper it is envisaged to highlight the traditional practices in vogue and the innovations of farmers that if validated can help us to retain our prominent global position in black pepper.

Varietal innovations

About 100 cultivars are reported to exist in South India. These were selected by farmers with their keen observations in various traits over the centuries. Among them 'Karimunda' is the best and is considered the ideotype in black pepper, always preferred by farmers. Cultivars with known traits such as drought tolerance (Kalluvally); less proneness to foot rot (Narayakodi, Thevanmundi, Neelamundi); big berries (Vadakkan); spiral nature of spike (Aimpiriyan); length of spike (Kuthiravally) *etc.* are popular. Nevertheless, farmer's innovations in varietal improvement are still going on and a brief account of these recent varieties are given as follows.

Kumbakkal: Originated as a clonal material from 'Karimunda' types as an escape from 200 vines planted by Mr. K.T. Varghese, (Kumbhakkal house, Murinjapuzha, P.O., Cheruvallikulam, Idukki district). After observing it for 12 years without any disease incidence and high yield of good quality berries, other farmers started using it. The study at Cardamom Research Station, Pampadumpara has indicated it as resistant to *Phytophthora* foot rot (personal communication). The Spices Board has also approved it and is spreading. The characters of the vine as compared to Karimunda are as follows

Table1. Characters of Kumbhakkal variety

Character	Kumbhakkal	Karimunda
Yield	4 to 6 kg/vine (dry)	2 kg/vine (dry)
No. of spikes/lateral	6	4
No. of berries/spike	100-120	70-90
Drought tolerance	Tolerant	Susceptible
Foot rot tolerance	Resistant	Susceptible
Quality	*Good; high oil*	Good
Driage	35%	33%

Sion Mundi: A shade tolerant and foot rot resistant type developed by Mr. P.G. George (Puliyanmmakkal, Pattayakudi, Venmani P.O., Idukki-685 606). This variety is capable of yielding good crops even in a shade of >50% and is able to resist the onslaught of *Phytophthora* foot rot. Berries are big, borne on long spikes. The vine bears regularly and early (December to January). It was selected from seedling progenies of two varieties 'Thottamundi' (seen in the forests and cultivated by Adivasis and is resistant to foot rot) and Neelamundi. Out of these one plant gave 3.5 kg of berries after 4 years and it was named 'Sion Mundi'. It is growing very successfully under shade of other trees as intercrop. It also performs well in the open condition with normal shade.

Pepper Thekkan: This was developed by Mr. T T Thomas (Thekkel house, Kanchiyar P.O., Idukki-685 511) near Kattappana. He stumbled upon this variety while cutting the forests for new plantings. He was awed by the extra ordinary growth and the large number of berries in each spike and preserved it. When it was planted in a new area with plenty of sunlight, the yield was four times higher and did not succumb to foot rot even when other popular varieties all died. He named it after his house name Thekkan. Its features are

Productivity	:	4000 kg/ha
Driage	:	1 kg dry pepper for 2.5 kg green pepper.
Disease tolerance	:	Tolerant to foot rot and nematodes
Yield	:	High in the open. Not shade tolerant
Spike characters	:	Through out the plant. Spikes are borne in clusters and each cluster with 800-1000 berries.

Pepper Zero: This claim is from Idukki (Dist.) and is used for grafting pepper for drought tolerance as a root stock. It resembles a North Indian type.

Mammachan Pepper: This claim comes from Mr. Mammachan (Thekkekaithakkal, Kollawadi, Kottayam District). The type has very god set and yield with very long spikes. It is reported to be a cross between Panniyur-1 and a local cultivar.

Kadukummakkal: This is claimed to have been developed by Sri. Abraham Mathew (Kadukummakkal, Kallanode P.O., Kakkayam, Calicut) from a cross between Aimpiriyan, a late bearing variety (April) and an early (January) bearing local type. Seeds were collected from Aimpiriyan and seedlings were raised. The most vigourous ones were planted and out of these one was outstanding. It is high yielding, regular, not easily infected by diseases and matured in January. It forms plenty of laterals and gives 3 kg dry yield/vine. The spikes are of about 13 cm long with close setting of berries with dark olive green colour. Litre weight of Aimpiriyan is 560 g and of local type is 600 g, whereas this seedling has 640 g. Probably it may be a good seedling of Aimpiriyan.

Two varieties from Wynad: Wynad also has two varieties developed by Mr. A. Balakrishnan (Ambili Nilayam, Kamana P.O., Mannanthavady, Wynad-670 645) claimed to be the progeny of the cross Uthirankotta x Cheruvally and Karimunda x Cheruvally. The first has spikes 6 -15 cm with good yield. The second has spikes of 15 cm length with blackish berries and good yield.

Planting material

Traditionally runner vines at the base of each plant are coiled and kept above ground level with wooden pegs to avoid rooting during summer. At planting time cuttings are prepared with 7 or 8 nodes, defoliated and 4 to 6 cuttings are planted per standard depending on its girth. Farmers were using 15-20 cm long cuttings as per Sir Francis Buchanan's observation.

Another method is to allow the runner to trail on the ground with nodes at intervals of 4 or 5 kept over coconut husk with an equal mixture of FYM:soil:sand making them root after covering with husk. After rooting, the vines are cut at 3rd or 4th node and planted with the husk. A modification of this is to fill a big bag with potting mixture and put one node in the mixture at intervals to allow rooting. If a *Gliricidia* cutting can be planted in this bag it also will root and provide support to the rooted cutting at the time of separation and direct panting of standard with vine is possible.

Some traditional wisdoms are

- Seedlings survive longer in the field
- Use cuttings only from the middle of the coiled runner vines from 15 year old mother vines.
- Use 2 feet cuttings of pepper for *Erythrina* and 4 feet long ones fro planting on coconut.

- Collect runners within 60 cm of main stem from the base of mother vines.
- Apply a paste of coconut shell charcoal at the base of cuttings, shade dry for 3 weeks, allow to grow on coconut husk for quick rooting.
- Plants from top shoots are short lived.
- Nilakodi (pepper plants naturally growing wild): The seeds excreted by the birds germinate. The local vaidyas uproot them and used it for medical purposes as these were believed to have more medicinal value. Such seedlings were also considered superior.
- Paste dung of she buffalo on the Western side wall of the house thickly and keep seeds of pepper for 7 days in it and expose to evening sun. Seedlings from these seeds show high germination, disease resistance and yield.

Planting

Available traditional knowledge on planting are

- Plant robust cuttings 4 to 5 per standard and bury two nodes into the soil.
- Plant one top shoot and 2 runner shoots per standard. Top shoots will give crops in 2nd year and others from 3 year onwards.
- Allow runner shoots to trail on ground and allow to limb support trees to survive drought and wilt. After 2 or 3 years severe the runner from the parent vine.
- Plant pepper on North East side of support. Yield is also better due to good exposure. Roots of pepper grow towards north and vine towards south (standard) and thereby reduce root competition.
- If more than one variety is gown yield losses will be reduced due to difference in performances of each cultivars.
- Pits of one foot size are dug close to standard.
- Spread handful of lime in the pit before planting.
- Coil the base of vines without breaking while planting.
- Fill pit with soil and press with hand to avoid water stagnation and form small mounds around standard.

A system of planting on coconut is described by Sir Francis Buchanan called 'Ettadi randadi chitta' – (Eight feet-2 feet system). The procedure involves taking a basin of 8 feet diameter from base of coconut all around. This basin is filled with green leaves, ash and cow dung for nourishment to coconut. Inside this ring another round basin is taken at 2 feet diameter from coconut in which pepper is planted and manured. It was believed that each plant would respect each other and take nourishment from the respective areas.

In olden days, two systems of planting in vogue were described by Sir Francis Buchanan: namely i) Kuzhikuthu-(planting in pit) and ii) Kutta thazhth (Planting with baskets). In the first method, soil was dug around the support tree and with the help of forefinger, a depression is created in the dug earth, the vine is pressed into this and covered with soil and mulched. No watering was done and the vines grew with the available moisture in the soil.

The second method is similar to the present method of raising in bags and planting with ball of earth. To prepare kutta (container), viny shrubs (such as odal, pullanthi, kariyilanchi, vallipala) are used. Vines are cult, wilted in the sun and containers to hold about 2 or 3. Coconut shell full of potting mixture consisting of soil having more of coarse sand, leaf mould, powdered cow dung and ash are made. This mixture is moistened with water while filling, kept in shade and vines are planted. Everyday water is given, the quantity being two hand full. Once the vines start growing, these were planted along with the container which rots gradually and become part of soil.

Season

- Traditionally it is best to plant pepper during the period between last week of June to first week of July called as Thiruvathira Njattuvela for 100% establishment of vines.
- The crop will be poor if South West monsoon is inadequate.
- If rain is poor, spraying water at spiking time will result in good fruit set.
- During the rainy period the pepper plants should be free from shade, for a good crop.

Exposure

Ideal exposure is towards East while planting where sun rises and attract the shoots. Even North-East can be considered. Southern and South West exposure is not good.

Shade

Filtered shade from support trees is considered the best and pepper and support tree are not supposed to compete for light. Generally shade removal is done twice: March-April and August-September. All excess branches are removed and one branch is retained.

Spacing

Do not plant vines closer. If more space is given to support trees it will result in more air movement and result in more yield.

Inter crops

Growing spices such as ginger, turmeric, galangal, koova, kacholam *etc.* is believed to increase berry set where as banana adversely affect yield of pepper.

Tying of vines

It is an age old practice to tie the vine with the fibres of a bushy tree with a local name Edampiri valampiri *(Helicteres isora)* extracted from its bark. It is a medicinal plant also. Long sticks separated from the tree are beaten on rock to loosen the inner bark. This fibre is preferred over banana/areca fibre since it is more softer and conducive to the young stem of pepper. Other fibres may cause injury or accumulation of rain water resulting in rotting of stem.

Mulching

It is considered ideal to scatter the mulch around the base of pepper instead of mixing or burying in soil.

Pruning

- Prune the growing vine at a height of 1.5 m from ground within one year after planting. It induces vigorous growth.
- Removing hanging shoots and top shoots of the vine after getting sufficient growth is helpful for development of more laterals and getting increased yield.
- Covering the pruned top shoots with poly bags has been observed to prevent further growth.

Lowering of the vine

This is an important traditional practice aimed at rejuvenating the vine, to induce better growth and form more laterals. The procedure involves removal of the vines from the standard carefully and after removing a few side shoots, the main stem is coiled around the base of support and retrailed on the standard. This is done usually within the first 3 years of growth period.

Drought management

To prevent scorching of vines in summer newly planted vines are shaded with twigs of trees. Use of twigs from vetti (*Olea dioica*) and irumullu (*Xylea xylocarpa*) is a traditional practice.

Repelling animals

To prevent feeding the leaves of pepper by goats or cows, cowdung paste is applied on leaves and shoots. To prevent berries being eaten by hen the base of vines were protected with coconut leaves in older times; chicken consuming pepper did not lay eggs.

Weed control

Scraping, raking of soil and hand weeding of basins yearly are the general measures adopted for weed control. Applying leaves of tamarind as mulch at the base controls weed growth.

Manuring

The best manure for pepper is the decomposed leaves of plants. Organic manures only are used generally such as FYM and ash for manuring pepper and are given abundantly. These are applied before monsoon. In the travelogues of Sir Francis Buchanan, it is said that the pepper cultivators of his period used a combination of dry cow dung, dry leaves and ash that were heaped together before monsoon and the well rotten mixture was applied to the vines by the onset of monsoon. The quantity is dependent on the stage of growth and varied from one 'koru' (handful measuring 250-300 g) or 3 or 4 'koru'. It is believed that if water and manure are increased, the vines will grow robust but spiking will be poor.

Standards/support

Even today, the ideal standard for pepper remains elusive. Traditional wisdom on this issue is worth exploring. All trees having rough bark are suitable as standard, such as *Erythrina*, mango, jack, hogplum, *Terminalia, Strychnos etc.* In olden days *Erythrina* or (murikku) was common. Later on *Gliricidia* became popular. Payyani (*Oroxylon indium*) Karayam (*Garuga pinnata*), Azhanthal (*Pajanelia rheedii*) were also traditionally important. However, jack is considered to be the best support for pepper by the farmers as it is attributed with good growth of vines, yield and higher driage. Sir Francis Buchanan while describing pepper culture in Kerala, indicated in his travelogues, that the pepper farmers of his period considered mango as the best support. Mango seedlings were planted along with *Erythrina* that survive 6-15 years only and even pepper was planted on big mango trees of 20 years and above. Almost any tree can be a support for pepper. Growing pepper in coconut was considered harmful. The following are some of the information evolved over time worth mentioning.

- Use narrow pits for planting pepper supports to avoid dodging in wind.
- Prune the supports to increase spike setting and to prevent pollu beetle damage in rainy period.
- Collect standard during descending moon period in the month of Kumbham (April-May). After collection keep in shady places horizontally for 15 days and afterwards keep in a slanting position till planted.
- Silver oak is a good standard for pepper for healthy growth and yield.
- Support must grow straight and upwards to get formation of more laterals in the vine.
- An innovation is brick support. Channel bricks can be joined with 6mm rod through the 3 holes and 14 bricks will be sufficient for one support of 4 m length. The holes are filled with cement and cured for one week. Bury 0.5 m deep into the ground to trail pepper. This is cheaper than concrete. Pepper adheres well to it and suitable for homesteads. Innovated by Mr. Sadanandan, Chettiankal, Chovva, Kannur, Kerala.

Prevention of wilt disease or its control

Some of the local knowledge regarding prevention of the dreaded wilt disease of pepper or means of controlling it are as follows:

- Heap small stones around base of pepper plants to prevent wilt.
- Do not disturb the base to reduce chances of the wilt.
- Apply 500 g common salt to the base of each vine before onset of South West monsoon and after North East monsoon.
- Apply lime on main stem from base to a height of 75 cm when wet to prevent fungal attacks.
- Keep one kg of neem cake (partially remove oil) in 25 lit. water and filter. It is an excellent fungicide.
- Garlic and mustard are ground, decoction prepared and sprayed to control wilt.
- Apply 250 g lime twice/year to reduce wilt.
- Mulch with leaves of maroti (*Hydnocarpus kurzii*) to control wilt and pests.
- Apply diluted oil of maroti to control quick wilt or its cake which controls nematodes also.
- Apply fleshy rind of nutmeg to the base.
- Apply 2 litres of liquid after extraction of starch from koova (*Curcuma zedoaria*). Actually planting koova around the base of pepper has been observed to prevent foot rot of vines besides giving an additional income to farmers.(Mr. K.J. Kurian, Kuriaplavunkal House, Padikkap P.O., and Mr. Johny George, Thannikkapara, Mundamudi, Vannapuram, Thodupuzha, both from Idukki District of Kerala).

'Amrutha' is a preparation reported from Karnataka to control wilt. In this method 5 litres of cow's milk is kept in a plastic bucket and fermented for 5 days (for 10 vines). It is then churned to remove the fat completely and filtered and further fermented for another 10 days. This solution is diluted with water 10 times and applied to the vines in August, September and October. Diseased vines with leaves shed but stem intact are found to recover (Dr. B. T. Suresh, Bakaravalli Village, Malasavara post, Belur Taluq, Hassan-573 101.)

Lemon grass has been found to be a good preventive as well as curative mulch for pepper. Cut the grass and apply as much around the base of pepper at the initial stage of the disease (Mr. E.J. Jose, Elavatharayil, Arangu P.O.-670 582). Coffee fruit skin and cowdung after mixing and applied to bas can reduce quick wilt.

Slow wilt control with wild sunflower

Wild sunflower (*Tithonia diversifolia*) is a wild plant occurring in plenty in cooler areas of the hig ranges. It is called 'Kaippan' in Malayalam. It is used to control nematodes in pepper mixing well th following.

Tithonia diversifolia chopped leaves and tender stems	:	50 kg
Neem cake (crushed seed)	:	4 kg
Biogas slurry	:	75 litres

Keep in a tank and ferment for 15 days. Afterwards strain and dilute @ 1.0 litre with 5 litres of water and drench the base of infected vines. Repeat once in 15 days if needed.

Pests

The oil extracted from *Pongamia pinnata* (Ungu) is reported to be cffective against mealy bugs and scales of pepper. Another method is use of the hot spent liquid after boiling tapioca chips. This hot solution if poured on the pest infected main stem it kills the pest without any damage to the stem or leaves. The farmer who used this technique has observed that the hot liquid after removal of boiled chips of tapioca if accidently fallen on hands or legs it did not cause any burning. So he assumed that this hot liquid will not kill the plant stem (Mr. Joseph, V.J. Valummel, Upputhara P.O., Kakkathode, Idukki, Kerala).

Harvesting and processing

Rayaguru *et al.* (2007) have also highlighted the export potential of the crop but the data provided by them are much less and therefore, do not match with those provided by Jana (1996).

Usually harvesting is done when 10% of the berries in a spike turn red. Some farmers say harvest when 5 berries in a spike turn to red colour. Bamboo ladders are used to harvest the spikes by hand picking and collected in temporary cloth bag tied to the back of the climber.

Berries are separated by trampling spikes with foot. Experience indicates that if spikes are exposed to sun for a whole day, berries can be removed easily. An innovation in spike trampling is the use of 'netrika' a plastic netting specially made for sericulture. In this method, spikes are spread over the netrika and trampled with foot. Berries get easily separated from the spike and are more cleaner.

If the berries have started ripening and one wants to ripen all berries quickly, the spikes can be heaped and covered with gunny for two days with good result.

Drying of berries is done traditionally in bamboo mats coated with cow dung or yards coated with a paste of mud and cow dung (it is not recommended now). Cemented floor or silpaulins are also used. Berries are spread on the mats with hands or wooden planks with long handles. Every day the hot berries are gathered in gunny bags at 3 or 4 pm, tied tightly and a weight with stones is placed on the bags. This will give jet black colour. Drying takes 4 to 5 days. Drying is stopped when the berries become hard and emit a specific sound when rubbed with hand.

The left over rachis of the spikes is spread on the front yard of pavings to be trampled upon believing that the more people walk over it the yield will be better in the following year.

The berries are stored in wooden containers called 'Pathazham' made of wood or in gunny bags for years together. Old pepper fetches higher price than fresh produce. Traders designate old pepper by the presence of whitish fungal growth. So farmers add rice flour to fresh produce to get better prices and is a malpractice. The traders assume that old pepper is properly dried whereas the fresh produce may not be so, resulting in reduced weight after purchase and may cause losses.

Processing machines

Ravi's threshing machine: This is an innovation in threshing machine reported from Idukki District of Kerala before other threshing machines were developed. This was developed by Mr. Ravi, a Workshop mechanic (Palathumkal, Our Engineering Industrial Workshop, Upputhodu, Marukkassery, P.O., Idukki). He has both hand operated and motor operated models. The hand operated one can thresh 55 kg per hour whereas the other one has double that capacity. The advantages claimed are:

- Contamination of threshed berries with other extraneous matter is avoided.
- The berries do not get crushed including ripe ones.
- 95% of berries are separated with the spikes in the first strip itself.
- If the leaf blades are removed and replaced with other blades paddy can be threshed.
- Mechanism to separate berries and spikes is available with the machine.
- Cost of threshing can be reduced.

Nirguna threshing machine: This machine operates on 0.5 HP motor capable of threshing 150-200 kg spikes/hour and 100% threshing is effected. If the spikes are allowed to wilt in the sun for one day the time can be reduced. The machine was developed in 2002 and six models were developed catering to different category of farmers. The machine weighs only 45 kg. The machine was developed by Mr. Mahabaleswara Bhat, Nithila, Kodapadavu P.O., Buntwal Taluq, Dakshina Kannada District (Ph: 082255-267475, Mob: 09748370404).

Top cutter: This is an innovative device for harvesting of black pepper spikes. The device helps one to harvest pepper from ground level. It can be fitted to a long pole. The device is 2 feet long and on its tip a scissor is fitted (one foot long) with coil spring, clamp and a plastic bag to hold the harvested spike. A cable is tied to the scissor and by pulling the cable harvesting is done. The device is useful for harvesting fruits, flowers, tender shoots *etc.* This can also be used to remove weeds from the sides of deep wells.

Traditional method to prepare white pepper

The method involves packing green mature spikes of pepper in plastic gunny bags with loose weaving but without holes. Bury in soil 60 cm deep and cover it with soil. Keep the soil moist by pouring water every 3 days. Allow retting for 15 days. Remove soil, wash and dry in sun. Normal recovery is 28%.

Another method prevalent in 18th century in Kerala is described by Ravindranath. After cleaning the base of the vine, large leaves or pieces of mats are spread. The ripened berries falling on the mat were collected and pressed between the thumb and forefinger to remove the skin. Then it is dried in the sun during day and kept in mud pots during night. This process is repeated 4 or 5 days. These are stored in bags and the berries were considered to have better medicinal value. This white pepper was usually given as special gifts in palm sized bags made of pandanus leaves containing about 50 g and was cherished by the foreigners.

Homoeopathic preparations

Now a days homoeopathic preparations are also being used successfully. The author has tried two preparations against rootrot of black pepper as test case namely Rootsan and Biofos. The Rootsan was applied @ 2 ml/litre as a drench thrice to rooted cuttings in bags and Biofos as a spray. There was no root infection of the vines upto six months indicating the potential of these preparations. However, research is needed to standardise the application mode and one has to shed the negative attitude towards homoeopathy. The above preparations were made by Dr. A.J. George, Athrasseril, Peravoor, Kannur District and are being used by experienced farmers with good success.

Special innovation in pepper cultivation

This is a special method developed by Mr. Francis, Cheruvallil, Narinada, Calicut, Kerala. Fed up with the devastating foot rot of black pepper, Mr. Francis, conceived a hypothesis based on the following observations and long years of acquaintance with the crop and developed a sustainable organic way of pepper production with the lowest threat from foot rot and slow decline, very successfully. For this innovation, he was awarded by the National Innovation Foundation, Ahmedabad in 2006.

The assumptions are

- Since foot rot generally attacks the collar region he hypothesized that if this junction of root and stem is exposed to the weather elements, it will help hardening off of the tissues and may resist infection. This idea was derived from the natural exposure of collar in very old vines where the soil was eroded but no infection was seen. As long as this region is under the soil, it is less hardier and may be easily susceptible to disease. His conclusion was also derived from his observation that when tubers of tapioca were exposed to sun, fibres formed at the exposed portion and made it hard or woody. So he devised a surface planting system whereby the collar and roots are exposed over a period of three years and remained 3" above ground level.
- He has observed that plants with single robust stem to a height of about 1 metre yielded more and also created an exposed base to prevent the disease.
- Tilling damaged the roots causing infection. Hence no tillage and cover cropping would be best alternative.

- Due to basal manuring, the roots tended to concentrate at the base and if infected the plants died. Hence ways may have to be devised to allow more spread of roots away from the base. Nutrients are given as per the need using organics. Allow more number of roots and its spread.
- Shade during rainy period is very conducive for disease incidence and pollu beetle and no shade shall be available from June to September while from October onwards shade is needed upto May end. He found jack an ideal standard for pepper because jack once pruned will develop shade only by end of September and this shade is retained throughout summer. The jack leaves are good nutrient sources. It does not compete with pepper for nutrients during June-September and grows straight. *Erythrina* is not ideal.
- He found Karimunda is the best variety capable of yielding maximum well under any existing agro-ecosystem and vigour of the vine is more important to ward off the disease.
- Lime application not only controls acidity but fungi infection as well.
- Over manuring/pesticide applications reduces the resistance power of the vine.
- Pepper has to be grown as a pure crop and not as an intercrop as its competing ability is limited (health and yield).
- Muddy water from other fields impedes drainage and aeration and cause infection.

Method: An area with good drainage and fertile soil is selected; all around the plot a trench of 30 cm deep and 30 cm wide is dug to prevent runoff and spread of roots from other trees; by onset of monsoon temporary supports such as *Erythrina, Gliricidia*, Drumstick, *etc.* are planted at 6mx 4m. Permanent support is jack.

Raising cuttings: Runner vines are collected from vigorous yielding vines from January-March and are cut into 20 cm length. The basal cut is given close to the lowest node; cuttings are planted in bag of 15 cm x 7.5cm size with soil. While planting the lowest node is 2/3rd below the surface soil. Three cuttings are planted in one bag.

Planting: By onset of monsoon in June, the base of standard is cleaned (no pit is taken) but levelled. The bag is removed and the cuttings are planted on surface close to standard with soil. Some soil is heaped from outside around the soil attached with the rooted cuttings and pressed. Spread 50g bone meal and 200 g powdered cow dung 60 cm around and a circular mount is made with heaped soil to the level of collar only. Tie the vine with areca sheath fibres. Banana fibre causes rotting. Mulch this mount with dry leaves, sawdust, coirpith *etc.*

Aftercare

- As the seasons pass, the soil will erode from base and the roots and collar are exposed to sun.
- Retain only the most vigorous vine out of three.

- Sow 5 seeds of jack close to the temporary standard. Retain the most vigorous one. After 3 or 4 years tie the top of temporary support to the jack at top and allow all vines to climb on jack and once this is accomplished, the base of temporary supports ringed to kill them. Height of jack can be up to 8 metres.
- Cover crop of mucuna is established in fourth year @ 40 rooted plants/acre and cover the whole area in 3 or 4 years. This control weeds, provide nutrients, prevent soil erosion and run off. Cover crop is not allowed to spread to the base and the path way made along the planting line and confined to in between rows of pepper plants.
- Remove all sprouts *etc.* up to 1 m from ground level. Remove soil if needed to expose the roots and collar so that the vine rest on 2 or 3 exposed main roots.
- To allow spread of roots away from base manuring is done away from base depending on root growth every year.
- Only organic manures are applied such as oil cakes, cow dung, bone meal, green leaf *etc.* Manuring is done in June and August. It is helpful if dung and groundnut cakes are mixed with water and this mixture is applied every month during first 2 to 3 years. Manures are spread on ground and covered with mulch and not dug in. Manuring is done only 5 to 6 years and gradually stopped and from 7 year onwards no manure is given. Jack leaves are mulched around the base.
- Remove all spikes upto 2 years. Allow bearing from 3rd year onwards.
- No pesticide or fungicide application needed. If vines are showing weakness remove all spikes to keep the vigour. Keep the base and walking line along the row free of weeds and exposed to sun.

Yield

The yield was 2 quintals in sixth year, 1.7 quintals in 7th year and 8 quintals in 8th year. It is surprising that no vine succumbed to the severe drought in 2004 and no vine was affected by wilt in the raining period of 2004. Now this plot in Paisakari is abandoned but another plot in Narinada is maintained.

Mr. Shajan Cherian (Erathel, Narinada, Koorachundu, Kozhikode-673 527, Mob: 9745087449) is another farmer who has adopted the technique. His garden is 7 years old with jack as support and Karimunda variety. His average yield is 4 kg dry pepper/vine (2 tonnes per hectare). The spacing is 20' x 10' accommodating 200 vines/acre. He gives 5 kg dry cow dung and ½ kg bone meal as fertilizer per vine/year. This method needs validation and modification of the method can improve yields further.

Conclusion

An over view of the traditional wisdom and innovations of farmers highlights the necessity of validating those knowledge that may be useful in black pepper production. The following ITKs or innovations need validation urgently.

- The varieties Kumbhakkal, Sion Mundi, Pepper Thekkan, Kadukummakkal may be tested for yield, quality and disease tolerance.
- The effect of evening sun (infra-red radiation) on seed germination and varietal improvement may be studied.
- Planting of top shoots and runner shoots together for early cropping may be tried.
- Jack and mango as standard for pepper need to be studied. The influence of jack rhizosphere in the multiplication of *Trichoderma* needs to be investigated.
- Use of channel bricks as support with shade trees planted in between rows using top shoots may be investigated because harvesting of tall standards is a problem.
- The use of garlic and mustard, maroti oil and cake, flesh of nutmeg, lemongrass, lactic acid and wild sunflower in controlling wilt disease and nematodes needs to be studied.
- The planting of koova (*Curcuma zedoaria*) at the base of pepper to control foot rot disease needs to be validated as it will give additional income also.
- The use of pongamia oil and controlling mealy bugs and scale may be studied.
- The effectiveness of homoeopathic preparations against foot rot needs investigation.
- Effectiveness of surface planting exposing the collar with mucuna as cover crop has to be studied for yield as well as foot rot control on a long term basis.
- Nirguna pepper threshers of varying capacities need to be evaluated.

References

Chandy Abraham 2001 Karshika Nattarivukal. Avanthi Publications, Kottayam, pp. 37-42.

Jacob T K, Prakash K M & Rajeev P (2004) Traditional practices in black pepper cultivation. Spice India 17(8) : 13-15.

Josy Joseph 2007 Indigenous knowledge on spices. Spice India (Mal) 20(2) : 18-19.

KAU 2008 Proceedings of first Farmers' Science Congress, KVK, Kerala Agricultural University, Panniyur, Kerala. 4-5, February, 2008, 1.1, 1.2.1.3, 3.5 3.7, 4.8.

Paulson Tham 2007 Agriculture and some natural phenomena. Spice India (Mal.) 20(8) : 11-12

Paulson Tham 2007 Natural way of pepper cultivation. Spice India (Mal.) 20(10) : 20-21

Paulson Tham 2004 Mulching black pepper with maroti leaves reduces pest infection Spice India (Mal.) 17(8) : 11-12.

Prakash K M, Manoj P S & Mathew P A (2002) Sustainable cultivation of black pepper. Kerala Karshakan 48(6) : 27-28 and 31.

Ravindranath E 2007 Chandu Nair and white pepper. Spice India (Mal.) 20(9) :10-11.

Ravindranath E 2007 Eight feet-two feet system of planting pepper in coconut gardens. Spice India (Mal.) 20(12) : 11-12.

Ravindranath E 2007 Pepper cultivation under 'Kana system'. Spice India (Mal.) 20(4) : 6-7.

Ravindranath E 2007 The sea and the vine do not let us down. Spice India (Mal.) 20(8) : 8-9.

Ravindranath E 2008 Hog plum and kanjiram for growing pepper. Spice India (Mal.) 21(8) : 12-13.

Saji KV, Johnson George K, Utpala Parthasarathy & Parthasarathy V A 2007 Biodiversity of *Piper* in India. National Biodiversity Authority, Chennai, India,. pp. 63-74.

Shinoj Subramanian & Zachariah T J (2002) Traditional method of preparing white pepper. Spice India (Mal.) 15(12) : 12 & 28.

Spices Board 2007 Outstandingly useful 'nirguna' threshing machine. Spice India (Mal.) 20(4) : 19-20.

Sreekumar V 2002 Current news-Brick post support for black pepper. Spice India (Mal.) 15(2) : 24-25.

Sreekumar V 2002 Samakaleena Visheshangal. Spice India (Mal.) 15(2) : 24-25.

Sreekumar V 2002 Ravi's threshing machine has several advantages. Spice India (Mal.) 15(6) : 4.

Sujith Kumar C K 2003 Fermented liquid mixtures. Karshakan (Mal.) 11(10) : 34-35.

Initiatives of Spices Board for post harvest and quality improvement of pepper

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Introduction

Black Pepper (*Piper nigrum*) is one of the popular and most sought after spice in the world. It is native to Malabar, a region on Western Ghat and Western coast of South India. It was mentioned as far back as 1000 BC in ancient Sanskrit literature. The name pepper comes from the Sanskrit word 'pippali' meaning berry.

Pepper is mainly cultivated in Brazil, India, Indonesia, Malaysia, Sri Lanka, Vietnam, Cambodia and China. The world pepper production is estimated at 2,62,900 tons (2008 projection) and the Indian share is estimated at 50,000 tons. The world export is around 1,90,800 tons (2008 projection). The balance is consumed within the producing countries. Some of the low cost economies in South East Asia like Vietnam, Cambodia, Thailand and China are emerging as major producers of pepper with practically no domestic consumption. Vietnam, the major producer in recent time has achieved a production level of one lakh ton during 2006 from 22,000 tons in 1998. The traditional producers like India and Indonesia show a declining trend in production. Brazil, the only Latin American source stepped up the production during the last couple of years.

The estimated area under pepper in India is 2,36,180 hectares (2006-07) and the estimated production is 50,000 tons (2007-08). The production of Indian pepper has come down from 80,000 tons (2002) to 50,000 tons (2007/2008 estimates). Similarly, pepper exports from India has dwindled from 45,156 tons (1999) to 14,049 tons (2004).

India is also importing pepper from other sources mainly for value addition and export. The import has reached 17,733 tons (2004-05). The major sources are Vietnam, Sri Lanka and Indonesia.

Low productivity of pepper plantations is the major challenge faced by India. Except for Indonesia and Sri Lanka, all other producing countries are having a productivity of above 1000 kgs/ha. In Vietnam and China it is around 2000 kgs/ha. In India productivity of pepper is very low to the tune of around 267 kgs/ha. The low productivity is mainly due to non-popularization of high yielding varieties, prevalence of diseases like 'foot rot' and 'little leaf', depletion of soil fertility, damage of live standards due to pest attack *etc.* Scattered pepper cultivation by small holders, lack of long-term investments for improving the crop are some of the added perils.

Spices Board is having mandate for production development of cardamom (small and large) only as per Spices Board Act, 1986. The production development of pepper is vested with the Union Ministry of Agriculture and State Agriculture/Horticulture Departments. Post harvest improvement of spices including pepper is looked after by Spices Board.

Most of the importing countries have prescribed stringent quality standards for agri products including pepper. These standards are becoming more and more stringent and could become effective trade barriers impacting exports. It is therefore necessary to educate, motivate and support the growers to adopt hygienic post harvest practices to improve the quality of pepper and to create a perception all over the world that India is a source of good quality pepper.

Keeping this in view, Spices Board has been encouraging use of drying yards, polythene/silpaulin sheets, bamboo mats for drying purposes and pepper threshers for hygienic removal of pepper berries from their stalks. Moisture meter is distributed for checking moisture of the dried product at farm level. Training of farmers, NGOs and officers of State Agri/Hort. Departments are also an integral part of this effort.

During XI plan, the following programmes are being implemented for improving quality of pepper prc at farm level.

Co :tion of drying yards

In ( ) enable growers to dry pepper under hygienic conditions, growers are financially assisted for coı ion of drying yards.

Du e plan period the estimated cost of construction of drying yard is Rs.600/- per sq.m. The rate of ıce as cash subsidy offered to growers is Rs.540/-, Rs.300/- and Rs.150/- sq.m. for scheduled tril eduled caste and general category towards 90%, 50% and 25% of the cost of construction res :ly.

Ind l growers are eligible for subsidy for constructing upto 150 sq.m of concrete/cemented drying yaı the NGOs, farmers associations, agricultural market committees are eligible for assistance prc nate to the members thereof.

Su f polythene/silpaulin sheets

In ( ) enable small and marginal farmers to dry pepper under hygienic conditions Spices Board is als lying polythene sheets/silpaulin sheets (of size 8 x 6 m. 250 GSM & 120 GSM respectively) at : ıbsidy to tribal growers and 33.33% to other growers. Board will arrange centralized puı of polythene sheets and supply it to growers. The non-subsidy portion will be collected from the growers.

Supply of moisture meter

One of the important parameters which decides quality of pepper is the percentage of moisture in the dried/cured produce. If moisture is excess than the optimum level, there are chances that the product will get affected by mould and finally contaminated by the presence of mycotoxin (aflatoxin). As the curing and processing are on farm operations, farmers are to be equipped with devices for detecting the moisture level present in the final product for maintaining the quality. Hence supply of moisture meter will be taken up. The cost of such a device is estimated at Rs. 8,000/- and subsidy @ Rs. 2,500/- per moisture meter is proposed towards 32% subsidy of the cost.

Supply of pepper threshers

Traditionally pepper berries were separated from the spikes by trampling under the feet which is un-hygienic and labour intensive. In order to separate the berries from the pepper spikes in a hygienic way, Board will be supplying pepper threshers which are mechanically operated and labour saving, by providing a subsidy subject to a maximum of Rs.7000/- per thresher, irrespective of the capacity of the equipment purchased by the beneficiary.

Supply of bamboo mats for pepper

In order to enable the growers to dry pepper under hygienic condition, Board is supplying bamboo mats of size 12' x 6' at 90% subsidy to tribal growers and 50% subsidy to others. The Board will arrange centralized purchase of mats and supply to growers after collecting the non-subsidy portion.

Organic production of pepper in North Eastern states

Spices Board is taking up a number of developmental programmes for spices with high export potential in North Eastern states as a special programme for development of North Eastern region. Under this, organic production of pepper is promoted by way of providing financial assistance to the growers. The programme is implemented by providing a subsidy subject to a maximum of Rs. 15,000/- per ha. in two annual installments of Rs. 13,000/- and Rs. 2000/- in the form of planting materials and organic inputs like *Trichoderma*, copper sulphate (for preparing Bordeaux mixture) *etc.* to small farmers. Organic inputs are multiplied with the assistance of non governmental agencies and supplied to the growers. The required planting materials are produced through rapid multiplication units with the help of governmental / non-governmental agencies which are under the technical supervision of the Spices Board.

By implementing the above programmes, it is expected that quality of Indian pepper at farm level could be improved to a great extent in order to make it exportable and internationally acceptable.

An overview of research and development of betel vine industry in india

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Introduction

Betel vine (*Piper betle* Linn.) is a native of tropical South-East Asia. Geographically, it is confined particularly in the region falling between 60°E and 118 °E longitude and 30°N and 12°S latitude. Betel vine is an evergreen, perennial, dioecious creeper cultivated in India for its leaves which is mainly used as masticatory as stimulant.

The crop is grown commercially as cash crop in the states of Assam, West Bengal, Bihar, Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Uttar Pradesh, Maharashtra, Orissa, Tamil Nadu and to a limited extent in other states. About 50,000 ha are under this crop which marginally increase or decrease depending upon the market demand and profitability (Maiti & Shivashankara 1998).

Betel leaf is mainly used for chewing as fresh along with several ingredients such as lime, araecanut, *etc*. In addition, it has many medicinal properties and are used widely in Indian system of medicine to cure indigestion, stomach ache, diarrhoea, flatulence and to heal wounds, scales and burns, swelling due to sprains, bruises, respiratory disorders, sore throat, constipation, boils and gum sores (Chopra *et al.* 1954). Amonkar *et al.* (1986) confirmed that betel leaves contain a chemical called hydroxy-chavicol, a phenolic compound that exhibited suppression of induced mutagenesis. It has a positive stimulatory influence on intestinal digestive enzymes, especially lipase, amylase and disaccharidases (Sandhya Prabhu *et al.* 1995). The antiinflammatory properties of the ecotypes of this plant has been investigated and three purified compounds namely, chavibetol, chavibetol acetate and chavicol were identified (Khozirah *et al.* 2000).

Role of AICRP in strengthening research

The coordinated project has made tremendous contribution in bringing together various agricultural universities and central institutions involving a common programme of work covering wide range of topics *viz*., survey and surveillance of diseases, insect pests and nematodes; loss estimation; disease, insect pests and nematode management through IPM; disease forecasting and epidemiology; crop husbandry including plant population, nutrient management, water requirement, micronutrient, inter cultures, packaging and storage; PGR management; identification of new varieties; hybridization, *etc*. Significant achievements of the projects are given below.

Genetic resources

Collection, conservation, cataloguing, evaluation and exchange of germplasm have been one of the major activities of AICRP/AINRP on betel vine. However, collection of new types and their evaluation is a continuous process in the programme.

Centre	Total collections	Evaluated & catalogued
AAU	14	51
ANGRAU	51	14
BCKV	40	32
JNKVV	25	25
MPKV	28	28
OUAT	40	40
RAU	20	20
TNAU	45	45
IIHR	87*	—

* Collected from AINRP centres for breeding purpose

Flowering and fruiting in betel vine

Sexual dimorphism for leaf character was noticed. The female leaves are cordate in shape and males are ovate. The length and breadth ratio of leaf in both sexes vary (1.84 ± 0.21 for males and 1.26 ± 0.13 for females). Betel vine is a non-agamospermy with true seed formation only through pollination. This opened up the field for heterosis breeding. Profuse flowering in both female and male clones of betel vine was observed throughout the year. Crossing between female and male genotypes was carried out by dusting pollen on female catkins (10.00 to 10.30 am). Successful crosses developed fruits, which matured in 90-100 days after crossing. The seeds extracted immediately were tested for germination. Germination was satisfactory with good radical and plumule emergence. Seedlings were grown in plots, which included single cross, poly cross and also open pollinated progeny. Variation in the progenies at seedling stage is being observed and crossing programme is being continued. Four selected hybrids are being evaluated in four centres.

Crop improvement

Varietal trial: A selection from Bangla cultivar named Ghanagatte has been identified as high yielder. The cultivar showed 10-60% higher yield against local check in multilocation and adaptive trials in the eastern region under bareja cultivation system. Typical characteristic of the variety is shorter internodal length. Performance of Ghanagatte for leaf yield was consistently superior to the local checks in AAU, BCKV and OUAT. Therefore, this variety has been recommended for release in these states. A proposal has been sent to CVRC for notification.

Released varieties: The following varieties have been released so far from the project.

Name of the Variety	Year of release	States recommended for cultivation	Centre responsible for release
SGM-1	1991	Tamil Nadu	TNAU
SGM-2	2000	Tamil Nadu	TNAU
Utkal Sudam	1997	Orissa	OUAT
Bidhan Pan -1	2004	West Bengal, Assam, Bihar and Orissa	BCKV
DPB-6 (Krishina Pan)	2003	Maharashtra	MPKV

Crop production

Nitrogen sources, levels and method of application: Band placement of 200 kg N as CAN produced significantly higher yield at BCKV. Keeping quality, however, deteriorated with the use of chemical fertilizers. Incidence of anthracnose and leaf spot was the lowest with the use of neem coated urea. At ANGRAU, the highest yield was obtained with 200 kg N /ha as urea, though the economic level was 100 kg N /ha only. Yield and keeping quality were not affected due to various sources and levels of nitrogen at JNKVV. But leaves per vine were perceptibly higher with linseed oil cake, urea and their combination treatments. Nitrogen applied through organic sources recorded lower disease incidence, but did not improve the keeping quality.

At OUAT, maximum elongation of vines and production of leaves was achieved with 150 kg N /ha applied as urea+mustard cake in 1:1 ratio. Further, lower doses of nitrogen through neem cake and mustard cake reduced disease incidence. In TNAU, different sources and levels did not influence the yield but 150 kg N /ha through neem cake + urea (1: 1) resulted in the highest yield with the lowest foot rot incidence. Four to twelve split applications of nitrogen were found to produce highest leaf with the lowest foot rot incidence.

Organic and inorganic fertilization on growth and yield of leaves: Application of FYM at full dose was found to increase all the growth and yield parameters significantly in addition to reducing the disease incidence in MPAU, OUAT, RAU and TNAU. FYM application also increased the keeping quality of leaves in MPAU, OUAT and RAU. However, in ANGRAU application of neem cake + urea (1:1) and in JNKVV and MPAU, oil cake + urea (1:1) gave maximum vine growth and leaf yield.

Keeping quality of leaves was also improved by neem cake + urea in ANGRAU, whereas in AAU and JNKVV, organic fertilizer (full dose) improved the keeping quality of leaves with low disease incidence.

Slow releasing organic nitrogenous fertilizers on yield and growth parameters: Neem coated urea (NCU) was superior to tar coated urea and prilled urea in terms of favourable growth and yield, improved quality and lower pest incidence. However, at BCKV, NCU did not show any positive effect on yield but influenced keeping quality significantly and decreased *Phytophthora* incidence. At RAU, yield and quality were not influenced due to NCU but decreased incidence of bacterial leaf spot and the Anthracnose. NCU increased leaf yield at ANGRAU.

Levels of potash on yield: The results from different centres indicated that potash had a positive effect on yield, keeping quality and disease incidence. 100 kg K_2O/ha at ANGRAU, JNKVV, MPAU and NBRI, 125 kg at BCKV and OUAT and 75 kg at TNAU were found superior in increasing the leaf yield.

Levels of phosphorus on yield: Application of phosphorus improved the yield parameters at ANGRAU (100 kg/ha), JNKVV (125 kg/ha), MPAU (100 kg/ha) and OUAT (100 kg/ha). However, no effect was recorded at AAU and BCKV.

Micro-nutrients on growth and yield: Studies on micro-nutrients showed that application of manganese (0.5%) and zinc (0.25%) at ANGRAU, zinc (0.5%) at BCKV, molybdenum (0.1 %) at JNKVV and manganese (0.5%) at OUAT improved the leaf yield.

Bio-regulators on yield and keeping quality of leaves: Triacontanol (0.05%) spray thrice at 30 days interval had favourable influence on growth and yield parameters in all the centres. However, an increase in keeping quality of leaves with the triacontanol spray was observed only in MPAU, OUAT and TNAU. A significant increase in cost benefit ratio was also observed in MPAU and RAU.

Irrigation schedules and methods on growth and yield of leaves: Application of irrigation water at an IW/CPE ratio of 1.00 with irrigation depth of 5 and 3 cm at RAU and BCKV, respectively, were found to be better for growth and leaf yield. However, irrigation did not influence keeping quality of leaves, incidence of bacterial leaf spot and uptake of major nutrients at RAU. Furrow irrigation after each row in ANGRAU and after two rows in MPAU were reported to be superior methods for higher leaf yield. Irrigation methods did not have any effect on keeping quality of leaves and disease incidence.

Drip irrigation on growth and leaf yield: Replenishment (100%) of pan evaporation rate through drip irrigation produced highest leaf yield (25.55 lakh/ha) at JNKVV. However, at MPKV center, 125% evaporation replenishment produced highest yield (42.32 lakh/ha). In this treatment, water saving was to the tune of 34.26 per cent.

Packing and storage: Packing of leaves without petiole was found to be a better practice for improving shelf life when compared to packing with petiole in all the centres. In general, keeping quality during storage was better in winter than summer and rainy seasons. Plantain leaves (fresh or dry) with or without hollow space performed better as packing material in all the centres except ANGRAU, MPAU and RAU where moist straw lining with hollow packing showed its superiority.

Evaluation of live support crop: Superiority of *Moringa* sp. as live support crop was recorded uniformly in two locations. *Sesbania grandiflora* was also good when growth parameters were compared. *S. sesban* was not found suitable since it started producing branches from the base of the plants and also had slow growth rate.

Crop protection

Disease survey: Two types of disease surveys namely: i) fixed plot survey at a monthly interval and ii) roving survey at pre and post monsoon period were conducted. Results revealed that *Phytophthora* leaf and foot rots, Anthracnose and bacterial leaf spot or stem rot were important in most of the locations. Disease pressure was in general low and none of the diseases were found alarming in the farmers field in Uttar Pradesh and Assam. Sclerotial rot and foot rot were serious in Andhra Pradesh. In Orissa, Sclerotial rot incidence was reported up to 27.5% in open type of cultivation.

A serious outbreak of bacterial stem rot was observed in Salem area of Tamil Nadu during 1989-90. A new species of *Phytophthora* (*P. capsici*) was isolated and identified as pathogenic to betel vine. A new disease caused by *Chlamydomyces palorum* was reported from Assam causing up to 22.5% leaf and stem infection at pre-monsoon months in Tinsukhia District.

Varietal resistance to diseases: Available varieties at different centres were rigorously screened under artificially inoculated conditions for resistance to important diseases. Halisahars sanchi was found to possess multiple resistance against *Phytophthora* rots, anthracnose, bacterial leaf/stem infection and basal rot. Pachaikodi and Karappu exhibited high resistance to *Phytophthora* rots and bacterial leaf/stem infection at JNKVV. All Kapoori varieties showed resistance to powdery mildew at IIHR.

***Phytophthora* leaf and stem rot control**: Experiments conducted at various centres during the earlier years revealed that maximum disease control can be achieved by spraying (0.5%) along with drenching (I %) of Bordeaux mixture. Fosetyl-AL (Aliette 3 g/l) 0.24% a.i. 4 drenches at monthly interval was either equally effective or marginally superior to Bordeaux mixture in AAU, BCKV and TNAU.

Chemical control of anthracnose leaf spot: Bordeaux mixture (0.5%) spray was found superior to control anthracnose in Assam and West Bengal. However, mancozeb (0.1% a.i.) spray was found most efficient in controlling the disease in Orissa. In Tamil Nadu, bitertanol (0.025% a.i.) spray was superior which was followed by mancozeb (0.1% a.i.) and Bordeaux mixture (0.5%) sprays.

Chemical control of bacterial leaf spot: Superiority of bacterinol (0.1 % ai) + Bordeaux mixture (0.5%) spray treatment was observed next to streptocycline (250 ppm) treatment in all the three locations where the experiment was conducted.

Spray schedule for *Phytophthora* leaf and stem rot: Three centres namely BCKV, OUAT and JNKVV reported the superiority of 4 drenchings (1 %) and 8 sprayings (0.5%) of Bordeaux mixture uniformly starting from June to September at monthly and fortnightly intervals, respectively. However, in Tamil Nadu, 3 drenchings and 6 sprayings starting from June to August were found to be the best.

Soil solarization: Effect of soil solarization in reducing the initial inoculum was tried. Results obtained from different centres clearly established the effectiveness of solarization for 15 days before planting during summer months in reducing the nematode and fungal populations.

Biological control of foot rot: Four applications of *Trichoderma harzianum* enriched neem cake at quarterly interval was next best to Bordeaux mixture in reducing the disease incidence as well as improving leaf yield at AAU, BCKV, JNKVV and TNAU. Cost benefit ratio was also next to Bordeaux mixture in AAU and TNAU, while in OUAT, VAM and *Trichoderma* (quarterly) applications were next best to Bordeaux mixture in terms of disease incidence and yield.

Integrated disease management of *Phytophthora* foot rot: First year result indicated that the Integrated Disease Management (IDM) with sanitation + one soil drench of Bordeaux mixture + *Trichoderma* application (after one month) + one more soil drench of Bordeaux mixture significantly reduced the disease incidence in addition to the increase in leaf yield in JNKVV, RAU and TNAU. In MPAU also, integrated disease management significantly reduced the disease incidence.

Nematode diseases

Nematode survey: Most predominant plant parasitic nematodes associated with betel vine were *Meloidogyne incognita* and *Rotylenchulus* spp. *M. incognita* was most destructive throughout the betel vine growing areas except in Andhra Pradesh. In Maharashtra, *M. incognita* was observed in very serious form followed by *Helicotylenchus microcephalus*.

Assessment of yield loss due to nematodes: Yield loss due to nematode diseases was estimated to be 23.64% at AAU, 3.9-10.80% at ANGRAU, 20.03-26.99% at MPAU, 28.65-54.40% at JNKVV, 38.09-40.28% at OUAT and 34.40-38.27% at TNAU.

Integrated control of nematode diseases: A combined treatment of neem cake (0.5 t/ha), carbofuran (0.75 kg a.i./ha) and NPK (150: 100:50 kg/ha) was found to be the best at all the five locations of experimentation.

Interaction of root-knot nematode with other pathogenic fungi: No significant additive effect was observed when *Fusarium solani* was inoculated simultaneously with root-knot nematode. However, highest disease incidence was recorded when *Colletotrichum capsici* and root-knot nematode were inoculated simultaneously.

Population threshold of nematodes: *Meloidogyne incognita* population at 1000 per pot was found to reduce leaf size and fresh weight of 100 leaves at ANGRAU. Population of reniform nematode (*Rotylenchulus* sp.) was found optimum at 10000 per pot to produce maximum root damage. In case of *Helicotylenchus incises*, 1000/nematodes nematodes per pot caused significant reduction in plant growth parameters at TNAU.

Biological control of root-knot nematodes: Field application of *Paecilomyces lilacinus* enriched oil cake thrice at 500 kg/ha reduced root-knot index and produced maximum vine growth and leaf yield in AAU, whereas in OUAT and JNKVV it was next best to carbofuran (1.5 kg a.i./ha) application in reducing the root knot index. However, both the treatments were equally good for leaf yield.

Resistance to nematodes: Awami pan showed resistance to root knot nematode in AAU. Halisahars sanchi (WB) recorded lowest root knot index in OUAT. Harapatta exhibited moderate resistance in RAU. However, none of the varieties showed resistance in JNKVV.

IPM of root knot nematodes: Application of oil cake (500 kg/ha) with soil drench of carbofuran (0.1 %) and three applications of *P. lilacinus* enriched oil cake (500 kg/split/ha) was on par with carbofuran (1.5 kg/ha) in AAU, JNKVV, TNAU, RAU and OUAT centres with respect to root knot index and leaf yield.

Pathogenicity of *Rotylenchulus reniformis* in betel vine: Increase in the nematode population from 100/kg of soil onwards decreased the growth and yield of the vine in JNKVV, OUAT and RAU. Maximum reduction in growth and yield was observed when the inoculum rate was 5000 nematodes/ kg of soil.

Insect pests and mites

Survey of insect pests and mites: In Assam, incidences of whitefly, mealybug and mites were observed. Whitefly infestation was at peak during April to July. In Andhra Pradesh, severe damage by *Spodoptera litura* (up to 30%) and red spider mite (up to 8%) were observed during October. An incidence of 5-15% betel vine bug (*Disphinctus politus*) was recorded around Tuni area during monsoon months which caused 40-50% damage during post monsoon months in Vishakapatnam District. In West Bengal, biackfly was observed to be serious in Midnapur and Bankura districts. In Orissa, whitefly and red spider mite were prevalent during summer months, whereas betel vine bug, aphids and jassids were confined to winter months. In Tamil Nadu, incidence of scales (*Lepidosaphas cornatus*), red spider mite, mealybug and *Spodoptera litura* were observed.

Population fluctuation of insects of betel vine: At ANGRAU, tobacco caterpillar incidence started during the second fortnight of September and was maximum during November-December. Infestation was nil from January onwards. Build up of white mite started during second fortnight of November and was maximum during December-January. Lower temperature was favourable for the development of the pest.

At BCKV, the population of white and black fly were maximum during August-September and June-August, respectively. Second peak in population of white and black fly were also observed during December-January and September-November, respectively.

Highest scale insect population was seen during April-May in TNAU. Mite population was high during March. Both scale and mite populations were positively correlated with maximum and minimum temperatures.

Use of plant origin and comparatively safer pesticides in control of insect pests: At ANGRAU, the effect of pesticides of plant origin (tobacco decoction 2% and neem seed kernel extract 5%) in controlling mites was on par with dicofol (0.05%) and dichlorvos (0.05%). However, at TNAU, wettable sulphur (0.5%) and phosphamidon (0.05%) were significantly better than plant origin pesticides in controlling mites.

Initial evaluation trial: The trial was conducted in three centers *viz.*, ANGRAU, MPKV and TNAU. Result of this trial revealed that Vasani Kapoori at ANGRAU, Shirpurkata at MPKV and Dindugal in TNAU yielded highest leaf compared to local checks. Yield increase was to the tune of 54.0%, 30.8% and 45.0%, respectively in ANGRAU, MPKV and TNAU centers.

Hybrid evaluation trial: The results of the trial conducted at MPKV and TNAU showed that only GN hybrid (Godi Bangla X Kapoori Nasik) showed normal vigour in TNAU. However, yield was much below than the local check in MPKV centre. Other three hybrids showed severe hybrid depression.

Plant population: Under close system of cultivation at BCKV centre, results showed that leaf yield was non significant. However, at JNKVV centre, 1.5 lakh/ha population was found to be the best in increasing leaf yield (15.80 lakh/ha). Disease pressure was found almost uniform in all the three populations. Keeping quality was also non-significant. Highest cost benefit ratio (1:4.78) was recorded in 1.5 lakh/ha population. In OUAT, 2.00 lakh/ha population treatment showed highest leaf yield per ha. In RAU centre, 1.50 lakh/ha population treatment yielded maximum number of leaves (37.51 lakh/ha). Disease incidence was found to increase with increase in population. Keeping quality was found to be non significant.

Results of experiments conducted under open system of cultivation showed that 1.0 lakh/ha population at ANGRAU (57.17 lakh/ha), 50000 at MPKV (71.11 lakh/ha) and 75000 at TNAU (41.83 lakh/ha) produced maximum leaf yield.

Efficacy of bio-fertilizers in betel vine production: Results of this experiment showed that there was no significant difference among the treatments at ANGRAU. However, in BCKV, Azotobacter 5 kg + 100 kg P_2O_5 + 100 kg K_2O treatment produced highest leaf yield per ha (41.56 lakh/ha). At JNKVV, biofertilizers produced lesser yield compared to oilcake + urea (1:1 ratio) treatment. However, vermicompost treatment was found second highest in increasing leaf yield at JNKVV and OUAT. In MPKV, recommended dose of fertilizers (200 kg N + 100 kg P_2O_5 + 100 kg K_2O) recorded highest leaf yield (90.55 lakh/ha) followed by Azotobacter 0.5 kg + Phosphobacter 0.5 kg + 100 kg K_2O treatment (84.24 lakh/ha). At TNAU, *Azospirillum* 5kg +100 kg P_2O_5 +100 kg K_2O, Azotobacter + Phosphobacter treatment was the second highest yielder (70.22 lakh/ha) after recommended fertilizer dose.

ntegrated crop management: Results revealed that integration of treatments such as best plant opulation /ha, 200 kg N + 100 kg P_2O_5+ 7100 kg K_2O, watering 100 % replenishment of PER and pplication of Bordeaux mixture (4 drenches + 8 sprays) produced highest leaf yield at ANGRAU, BCKV, JNKVV and OUAT.

Biological control of *Phytophthora* foot rot: Results revealed that four applications of *Trichoderma* spp. was found to increase leaf yield and it was found statistically at par with Bordeaux mixture (4D + 8S) treatment in increasing leaf yield and in reducing the disease incidence in all the centres except in MPKV centre where four applications of *Trichoderma* at quarterly interval produced highest leaf yield (54.18 lakh/ha) followed by four drenching + 8 sprays of Bordeaux mixture.

Epidemiology of important diseases

***Phytophthora* stem and leaf rots:** Results revealed that at ANGRAU centre, disease incidence showed a significant and negative relationship with maximum temperature (r = -0.4972). The other remaining weather factors studied did not show any significant correlation with PDI.

Experiments conducted on variety Simurali Bhabna at BCKV showed that x-coefficients for all the weather parameters like temperature (maximum and minimum), relative humidity (maximum and minimum) and rainfall had positive significant effect on per cent disease incidence of stem rot in variety Ghanagete. The results of correlation studies for the variety Simurali Bhabna revealed that coefficients of T_{max} (1.45), RH_{max} (2.29), RH_{min} (0.31) and rainfall (0.008) had positive significant effect on the per cent disease incidence of stem rot while T_{min} (0.047) showed a negative correlation. For Simurali Deshi and Harishpur Bangla varieties, coefficients of all the weather parameters had positive significant effect on per cent disease incidence of stem. Coefficient of all the weather parameters like T_{max} (2.21), RH_{max} (3.19), RH_{min} (0.46) and rainfall (0.001) were positively correlated with per cent disease incidence of stem rot, while T_{min} (0.29) had negative effect.

Results of JNKVV revealed that the temperature, RH and rainfall had direct influence over the disease incidence. At OUAT, results showed that a significantly positive linear relationship of minimum temperature (0.620), afternoon RH (0.594), and number of rainy days in a week for causing the vine rot disease. Experiments carried out at RAU showed that important contributing factors are maximum relative humidity above 90 per cent and minimum temperature 25.8^0 to 27.5^{0}C which prevailed during the period accounted for 20.05 and 12.10 per cent of the total variation in per cent disease index, respectively.

Integrated disease management of *Phytophthora* foot rot: Results indicated that disease can be best managed by the treatment having sanitation + single application of Bordeaux mixture (1%) at the monsoon + biocontrol agent (*T. harzianum*) after 1 month + one additional Bordeaux mixture spray after 2 months at AAU, ANGRAU, BCKV, MPKV, OUAT and RAU.

Field application of *Trichoderma viride* for root-knot control: Three applications of *Trichoderma viride* enriched oil cake at quarterly interval was found, second best in reducing nematode population and leaf yield in AAU center after carbofuran treatment compared to control. However, both the treatments, carbofuran and three applications of *Trichoderma viride* were at par in producing leaf yield at JNKVV.

IPM for root knot nematode: The results showed that the application of oil cakes + carbofuran + three inoculations of *P. lilacinus* enriched oil cakes showed best control of root knot nematode and increased leaf yield compared to other treatments at AAU, JNKVV and RAU.

Population fluctuation of insects of betel vine: Results of ANGRAU, showed the incidence of tobacco caterpillar from October to December with a maximum leaf damage of 15.8% during the first fortnight of November. White mite incidence ranging from 9.2-14.0% leaf damage was observed from December to February. Severe incidence of red spider mites ranging from 16-27% loss in leaf yield was recorded during the month of March. On *Sesbania* support, higher incidence of leaf eating caterpillars was recorded with a maximum plant damage of 31.4% during the first fortnight of September, resulting in total death of newly planted seed vine cuttings ranging from 16-24%. Stem borer incidence with a range of 5.7-18.6 was noticed from August to February. Lady bird beetles (*Verania vincta*) were observed to be the most common predator in betel vine crop ecosystem followed by spiders. The beetles are found to feed on the early instar larvae of tobacco caterpillar and eggs of mites. At BCKV in the new bareja, the Homopteran fly complex white fly (*Dialeurodes pallida*) and black fly (*Aleurocanthus rugosa*) in MPAU, black fly and scale insects, mites and betel vine fly were most dominating insects.

Management of insect pests of live standards: At TNAU, spraying NSKE 5% or neem oil 2% after initial drenching with the same had significant effect in reducing the pest population. At 3rd day after spray, the mean number of freshly formed bore holes per plant was 0.70 in plots that received NSKE 5% spray and 0.80 in plots sprayed with neem oil 2%. These were significantly superior compared to drenching alone followed by neem cake application. The effect was also similar on 7th day after spraying. Though spraying NSKE 5% or neem oil was superior compared to control at 10th and 14th day, these were on par with the other treatments where spraying was not done. Based on the results, it may be concluded that drenching NSKE 5% or neem oil 2% followed by spraying suppress the stem borer on *Sesbania*.

Nutrient uptake studies: Nutrient uptake studies at different doses of N, P and K showed that the application of higher doses of major nutrients increase the uptake in plants. The soil depletion of nutrients was least under higher doses of NPK. Highest leaf yields were recorded in various centres with application of 200 kg N in the form of oil+ Urea or FYM with 100 kg each of phosphorus (SSP) and potash (MOP) per ha.

Rhizosphere competence and survival period of *Trichoderma* sp.: The population of *Trichoderma* sp. in the rhizosphere region increased with number of days after application from 20 to 80 days during the first year. Before application of *Tichoderma,* the population range was 4.5 cfu/ gram of dry soil. The maximum population of 83.70 x 10^3 cfu/gram of dry soil was recorded at 80 days after application. The population of *Trichoderma* was positively correlated with organic carbon content and number of days after application.

Standardization of inoculum for mass multiplication of *Trichoderma*: *Trichoderma* spore production was maximum when 60 g of culture was inoculated in 10 kg of de-oiled mustard cake or ground nut oil cake and incubated for 60 days and the spore concentration decreased significantly as the days of incubation period increased.

Crop loss assessment due to insect pests and mites: The loss in leaf yield was observed to be 32.4% and a net monetary gain of Rs.6,040/- per ha with a cost benefit ratio of 1 : 4 was recorded by controlling the pest through neem oil 0.5% spray. The leaf yield reduction was recorded to be 12.18 % in unprotected. Over all, monetary loss due to pest damage was Rs 18208/ per ha (34.13%) for five months.

The average number of mites observed in dicofol treated plots remained significantly lower (3.1) over control (7.2) after every spray at MPKV centre. The leaves coming from treated plots fetched 38.69 % more price in the market over those from control plots. The treatment with 0.05% dicofol for the control of mites in betel vine is essential for getting marketable leaves.

A total loss of 36.95 per cent marketable leaves due to linear scale insect was recorded and 14.09 per cent loss of marketable leaves due to scale insect in treated plot and 58.29 per cent loss of marketable leaves due to linear scale insect in untreated plot at TNAU. The cost benefit ratio was 1:14.99.

At TNAU centre, the plots protected with wettable sulphur 0.15% spray significantly reduced the number of red spider mites per 2m length of vine ranging from 0.0 to 0.13 with a mean of 0.07 as against 0.25 to 2.44 with a mean of 0.75 in unprotected. Loss of marketable leaves (36.95%) due to red spider mite was recorded in untreated plots and 14.54% in treated plot was recorded and the cost benefit ratio was 1:13.94.

Management of insect pests in live (*Sesbania*) standards: Application of NSKE 5% spray 3 times + NSKE 5% drench 3 times or application of *Beauveria bassiana* 5g/lit containing 1.8 x 10^6 spores/gm recorded higher mean plant height, stem girth and lower number of grubs per plant there by effectively checking the incidence of stem weevil at ANGRAU. Application of NSKE 5% and neem oil 0.5% checked the insect pest at TNAU.

Management of pests in betel vine garden: Higher leaf yield (43.3%) was recorded when wettable sulphur 0.3% was sprayed during the period of mite infestation. Spay of wettable sulphur 0.15%+NSKE 5% at 15 days interval recorded a maximum of 94.99 per cent reduction in linear scale insect population with leaf yield of 69.0 lakh leaves/ha.

The combination of wettable sulphur 0.15% + Azadirachtin 0.03% was found to be the best treatment for effective management of mites thereby reducing the number of damaged leaves. The cost benefit ratio was highest (1:99.7) for treatment with wettable sulphur followed by wettable sulphur + Azadirachtin (1:77.1).

For effective linear scale management, control methods should be started during third week of scale appearance and there after need based spray is advisable to keep the scale population below economic injury level.

Host range study of betel vine whitefly: *Dialeurodes pallida* is a monophagus and only host is betel vine (*Piper betle* L.). The adult *D. Pallida* harboured and layed eggs on all species of *Piper* tested. Eggs hatched and successful adult emergence also took place on all species. Percentages of egg hatching and adult emergence on *Piper longum, Piper chaba* and *Piper hamiltonii* were at par as that on *Piper betle*. So these species are new hosts of betel vine whitefly, *D. Pallida*. One unknown black fly and one new scale insect also have been recorded.

Betel vine industry

In spite of the importance of the crop in the economic life of the people, very little attention was paid in the past towards the its development. The betel vine leaf industry has come up in the country of its own even though it was neglected by the Government. In most of the states, market regulation has not been extended to this commodity. Betel leaves are highly perishable and are treated at par with vegetables. Market charges are very high in this crop in the absence of any control or regulations. The vast economic potentiality of the crop is recognized by the fact that about 15-20 million people consume betel leaves in India on a regular basis. However, worldwide there will be over 2 billion consumers of betel leaf (Jeng *et al.* 2002). Further, it is estimated that about 20 million people earn their livelihood directly or indirectly, partly or fully from production, processing, handling, transportation and marketing of betel leaves in India, which includes about 5 million workers from West Bengal (Guha 2006). The crop provides substantially to the national income to the tune of Rs 6000- 7000 million every year. In addition, the Railways earn about Rs 100 million every year by transporting betel leaves from West Bengal to different parts of India (Samanta 1994). The leaves are also exported to several other countries of the world where it is either not grown or in short supply. On an average betel leaves worth of about Rs 30-40 million are exported to the countries like Bahrain, Canada, Great Britain, Hong Kong, Italy, Kuwait, Nepal, Pakistan, Saudi Arabia and many other European countries (Singh *et al.* 1990).

Future options

- Betel leaves although used as masticatory, possess medicinal properties and used in most of the Indian systems of medicines. Therefore, it is necessary to find out diversified use of leaves which would support the betel vine industry to grow. There is great potential of its use for development of mouthwash and digestive medicines.

- Since betel vine hybridization is now possible because of its continuous flowering and fruiting at Bangalore condition, different traits recombination followed by proper selection would result in new varieties with desirable traits such as pest resistance, high quality in terms of essential oil, medicinal value, *etc.*
- Selection for high essential oil will be ideal to attempt for alternate uses of leaves. Essential oil of betel leaves is of high value and has a great demand in confectionary industry. However, extraction at present is not very economical because of low oil content in leaves.
- Maintenance of genetic resources of betel vine germplasm for future utilization needs attention and should get priority.
- Research priority for development of Good Agricultural Practices.

References

Amonkar A J, Nagabhushan M, D Souza A V & Bhide S V 1986 Hydroxychavicol: a new phenolic antimutagen from betel leaf. Food Chemistry and Toxicology 24: 1321-1324.

Chopra I C, Jamwal K S & Khajuria B N 1954 Pharmacological action of some common essential bearing plants used in indigenous medicine including Piper betle. Indian J. of Medical Research 42: 385.

Jeng J H, Chen S Y, Liar C H, Tung Y Y, Lin B R, Hahn L J & Chang M C 2002 Modulation of platelet aggregation by areca nut and betel leaf ingredients. Roles of relative oxygen species and cyclooxygenase Free Radical Biology and Medicine 32 (9): 860-871.

Guha P 2006 Betel leaf: The neglected green gold of India. J Hum. Ecol. 19(2): 87-93.

Khozirah S, Ling S K & Nik M 2000 Evaluation of the anti-inflammatory properties of *Piper betle* L II[nd] International Symposium on Chromatography of Natural Products, Kazimierz Dolny, Poland 14-16 June 2000 Herba-Polonica 46: 308-318.

Maiti S & Shivashankara K S 1998 Betel vine Research Highlights (1981-1997) Indian Institute of Horticultural Research, India.

Samanta C 1994 Paan chaser samasyabali-o-samadhan: Ekti samikkha (In Bengali): "A Report on the Problems and Solutions of *Betel vine* Cultivation" A booklet published by Mr H R Adhikari, C-2/16, Karunamoyee, Salt Lake City, Kolkata-64 (WB), India.

Singh K K, Balasubrahmanyam V R & Kochhar V K 1990 Effect of different packing methods, temperature conditions, treatment with chemicals on the senescence and storage behaviour of betel (*Piper betle* L.) leaves. J. Plant. Crops 18 (1): 23-28.

Sandhya Prabhu M, Patel K, Saraswathi G & Srinivasan K 1995 Effect of orally administered betel leaf (*Piper betle* Linn.) on digestive enzymes of pancreas and intestinal mucose and on bile production in rats. Indian J. of Experimental Biology 13:752-756.

Betel vine (*Piper betle*) in Vidarbha region

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Betelvine is a climbing vine cultivated for its leaves locally known as 'pan' or 'tambuli' in Hindi, 'nagavelli' or 'tabula' in Sanskrit and pan in Marathi. The oil extract of betel leaves is found to contain phenol and tarpin like compounds, eugenol, cardinen, eugenol methyl ester, estreogol, chavicol and caryophyllene. Betel leaf is also antirheumatic, anticough and and antirodent.

History

Betel leaves or pan is widely cultivated in tropical and subtropical regions and is probably a native of Malaysia. Betel leaves are also foreign exchange earner. Betel vine cultivation is a distinct plant based industry of our country with an approximate turn over of Rs. 6700 millions. It occupies an area of 3360 ha in India. Betel vine cultivation in Vidarbha is mostly confined to Akola, Amravati, Buldhana, Nagpur and Yeotmal districts.

The crop is prone to various diseases in central India, *Phytophthora, Fusarium*, *Sclerotium* and *Rhizoctonia* which cause the wilt/root rot/foot rot of betel vine. The losses estimated due to different pathogens varied in different parts. Due to *Rhozoctonia* sp., 50% loss was reported. Similarly 44 to 86 % loss due to *Phytophthora* and 25 to 90% due to *Sclerotium* sp. were reported. The wilt caused by *Fusarium* sp. seems to be of minor importance, although it has been considered as very important and serious in Maharashtra.

At present, it is cultivated only 41 ha in Vidarbha. The major area of betel vine is in Amravati, Akola and Buldhana districts and there is a fast decline in area during recent years. The reasons for this is often attributed to severe incidence of diseases likely wilt complex, leaf and stem blight, *etc*. In many areas it has been reported that the cultivation of this crop has been abandoned altogether due to severe rotting and wilting of vines.

A survey was undertaken during 2000 on incidence of betelvine diseases and plant protection measures adopted by farmers. The data revealed that the highest (13.63%) wilt incidence was observed in Akola District and lowest (8.83%) from Buldhana, with an average of 11.45%. The per cent disease intensity of leaf blight ranged from 12.79 to 17.18% with an average of 15.40%. The disease intensity of stem blight was observed to be 6.24% in Akola, 5.62% in Amravati and 5.03% in Buldhana. Another important disease was root knot caused by nematode, the intensity of which was 6.00% in Amravati, 5.33% in Akola and 4.66% in Buldhana with an average of 5%.

The individual farmer to farmer contact revealed that, the use of pesticides for the control of betel vine diseases was negligible. On an average only 1.59% farmers were using pesticides for the control of diseases. However phorate application for control of nematode in general is practiced. Phorate application was practiced by 68.19% farmers in Akola followed by 54.12% in Amravati and a minimum 12.11% in Buldhana District. In Buldhana District, 35.41% farmers applied ground nut cake in soil, however they are not using neem cake which possesses nematicidal properties.

Due to the low cost of betel vine (Akot Kapoori) in market and problem of wilting the pan growers of this area are attracted towards cultivation of pan pimpri. Many growers are shifted to pan pimpri cultivation but this will aggravate the problem of wilt complex and nematode in future.

There are two cultivation systems of betelvine

Open system : Kapoori variety is grown usually under live shade, as it fetches lower market value. It is uneconomical to cultivate *Kapoori in pendal* system. Kapoori is grown by creating artificial condition by making special pan orchards called 'tanda' in Maharashtra. This system of cultivation provides congenial condition to pathogen and nematodes infestation.

Pandal system : A house like structure with 2.5 m height using bamboo, wooden poles and grass is used for construction which normally costs Rs.1.5 to 2 lakh/ acre. At Betel vine Research Station, Ramtek, conservatory was erected using iron pole and galvanized iron wire that cost only 0.6 lakh/ acre. The sides and top of the conservatory were covered with locally available thatching material such as dried grass, paddy straw or sugarcane leaves to get quality and quantity leaves from meetha. A net house was commissioned at Ramtek to cultivate *Bangla*, *Sanchi* and *Deshavari* varieties. A polyhouse for meetha was found better so as to save the vines from stem canker which is major problem of this variety.

In Vidarbha region, Kapoori variety is grown in open shade system. The land is divided in to beds of 6'x 4' with required channel for irrigation. The planting is done on the sides of the bed and the vines are tied on to the live support of pangara/ hadaga/shewari/heta. Generally there are four to five tenants in each field holding about 0.25 to 0.5 acre land. The source of irrigation is from open well with common irrigation channel.

Recommendation and suggestion by the University

- Soil solarization of betel vine garden in the month of April – May.
- Marigold planting before cultivation of betel vine as a trap for nematodes.
- Soil application of neem cake 8q /acre in two split doses in the month of July and December.
- Application of 1% Bordeaux mixture to be spread on soil if not solarized.

- Dipping of cuttings in 0.5% copper-oxychloride or 1% Bordeaux mixture for 30 minutes prior to planting.
- Application of *Trichoderma (*as set treatment for 30 min.) before planting. Soil application of *Trichoderma* with FYM 4 kg/ vine in June and December in affected area.
- Set treatment of IBA or Ceredex for rooting of cutting.
- Inter cropping of pan pimpri in betel vine should be avoided.
- Planting of pangara (*Erythrina indica*) is instead of shevari (*Serdania aeqyptica*) in betel vine orchards for shade and support.
- Drenching of 1% Bordeaux mixture 10 l / 5 m^2 in the months of July to December once in a month or after two months in root zone of betel vine. One kg *Trichoderma* and 9 kg FYM kept moist for 8 days and applied through soil @ 100 g / m^2 for controlling the wilt of betel vine.
- spraying with 25 g copper oxychloride or 20 g dithane M- 45 in 10 l of water, two sprays at an interval of 15 days for the control of leaf spot.
- Adoption of drip irrigation for water management to minimize the wilt.
- Application of phorate 10 G @ 4 kg/acre through soil for the management of nematodes.
- For minimizing the wilt in betel vine, treatment of cuttings with *Trichoderma* (1 kg *Trichoderma* + 9 l of water) at the time of planting, followed by soil application (1 kg *Trichoderma* mixed with 9 kg FYM) at the rate 100 g mixture / m^2 at monthly interval (from June to January).

IDM module

- *Trichoderma* (set treatment + soil application) 1 kg *Trichoderma* + 9 l water at the time of planting and 1 kg *Trichoderma* + 9 kg FYM @ 100 g/ m^2 during June to January at monthly interval.
- Application of neem cake @ 20 q/ha twice in a year (June, January).
- Spraying of 10 ppm salicylic acid, 2 sprays.
- Application of fertilizers 100:50:50 kg ha^{-1} NPK (nitrogen through ammonium sulphate) in June, half dose of nitrogen to be given in December.
- Drip irrigation.

Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, established two Research Stations for betel vine. One is at Ramtek (Nagpur District) and another is at Diwtahna (Akola District) to facilitate the research of betelvine in Vidarbha region. The research has been carried out by these stations on the various problems of betelvine and necessary guidelines are given to betelvine growers.

The pan growers are marginal farmers having land holding of 0.25 to 0.5 acre. There are 4 to 5 tenants in pan field with common irrigation source. They are economically poor and can not adopt improved practices of betel vine cultivation. Most of them are reluctant to undertake the control measures as they were more convergent with the religious and indigenous practices. Even if it is taken up by individual tenants for small area the control of disease is not possible because of the inoculum built up in adjacent area of same field, where such practice is not adopted. Enough care is not taken by the grower to maintain the fertility of soil as they are only tenants and not owner of the field. The ground water table of this area is going down day by day and pan growers are facing acute irrigation problems due to short of rains.

Kapoori pan fetches very low price in the market and this is the reason for not adopting the improved practices. Many farmers shifted to cultivation of *Piper longum* as it fetches higher price being a medicinal value and spices. The marketing is through commission agents, such agencies take undue advantages of economic status of pan growers. Marketing through co operative societies may give higher price to betel vine growers. The marketing of the betel vine can be improved by support through govt. authority and some export oriented facilities should be provided to this commodity.

The main problem of the betel vine growers is the wilt complex and it is only due to specific belt that is being used for cultivation. Due to continuous use of same belt under single crop the soil became sick . The farmers neither adopt improved practices nor adopt plant protection measures which aggravate the disease problem.

Strategy for improvement of betelvine cultivation in Vidarbha region

- Formulation of need based research programmes
- Provision for poly house / shed for betel vine cultivation in Akot area to combat wilt problem and improve production and quality of betelvine.
- Frontline demonstrations in farmers fields
- Regular guidance for cultivation and management of wilt complex
- Production of disease free seedlings using tissue culture technique

Government level

- Providing subsidies to betel vine growers on inputs for management of betel vine wilt complex
- Strengthening of betel vine research stations
- Subsidies for drip irrigation sets to promote drip for betel vine
- The possibility of exporting betel vine leaves should be explored
- The betelvine by-product industries should be supported
- Water conservation programmes to recharge ground water

Selected references

AgarkarG V, Bhagwat Y & Somani R B 1992 Microbial population in rhizosphere of diseased & healthy betel vine. Indian J. Microbial Ecol. 2: 21-27.

Patil M R, Waghe S V, Wangikar P D & Khune N N 1986 Chemical control of wilt of betelvine. Pesticide 20(9): 28-29.

Raut S P &V N Shukla 1973 *Fusarium moniliforni,* a potential pathogen of betelvine wilt. PKV Res. J. 2 (1): 59-60.

Gawande R L & Shukla V N 1977 Effect of some fungicide on control of betelvine cultivation. PKV Res. J. 49 : 7-10.

Patil M R, Waghe S V, Dwangikar P & Khune N N 1982 TROC first national workshop on betelvine: p 37.

Wangikar P D, Khune N N & Waghe S V 1982 TROC first national workshop on betelvine: pp. 48-49.

Waghe S V (1992) Pan velichi lagwad va niga. PKV bulletin No. 182.

Waghe S V, Bhombe B B & Khune N N (1993) Effect of drip irrigation on incidence of betel vine foot rot. Advances in Betelvine Production Tech: 60-63.

Bindu R J 1968 Investigation on the role of *Meloidogyne incognita* and *Fusarium* spp in causing the wilt of betelvine (*Piper betle* L.). M.Sc. (Agri.) thesis, Nagpur University, Nagpur.

Agarkar G D 1971 Study of rhizosphere fungi of betelvine as influenced by nematode infestation and seasonal variation. M.Sc (Agri) thesis, Dr P D K V, Akola.

Waghe S V 1991 Studies on betelvine wilt disease in Vidarbha Ph.D thesis, Dr P D K V, Akola.

Bramhankar S B 2003 Investigation in to status, causes and management of betelvine wilt / foot rot in Vidarbha, Ph.D thesis, Dr P D K V, Akola.

Current status of genetic resources of *Piper betle* in India

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Introduction

The genus *Piper* consists of shrubs, rarely herbs and trees which are distributed through out the tropical and sub tropical regions of the world. In India, there are about 30 species available of which *P. betle*, *P. nigrum* and *P. longum* are the cultivated species. *P. betle* is a perennial, evergreen, dioecious climber which is a native of Central and Eastern Malaysia from where it has spread through out tropical Asia and Malaysia; Madagascar and East Africa at a later date.

Betelvine or betel leaf is associated closely with cultural traditions of India and is considered as a holy plant. Fresh leaves are generally consumed along with betel nuts (*Areca catechu*). It has many medicinal usages in Indian system of medicines to cure indigestion, stomach-ache, diarrhoea, flatulence and to heal wounds, bruises, swellings due to sprains, bruises, respiratory disorders, constipations, boils and gum disorders. Studies also revealed that the leaf improves immune system and inhibits cancer growth.

It was believed that only male plants were grown in India (Aiyer 1947) until the discovery of female and male flowering and fruiting in the species (Raghavendra Rao & Maiti 1989). Germplasm collection of betelvine was not systematic until the establishment of All India Co-ordinated Research Project (AICRP) on betelvine in 1981 wherein a large number of collections were made at the national level which were exchanged and maintained at its different centres.

Nomenclature

All the germplasm collections were under cultivation and were the result of selections made by the farmers. The farmers had used the taste, shape or colour of the leaf or the locality to name the cultivars in the respective vernacular languages. Hence there are same names for different cultivars and different names for the same cultivars exist at different geographical boundaries. Deshawari is also known as Bilhari; Sanchi as Kalipatti; Kapoori as Safedi (Balasubrahmanyam *et al.* 1994a). Also the term 'Desi' refers to Bangla types in North East India and North India and Kapoori in Southern India. Similarly, Assamiya Pan is also known as Gach Pan. All these resulted in duplication of some germplasm in addition to confusion in identification.

Morphological variability

Ganguly & Gupta (1973, 1974a) described cultivars available in the market of West Bengal in India as Sanchi, Meetha and Bangla on the basis of morphological characters and texture and test of leaves. Such cultivars fall in different categories according to quality as recognized in the market by the traders. Ganguly & Gupta (1974b) classified twelve Bangla type cultivars in two distinguishable groups on the basis of leaf morphology, one having ovate shape and the other having elongated shape especially towards upper half of the leaves. Similarly they observed that Sanchi cultivar is an assemblage of two morphologically distinguishable forms. Ganguly (1984) recognized 15 types of Bangla cultivars based on taste, texture and morphology. Das & Chattopadhyay (1984) grouped the cultivars of Midnapur District of West Bengal into 17 types based on morphological, anatomical, micrometrical and phytochemical parameters. However, Narayan Reddy (1984) classified 55 cultivars collected from different parts of India into two groups, such as pungent and non- pungent. Sexual dimorphism in terms of length: breadth ratio is also reported in the species (Maiti & Biswas 1991; Maiti *et al.* 1992). Male plants have leaves which are narrowly ovate with 1.84 ±0.21 length: breadth ratio and female plants have cordate or ovate to round leaves with 1.26 ±0.13 length: breadth ratio. Leaves of the female plants are mostly pungent and male plants are less-pungent. Balasubrahmanyam *et al.* (1994b) classified 85 collections at National Botanical Research Institute into five distinguishable types *viz.*, Bangla, Desawari, Kapoori, Meetha and Sanchi.

Chromosome number and ploidy status of the germplasm

Chromosome number reported by various workers in India are 2n=26 and 52 (Samuel & Bavappa 1981), 2n=32 and 64 (Sharma & Bhattacharya 1959; Dasgupta & Dutta 1976), 2n=78 (Mathew 1958; Jose 1982) and 2n=42, 52, 58, 78, 195 (Jose & Sharma 1988). Hence the betel vine workers report it as a polyploid species with a basic chromosome number x=13. As far as chromosome structure is concerned, all cultivars showed uniformity in the karyotype.

Hybridization work was also initiated and a few hybrids have been developed in India. But in certain cross combinations, hybrid depression has been noticed. It was assumed that the reason for the hybrid performance may be due to the incompatible ploidy number between the parents. Cytological study conducted at NRCMAP (unpublished) showed that females were tetraploids (2n= 4x= 52) and males were triploids (2n= 3x= 39). Ploidy comparison by flow cytometry confirmed that all the accessions could be grouped into two classes *i.e.,* all the males were triploids and females were tetraploids.

Molecular characterization

RAPD analysis in selected cultivars of Kapoori and Bangla was carried out in order to ascertain the relatedness of the cultivar groups (Ranade *et al.* 2002). On the basis of the data from 10 RAPD primers, it was found that the Kapoori cultivars were more heterogeneous while the Bangla cultivars were mostly similar to each other. Within each type, the overall polymorphism of RAPD bands was more than 70 %. When RAPD band data for both types of cultivars were considered cumulatively, the two were clearly separated out from each other. Only six bands out of the total of 60 bands were found to be common to cultivars of both types. The study showed that bands specific to only one of the two types have potential for developing betelvine cultivar-specific probes and SCAR markers.

Another study by Verma *et al* (2004) gives the first systematic evidence that gross molecular profiling reflects gender distinction in betelvine. They used random amplified polymorphic DNA (RAPD) analysis in several landraces which were considered in four groups, namely, 'Kapoori', 'Bangla', 'Sanchi' and 'others' suggests the primary splitting of the groups in the NJ tree was based on gender since all the landraces in the group 'Kapoori' clustered together and are known to be male vines. On the other hand, all known female vines amongst the groups 'Bangla', 'Sanchi' and 'others' were clustered separately along with vines of unknown gender. Hence the study doubts presence of gender-based distinction among the betelvine. The data suggested that 'Kapoori' groups or the male betelvine groups are more heterogeneous relative to the female vines. Also it is not known whether the betelvine plants have the similar chromosomal basis of sex determination as the other dioecious plants have.

Variability in essential oil content

Study conducted based on the essential oil content from *P. betle* showed that the different landraces were distinguished on the basis of the proportion of chemical constituent in the essential oils of the leaf (Sharma *et al.* 1982, 1983, 1987; Rawat *et al.* 1989). On the basis of chemical constituent analysis of leaf essential oils, five prominent groups of betelvine landraces, namely, Bangla, Kapoori, Meetha, Sanchii and Deshawari have been recognized. The oil of Kapoori is the lightest (specific gravity 0.9650) followed by Meetha (specific gravity 0.9991). Oil yield is highest in Meetha pan (0.85%). Bangla possess clove like spicy odour, with a sharp pungent taste; Desawari is yellow coloured with pungent taste followed by sweet taste; Kapoori oil is yellow with greenish tinge and aromatic odour; Meetha pan is having yellowish oil with fennel like odour and sweet taste and Sanchi oil is dark brown with sharp pungent taste. Eugenol is the major constituent and less pungency in Kapoori and Deshawari is due to the low concentration of eugenol content. Fennel like smell in Meetha pan is due the presence of anethole in the oil. But classification based on essential oil content may be erroneous until the cultivars are grown under same environmental conditions and then classified.

Descriptor

AICRP (= AINRP) has developed and used a descriptor for the characterization of the available diversity present in the assemblage of germplasm. There are 25 morphological and other characters as follows:

Branching habit; Leaf area; Leaf breadth; Leaf length; Leaf shape; Leaf colour; Lamina; Colour of branch; Internodal length; Colour of internode; Petiole length; Main vein numbers; Leaf tip; Vein termination numbers; Stomata numbers; Stomatal size; Stomatal Index; R- value; Palisade ratio; Organoleptic test; Disease reaction; Insect pest reaction; Keeping quality; Post harvest disease reaction; Special characters, if any.

Germplasm collection at different AICRP centres

At present there are eight centres of AICRP where a large number of germplasm is maintained. All these centres collected and exchanged the available genetic variability present in their respective states. In addition to this, in the Xth plan, ICAR has created a breeding centre for betelvine at Indian Institute of Horticulture Research, Bangalore since flowering is common through out the year at Bangalore climate. The centre is maintaining all the germplasm collected by different centres at their field gene bank. Since the origin of the species is in Malaysia, all the available germplasm are the naturalized population maintained through cultivation over centuries. Hence the available germplasm are the selections made by the farmers over a period of time based on their personal preferences influenced by the market trends or consumer trends from time to time. All these different types of cultivars were collected by the AICRP centres and characterized. Characterization data of germplasm collections made by different AICRP centres are as follows:

Assam Agricultural University (AAU), Jorhat maintains eleven accessions of *P. betle* collected from Assam. All the accessions are females. Except two accessions (APb 3&4), all the others are grown as perennials along with plantation crops *viz.,* coconut and areca nut. APb 2 showed resistance against all the major diseases and the species can be used for resistance breeding programmes.

Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani maintains 14 accessions and all are females. KPb 3 (Meetha pan) is the promising and unique among these accessions. It is having the major share in Indian market, it contains high methyl eugenol. However, the clone is highly location specific (a potential GI) and suffers high degree of disease susceptibility and poor keeping quality. KPb 10 (Halisahar Sanchi) is also specific due to its scented taste and multiple disease resistance. KPb 2 (Ghaneghette) is another promising type due to its closely spaced internodes and high yield potential. KPb 13 (Birkuli Bangla) shows very good keeping quality.

Acharya N G Ranga Agricultural University (ANGRAU), Bapatla maintains 12 germplasm and all are males and could be classified into Tellaku, Kuljedu, Kapoori and Karapaku groups. Except Karapaku all the others are non-pungent type. Tamil Nadu Agricultural University (TNAU), Siruganani maintains thirteen accessions and all are males. Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Jabalpur maintains ten accessions comprising of Bangla and Kapoori types.

Mahatma Phule Agricultural University (MPAU), Sangli has eleven accessions. Majority of these accessions are of Kapoori type. DPb 6 (Shirpurkata) is moderately resistant to foot rot and all the other accessions are highly susceptible to foot rot. DPb 7 (Vasani kapoori) is good in keeping quality. Orissa University of Agriculture & Technology (OUAT), Bhubaneswar has eleven accessions and all are females. Except OPb 3 (Berhanpur sanchi) which is a moderately pungent type, all the accessions are pungent. Most of the accessions show very good keeping quality at this centre.

Rajendra Agricultural University (RAU), Pusa maintains ten accessions and all are females with cordate leaves. All the accessions are of pungent type. PPb 3 (Maghai pan) has a major share in export of betelvine from Bihar due to its good taste and flavour resulting in better palatability. At this centre also most of the accessions show very good keeping quality.

Future prospects

Yield potential of the species has to be enhanced further. Hybridization work has to be targeted with definite objectives from the information available from the characterization data of the germplasm. Hence a multilocational characterization of the available germplasm is to be focussed for the identification of different parental combinations *i.e.,* morphological characterization for defining the DUS characters, molecular characterization for identifying the distant male and female parents for haploid production and in heterosis breeding and the inheritance of sex by the study of hybrid progenies.

References

Aiyer A K Y N 1947 Field crops of India. The Superintendent, Government press, Bangalore, pp. 468-479.

Balasubrahmanyam V R, Johri J K, Rawat A K S , Tripathi R D & Chaurasia R S 1994a Betelvine (*P. betle*) Economic Botany Information Service, National Botanical Research Institute (Council of Scientific and Industrial Research), Lucknow, 226 001, India, p.13.

Balasubrahmanyam V R, Johri J K, Rawat A K S, Tripathi R D & Chaurasia R S 1994b Betelvine (*Piper betle*) Economic Botany Information Service, National Botanical Research Institute (Council of Scientific and Industrial Research), Lucknow, India, p. 14.

Das A K & Chattopadhay N C 1984 Studies on the standardization of betelvine cultivars of Midnapur District. In : Proceedings of national workshop on betelvine Roy S K *et al.* (Ed.), Calcutta university, Calcutta, The Agricultural Society of India, Calcutta, India, pp. 23-32.

Dasgupta A & Datta P C 1976 Cyto-taxonomy of piperaceae. Cytologia 41: 697-706.

Ganguly P & Gupta D 1973 Identity of betel leaf (*Piper betle* Linn.) in West Bengal market-part I. Indian Agric. 17:251-55.

Ganguly P & Gupta D 1974a Identity of betel leaf (*Piper betle* Linn.) in West Bengal market-part II: Bangla or country variety. Indian Agric. 18:37-45.

Ganguly P & Gupta D 1974b Identity of betel leaf (*Piper betle* Linn.) in West Bengal market-part III: Sanchi variety. Indian Agric. 18: 249-52

Ganguly P 1984 Varietal classification and quality control of betelvine in West Bengal. In: Proceedings of group discussion on improvement of betelvine cultivation. Khanduja S D & Balasubrahmanyam V R (Eds.) National Botanical Research Institute, Lucknow. pp. 94-100.

Jose J 1982 A comparative analysis of chromosome constitution and aromatic components in different cultivars and wild varieties of *Piper betle* Linn. in India. In: Proceedings of the second national workshop on betelvine. Pp. 6-7. Calcutta.

Jose J & Sharma A K 1988 Karyomorphological studies on *Piper betle*. Acta Bot. Indica. 16: 186-194.

Maiti S & Biswas S R 1991 Sexual dimorphism in betelvine. Indian J. Agric. Sci. 61: 656-658

Maiti S, Biswas S R & Raghavendra Rao N N 1992 Divergence in sexual dimorphism among betelvine (*Piper betle*). Indian J. Agric. Sci. 62: 780-782.

Mathew P M 1958 Studies on piperaceae. J Indian Bot. Soc. 37: 153-171.

Narayan Reddy 1984 Betelvine research in Andhra Pradesh. In : Proceedings of group discussion on improvement of betelvine cultivation. Khanduja S D & Balasubrahmanyam V R (Eds.) National Botanical Research Institute, Lucknow. p. 125-128.

Raghavendra Rao N N & Maiti S 1989 Occurrence of flowering in betelvine (*Piper betle*). Indian J. Agric. Sci. 59:665-666.

Ranade S A, Verma A, Gupta M & Kumar N 2002 RAPD profile analysis of betelvine cultivars. Biol. Plant. 45: 523–527

Rawat A K S, Tripathi R D , Khan A J & Balasubrahmanyam V R 1989 Essential oil components as markers for identification of *Piper betle* L. cultivars. Biochem. Syst. Ecol. 17: 38–55

Samuel M R A & Bavappa K V A 1981 Chromosome numbers in the genus piper. Curr. Sci. 20: 197-198.

Sharma A K & Bhattacharya N K 1959 Chromosome studies on two genera of family piperaceae. Genetica 29: 256-289.

Sharma M L, Rawat A K S, Balasubrahmanyam, V R & Singh A 1982 Essential oil of betelvine leaf (*Piper betle*) var. Kapoori. Indian Perfumer 26 (2-4): 134-137.

Sharma M L, Rawat A K S, Balasubrahmanyam, V R & Singh A 1983 Essential oil of betelvine leaf (*Piper betle*) Part II. var. Desi Bangla, Ramtek Bangla and Culcuttia Bangla. Indian Perfumer 27(2) :91-93.

Sharma M L, Rawat A K S, Balasubrahmanyam, V R & Singh A 1987 Essential oil of betelvine leaf (*Piper betle*) Part III. var. Desi and Mahoba Desawari. Indian Perfumer 31(4): 319-324.

Verma A, Kumar N & Ranade S A 2004Genetic diversity amongst landraces of a dioecious vegetatively propagated plant, betelvine (*Piper betle* L.). J. Biosci. 29: 319–328.

Crop improvement in *Piper betle* L. status and future strategies

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Introduction

Betel vine (*Piper betle* L.) is a perennial diocious climber belonging to Piperaceae. It is a heritage cop of India, being mentioned in Vedic literature and epics. Betel leaves are an integral part of all Hindu customs and religious ceremonies. Betel vine is cultivated in different parts of the country for its fresh leaves, which are used as masticatory. Chewing pan is an age-old custom in Asia especially in India. The quid or pan is prepared by spreading a layer of slacked lime and chewed along with areca nut powder and a wide variety of other flavorings like clove, cardamom, nutmeg *etc*. Besides this, betel vine is widely used in traditional medicine. In Ayurveda, leaves are used to cure kapha and vata, foul smell in mouth, ozoena, elephantiasis in leg and loss of appetite (1980). Leaves are used to cure indigestion, cough, and cold and to heal cuts and wounds. The betel vine roots are used to prevent conception. The volatile oil of betel leaves has antiseptic properties. The cultivars from India are favoured and have been introduced in other countries in preference to Malaysian or Javan cultivars because of their high oil content and more pungency (Weiss 2002).

It is also an important cash crop of our country. It is estimated that 20 million people derive their livelihood from production, processing, handling, transportation and marketing of betel leaves in India. The leaves are also in great demand in several other countries earning a foreign exchange to the tune of 30-40 million rupees.

Origin and distribution

Unlike *Piper nigrum* L. which originated in Western Ghats of India, *Piper betle* might have originated from Malaya archipelago. Burkill (1966) described the native place of betel vine as Central and Eastern Malaysia from where it has spread to tropical Asia and Malaysia. Later it reached to Africa and West Indies. In India, betel vine is widely cultivated in the states of Uttar Pradesh, Bihar, Madhya Pradesh, North Eastern India, Maharashtra, Karnataka, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Andamans with an area of 55,000 ha with an annual production worth 9000 million rupees. In Karnataka, it is grown in an area of 7537 ha with a production of 144885 lakh leaves, mostly as an intercrop in arecanut gardens.

Karyomorphology

Study of karyotype is essential for understanding interrelationships and evolutionary trends. In genus *Piper* polyploidy is associated with a marked reduction in chromosome length. Different studies reported the chromosome number (2n) varying from 32 to 195 in *Piper betle*. Dasgupta & Dutta (1975) opined that among *Piper* genus, *Piper betle* (2n=64) seems to represent a different line of evolution having X=8 or 16. Viji & Subramanian (1988) reported that *Piper betle* is an aneuploid not having the chromosome numbers in multiples of 12.

Crop improvement

Crop improvement in betel vine is mainly aimed at producing varieties for high yield combined with resistance to biotic and abiotic stress with high quality attributes. Betel vine does not have much variation as the crop is propagated clonally through centuries. Creation of variations through different breeding approaches is an essential pre-requisite to evolve new types. Breeding methods like selection and hybridization have been attempted in betel vine. Induction of new variations can also be achieved through mutation and somaclonal variations. Inter specific hybridization involving different species harboring resistant genes for biotic and abiotic stresses can be a possible approach for evolving resistant varieties.

Germplasm evaluation: Germplasm collection, characterization, classification and identifying diverse genotypes are the essential prerequisites for any breeding programme. There are around 100-150 known types of betel vine in India. The naming of these cultivars is ambiguous as many of them are generally named after the locality where they are grown. Many studies classified the betel vine cultivars into different categories based on leaf traits, morphological, anatomical and phytochemical properties. These studies placed the cultivars into Bangla, Meetha, Sanchi (Das & Chattopadhyay 1984) and pungent/non pungent (Reddy 1996) categories. Another study based on morphological and chemical analysis grouped the cultivars into Bangla, Desawari, Kapoori, Meetha and Sanchi (Rawat *et al.* 1989). In *P. betle* gender-based differences were reported on the basis of leaf shape, amount of chlorophyll, essential oil composition and in total phenol and thiocyanate content (Maiti *et al* 1992; Pandey *et al.* 1998; Tripathy *et al.* 2006). There is need to evaluate all the available cultivars under uniform field conditions and develop comprehensive morphological, biochemical and molecular descriptors for proper classification of the existing cultivars.

All India Network Research Project (AINRP) on betel vine identified 25 distinguishing morphological traits and other attributes as descriptors (Maiti & Saikia 2002). Germplasm holdings from the centers are being characterized with the available descriptors. At Indian Institute of Horticultural Research (IIHR), efforts are on way to develop comprehensive descriptors including flower traits and other additional quantitative and qualitative characters.

Sources of disease resistance for different diseases: Breeding of betel vine for disease-resistance should be aimed at foot and leaf rot, bacterial leaf spot and wilt. Locating the sources of resistance, their transfer and isolation of desired recombinants in segregating populations can help in evolving resistant cultivars.

Resistant cultivars of betel vine

Disease	Resistant cultivars
Phytophthora (leaf spot, foot rot)	Halisahar Sanchi, Pachaikodi, karapaku
Anthracnose	Halisahar Sanchi, Awanipan
Sclerotium rot	Halisahar Sanchi, Alupatria
Bacterial leaf spot	Pachaikodi, Halisahar Sanchi, Awanipan, Simurali Bangla
Powdery mildew	All Kapoori cultivars

(Maiti & Shivashankara 1998; Maiti & Saikia 2002)

These identified sources of resistance are being utilized as parents in the hybridization. programme at IIHR.

Biometrical studies: Studies on genetic diversity showed that the diversity in betel vine is not related to the geographical origin but can be attributed to the sexual dimorphism. Das *et al.* (2000) in their study with 16 genotypes observed that clustering pattern of genotypes into 5 clusters was random and did not follow the geographical origin. Similar results were reported by Rahaman *et al.* (1997a). The clustering pattern of 27 genotypes into 10 different clusters was random and geographical origin did not play any role in their divergence pattern. They identified leaves/vine, leaf area, shelf life as the potent variables in selecting diverse parents for hybridization programme. Maiti *et al.* (1992) studied the divergence pattern in thirty cultivars and noted the gender based clustering pattern. Stability analysis of twenty seven genotypes of betel vine in three seasons for 10 yield components showed that the differences among seasons were highly significant for all the characters except leaf thickness. Stability estimates showed that only Kare Bangla and Adi Bangla cultivars recorded high mean values for leaf yield and total leaf area/vine (Rahaman *et al.* 1997b).

Clonal selection: Advanced cultivars have been derived by clonal selection from land races, through multi location testing for their adaptability and yield under AICRP on betel vine. SGM-1 is a selection from a collection from Kerala ('SB-35') released in Tamil Nadu. It bears prolific secondary and tertiary branches and gives 20-30 per cent higher leaf yield than the local cultivars with good resistance to most of the important diseases. Bidhan Pan is a selection from the local 'Bangla' cultivar with short inter nodal length released in West Bengal and Orissa. Another selection DBP-6 is a high yielding selection from a local 'Kapoori' collection and released in Maharashtra for cultivation.

Hybrid breeding: *Piper betle* L. is a dioecious perennial climber. Betel vine being vegetatively propagated crop, variability present in the cultivated clones is limited. Hybridisation is a potential tool to breed new varieties having high yield potential with better quality and resistance to diseases and pests. Report on flowering of male and female vines and fruit setting at Bangalore conditions in India opened up the possibility of hybridization in betel vine. Since the plant is clonally propagated, heterosis can be fixed and exploited easily. Among four hybrids (GN, GB, P1 and P2) developed under the All India Network Research Project on betel vine, hybrid GN expressed hybrid vigour and is now under multi-location testing. (Anon 2006).

Considering the requirement of varietal development of betel vine, Indian Institute of Horticultural Research (IIHR), Bangalore has been included in the AINRP on betel vine to revive the programme on hybridisation. Systematic breeding programme was initiated by collecting the germplasm from different AINRP centers and through other secondary sources and through exploration, A total of 104 different lines have been collected and eighty lines were established with areca nut as a standard at CHES, Hirehalli, a regional station of IIHR. Hybridisation started during November 2005, when the first flowering was observed in the germplasm. Subsequently flowering was observed in 36 female clones and 26 male clones and these are being utilised in the hybridisation programme. The techniques of hybridisation, seed germination and seedling establishment have been standardized.

The vine exhibits dimorphic growth pattern. The main stem (orthotropic shoot) climbs up the support. It produces lateral branches (plagiotropic shoots), which bear inflorescence. In the inflorescence naked flowers are arranged in a dense spike akin to catkin. Male spike is long, cylindrical and pendulous. There is wide variation in the length of spike among the 26 male clones, (5.1 to 10.63 cm) with a thickness ranging from 0.65 to 1.25 cm. The growth of male spike was completed within 35 to 40 days after emergence. Female inflorescence is a short, blunt and flowers arranged in spiral rows on the spike. The length of the female inflorescence among the flowered clones ranged from 1.06 to 3.9 cm and its thickness ranged from 1.0 to 1.6 cm. The female inflorescence takes 30-35 days to complete its growth from emergence. Variation in flowering behavior is also observed among the accessions. The genotypes Kakair and Meetha pan did not produce laterals or flowers even after three years of planting. Clones Bangla Mandsore, Maghai and Black Leaf have produced very few laterals and inflorescence after two and half years of planting. Among the female accessions, Kalipatti has shown very shy flowering and produced very few laterals and spikes. Continuous and profuse flowering was seen in female clone SGM1 and male clone Swarna Kapoori. Significant differences were observed among the accessions for the production of spikes, which varied from 2-8 per lateral.

In the male catkins, period of anthesis ranged from five to seven days and peak anther dehiscence was recorded between 2 to 4 PM. Female catkins stay in receptive phase for 7-8 days. Continuous pollination for 7-8 days resulted in uniform fruit development and 80-85% fruit set is observed in all crosses. Fruits take 90-120 days to ripen and turn brownish green and soft. Wide variation was observed among hybrids for number of seeds per fruit (8 to 61).

Seed germination ranges from 2.0 to 80% in different crosses. Emergence of radicle is seen from 11-15 days. Seeds from dried fruits on the vine, air dried fruits and air-dried seeds recorded poor germination. One hundred and fifty different crosses were attempted and large number of hybrid seedlings (> 3000) was raised. The hybrid seedlings showed segregation for many morphological traits like plant vigor, leaf size, leaf shape, leaf color, internodal length and stem pigmentation. Severe reduction in growth and vigor, leaf size and growth abnormalities were also observed among the hybrid population. Vigorous hybrids selected from different crosses based on the plant vigour, vine length, internodal length, number of leaves, leaf size and leaf colour are being multiplied. Selected hybrids are being propagated through split bamboo technique for further evaluation.

Biotechnology

Micro propagation: Development of micro propagation techniques helps in producing disease free planting material, creation of somaclonal variation and enables the application of biotechnological tools. The success of genetic transformation technology largely depends on efficient regeneration system. Tissue culture techniques play important role in clonal propagation and conservation of germplasm. Few studies have been reported on the standardized protocols for micro propagation of *Piper betle*.

The regeneration was obtained directly or through intermediary callus phase with explants from shoot, leaf and root tissues in cv Lakkuvalli (Nirmal Babu *et al.* 1992). Woody plant medium (WPM) supplemented with 3 mg l^{-1} BA and 1 mg l^{-1} kinetin was found to be ideal for multiple shoot production and regeneration of plantlets. Regeneration of betel vine through somatic embryogenesis was reported in cv Desi Bangla (Johri *et al.* 1996) and callus tissue was developed from shoot tip explants cultivated on MS medium (NAA 3 mg l^{-1}, BAP 0.05 mg l^{-1}). Embryogenic tissue at cotyledenory stage was cultured in differentiation media with 0.9 mg l^{-1} kinetin, 0.5 mg l^{-1} IAA and 20g l^{-1} sucrose. Development of complete plantlets from callus phase took 9 to 10 months. Bhat *et al.* (1995) reported shoot bud regeneration on internodes and nodal explants. Where as root and leaf explants of betel vine though produced callus failed to show organogenesis. Aminuddin *et al.* (1993) developed regeneration protocol of *P. betle* from callus tissue. Tissue cultures derived plantlets were successfully transplanted into pots for hardening.

Molecular markers: Few attempts have been made in b*etel vine* to distinguish the cultivars based on biochemical and molecular markers. Studies using isozymes could not identify the groups based on peroxidase banding pattern (Kocchar *et al.* 1984). RAPD analysis of selected cultivars of 'Kapoori' and 'Bangla' betel vines revealed that the 'Kapoori' cultivars were more heterogeneous while 'Bangla" cultivars were mostly similar to each other. Within each type, the overall polymorphism of RAPD bands was more than 70 per cent (Ranade *et al.* 2002). Another study using 11 RAPD primers, grouped 41 land races into Kapoori, Bangla, Sanchi and others. The results indicated the 'Kapoori' group is the most diverse, all known male or female betel vine landraces have separated indicating gender based grouping among the lines.

Conclusion

Lack of homozygous plant material for hybridization and unknown meiotic segregation are some of the limitations in the hybridization of betel vine. Successful raising of large number of hybrid population and selection of vigorous hybrids for leaf and growth traits at IIHR shows that hybridization is a viable approach for the genetic improvement of betel vine. Karyomorphological studies including meiotic studies of parents may help in understanding the large amount of variation observed in the hybrid progenies of *Piper betle.* Future research strategies should concentrate on developing comprehensive descriptors and classification of the existing cultivars, exploitation of hybrid vigour and development of cultivars for biotic and abiotic stresses. Application of biotechnological tools is another promising avenue for characterization and genetic improvement of betel vine.

References

Aminuddin, Johri J K, Anis M & Balasubramanyam U R 1993 Curr. Sci. 65: 793-796.

Bhat S P, Chandel K P S & Malik S K 1995 Plant Cell Rep. 14:398-402.

Burkill I H 1966 A dictionary of the economic products of the Malaysian Peninsula Vol. II, Min. of Agric. Malaysia: 1767-72

Das A K & Chattopadhyay N C 1984 *In*: Proc. Natl. Workshop on Betel vine. Roy S K *et al*. (Eds.) The Agricultural Society of India, Calcutta, pp. 161-170.

Das R C, Das J N & Misra P K 2000 Indian J. Hort. 57: 259-263.

Johri J K, Aminuddin & Pal A 1996 Indian J. Exp. Biol. 34: 83-5.

Kocchar V K, Kocchar S, Rawat A K S & Balasubrahmanyam V R 1984 *In*: Proc. of Group Discussion on Improvement of Betel vine. Khanduja S D & Balasubrahmanyam V R (Eds.) Nat Bot Res Inst, Lucknow, pp. 63-70.

Maiti S & Biswas S R 1991 Indian J. Agric. Sci. 61: 656-658.

Maiti S, Biswas S R & Raghavendra Rao N N 1992 Indian J. Hort. Sci. 62: 780-782.

Maiti S & Shivashankra K S 1998 Betel vine Research Highlights (1981-1997) Indian Institute of Horticultural Research, India.

Nirmal Babu K, Rema J, Geetha S Pillai, Minoo Divakaran, Ravindran P N & Peter K V 1992 J. Spices and Aromatic crops 1:160-162.

Pandey S, Misra S K & Kumar N 1998 Indian J. Exp. Biol. 36: 95–98.

Rahaman M, Das N D & Jana S C 1997 J. Plantation Crops 25: 189-192.

Rahaman M, Hossain M & Das N D 1997 J. Plantation Crops 25: 57-61.

Ranade S A, Verma A, Gupta M & Kumar N 2002 Biologia Plantarum 45: 523-527.

Rawat A K S, Tripathi R D, Khan A J & Balasubrahmanyam V R 1989 Biochemical Systematics and Ecology 17: 35-38.

Reddy L N 1996 J. Plantation Crops 24: 115-118.

Samuel R 1987 Kew Bulletin 42: 465-70.

Samuel R & Morawetz W 1989 Plant Systematics and Evolution 166: 105-18.

Samuel M B A & Bavappa K V A 1981 Curr. Sci. 50: 197-198.

Sharma A K & Bhattacharya N K 1959 Genetica 29: 256-289.

Tripathi S, Singh N, Shakya S, Dangi A, Misra-Bhattacharya S, Dube A & Kumar N 2006 Curr. Sci. 91: 746-749.

Weiss E A 2002 In: Spice Crops, CABI Publishing, pp. 185-186.

Agronomic manipulations for crop production in *Piper betle*

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Introduction

Betelvine *(Piper betle* Linn.) is an evergreen, perennial, dioecious creeper cultivated mainly in South-East Asian countries, *viz.*, India, Bangladesh, Sri Lanka, Malaysia, Singapore, Thailand, Philippines, Taiwan and Papua New Guinea for its leaves, which are used as a masticatory. In India, it is grown on commercial scale as cash crop in the states such as Assam, West Bengal, Bihar, Uttar Pradesh, Meghalaya, Orissa, Karnataka, Kerala, Andhra Pradesh, Madhya Pradesh, Tamil Nadu and Tripura. About 50, 000 ha is presently under betelvine cultivation. The crop is highly labour intensive and particularly suited to small holdings. Once established, it becomes a perennial source of employment and cash flow for day to day requirements of the farmer. Betelvine is cultivated primarily in two systems namely, natural forest eco-system and artificially created shade. Under natural forest eco-system cultivation, fast growing plants such as *Sesbania grandiflora, Erythrina variegeta* or *Moringa oleifera* are used to provide support as well as shade to betelvine plants. Whereas, it is cultivated in artificially created shade environment known as 'Boroj', 'Bareja' *etc.*, in Northern India under sub-tropical conditions. It has been shown to be an unique case of plant establishment under anthropogenically regulated microclimatic conditions (Kumar 1999). Besides above mentioned two systems, a third system known as mixed cropping with arecanut, coconut, jack fruit, mango *etc.*, is followed in a limited scale. Various agronomic practices which were developed for increasing the productivity, yield and quality of betelvine through the Networking Research Project on betelvine (AINRP) sponsored by the ICAR (Indian Council of Agricultural Research) during the last three decades are reviewed in addition to the works carried out by other workers.

Nutrient management

Betelvine is a high input demanding crop. The leaves are harvested at regular intervals, therefore it needs continuous nutrient supply for maintaining higher yield and productivity. Fertilizers are key inputs in increasing productivity, however, because of their expensive nature, adverse consequences on the environment, influence on pest and disease susceptibility of the crop, serious concerns are raised for their excess usage and supplementing their requirement through organic manures and biofertilizers become necessary for successful cultivation. Application of various types of nutrients including biofertilizers and nutrient uptake in betelvine crop are discussed here.

Nitrogen sources, levels and method of application: The leaves are the economically important produce from betelvine, hence the response of betelvine for the applied nitrogen in terms of yield and quality was studied at different centres. Placement of 200 kg ha^{-1}N as CAN (calcium ammonium nitrate) in bands produced significantly higher yield at Kalyani (W.B). Keeping quality, however, was deteriorated with the use of chemical fertilizer. At Bapatla (A.P), the highest leaf yield was obtained at 200 kg N ha^{-1} as urea, though the economic level was 100 kg N ha^{-1}. Effect of different sources of N was not evident. Leaf yield and keeping quality were not influenced by various sources and levels of nitrogen at Jabalpur (M.P.), however leaves per vine were perceptibly higher with linseed oil cake, urea and their combination treatments. Nitrogen applied through organic sources recorded lower disease incidence, but did not improve the keeping quality. Dibbling of fertilizer was found to be superior to band placement. At Sangli (Maharastra), 200 kg N ha^{-1} was beneficial to improve yield of leaves whereas at Bhubaneswar (Orissa) maximum elongation of vines and production of leaves were achieved with 150 kg N ha^{-1} applied as urea + mustard cake in1 : 1 ratio. In Sirugamani (T.N) different sources and levels did not influence the yield but 150 kg N ha^{-1} through neem cake + urea (1:1) resulted in highest yield with the lowest foot rot incidence. Four to twelve split applications of nitrogen were found to produce highest leaf yield with the lowest foot rot incidence. Maiti *et al.* (1997) reported that vine elongation, number of branches and leaf yield were significantly higher when N (200 kg ha^{-1}) was applied in 12 split doses at Pusa (Bihar), Kalyani and Sangli, 6 split doses at Jabalpur and Chinthalapudi (A P.), and 4 split doses at Bhubaneswar and Jorhat (Assam) and recommended split application of N for betelvine cultivation on light-textured soils (Fig. 1). However, Saikia *et al.* (1995) reported that the keeping quality of betel leaves (cv Bangla) was highest when plants received 100 kg N ha^{-1} in the form of mustard oil cake even though N at 200 kg ha^{-1} as urea + mustard oil cake (1:1) gave the best growth and highest leaf yield. Kadam *et al.* (1993) also reported that leaf rotting after the harvest increased with increasing N levels, and was particularly high (15.75%) when urea was used as the N source.

Organic and inorganic fertilization on growth and yield of leaves: Several studies have indicated the benefit of integrated use of organic manures and inorganic fertilizers for sustaining the productivity of soil and crop in an intensive cropping system (Nambiar and Abrol 1989). Application of FYM at full dose (equivalent to 200 kg N) was found to increase all the growth and yield parameters significantly in addition to reducing the disease incidence in Sangli (MPAU), Bhubaneswar (QUAT), Pusa (RAU) and Sirugamani (TNAU). The response to FYM application can be attributed to the better nutrient availability due to better absorption and assimilation and its favourable effect on physical and biological properties of soil, resulting in increased growth and yield. FYM application also increased the keeping quality of leaves in Sangli, Bhubaneswar and Pusa. However, at Bapatla application of neem cake + urea (1: 1) and at Jabalpur and Jorhat, application of oil cake + urea (l: 1) gave maximum vine growth and leaf yield. Keeping quality of leaves was also improved by neem cake + urea. Whereas in Jorhat and Jabalpur, organic fertilizer (full dose) improved the keeping quality of leaves with low disease incidence (Fig. 2). Roy *et al.* (2002) also reported that application of FYM alone in betelvine (cv. Simmurali Bhabna) equalling 200 kg N ha^{-1} recorded highest leaf weight (464.62 g) and leaf yield (45.64 lakh ha^{-1}) with lower disease incidence and gave a cost:benefit ratio of 1:23.23 which was at par with that

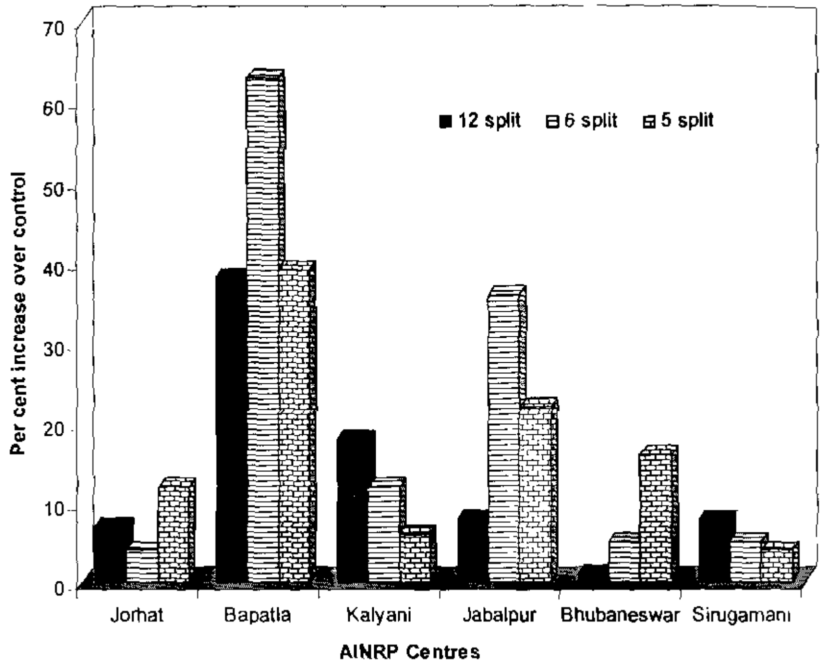

Fig. 1. Effect of split doses of nitrogen on leaf yield of betelvine

obtained with urea (1:24.13). Similarly, Arulmozhiyan *et al.* (2002) found that application of N at 200 kg/ha as FYM in four splits at 45-day intervals was the best for a higher productivity (31.01 lakh ha^{-1}) and quality in betelvine in an open system of cultivation.

Slow releasing organic nitrogenous fertilizers on yield and growth parameters: Slow release nitrogenous fertilizers are successfully utilized to improve the nitrogen use efficiency and crop productivity

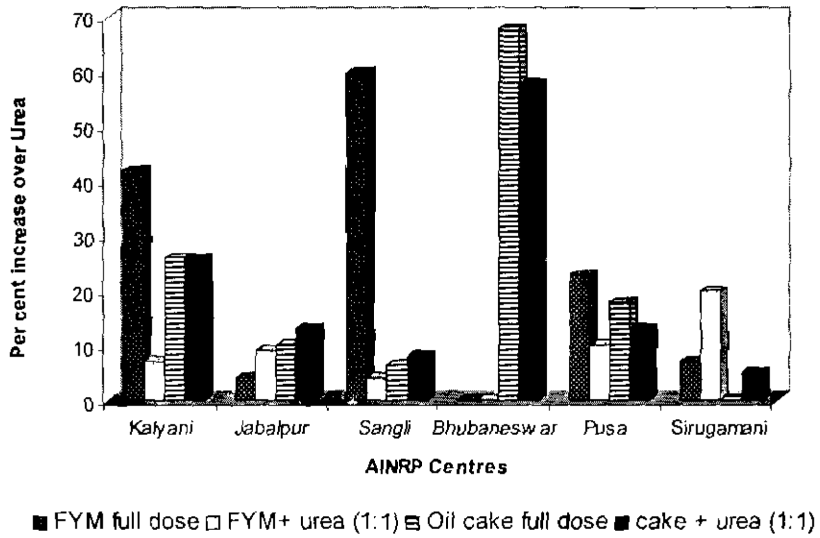

Fig. 2. Comparison of organic and inorganic fertilizers on betelvine

in various field crops. In betelvine, neem coated urea (NCU) was superior to tar coated urea and prilled urea in terms of enhancement of growth, yield, improved quality and lower pest incidence. NCU increased leaf yield of betelvine at Bapatla. However, at Kalyani, NCU did not show any positive effect on yield but influenced keeping quality significantly and decreased *Phytophthora* incidence. At Pusa, yield and quality were not influenced due to NCU but decreased the incidence of bacterial leaf spot and anthracnose. Mishra *et al.* (1995) tested gypsum-coated urea (GCU), urea rock phosphate (URP) and Nimin (neem seed extract) coated urea (NCU)) at three rates (100, 150 or 200 kg N ha^{-1}) in betelvine. They observed that N application increased leaf area compared to control. The average leaf area was greatest at 100, 150 and 100 kg N ha^{-1} for GCU, URP and NCU, respectively and the disease incidence was lower on NCU-treated vines.

Application of potash on yield and quality: The results from different centres indicated that potash had a positive effect on yield, keeping quality and disease incidence. The dose of 100 kg K_2O ha^{-1} at Bapatla, Jabalpur, Sangli and Lucknow, 125 kg at Kalyani and Bhubaneswar and 75 kg at Sirugamani were found superior in increasing the leaf yield. Mishra *et al.* (1993) applied K at 50, 75, 100, 125 or 150 kg ha^{-1} in 2 split doses to betelvine cv. Desawari along with150 kg N and super phosphate at 100 kg P_2O_5 ha^{-1}. They found that application of K at 100 kg ha^{-1}gave the highest yield, which was of acceptable quality with negligible disease incidence. Leaf essential oil concentrations were highest in this treatment. Rabindran *et al.* (1987) found that potash treatment significantly increased leaf yield compared to control (no K) but the effect of doses >50 kg K_2O ha^{-1} was not significant. Leaves from plots treated with 50 kg K_2O ha^{-1} had a longer shelf life.

Application of phosphorus on yield: Application of phosphorus improved the yield parameters in betelvine at Bapatla, Sangli, Bhubaneswar (100 kg ha^{-1}) and Jabalpur (125 kg ha^{-1}). However, no effect was recorded at Jorhat and Kalyani. Pal (1987) treated two year old vines of betelvine with N at 0, 46, 230 or 460 kg ha^{-1} and P_2O_5 at 0, 16, 32 or 64 kg ha^{-1} + K_2O basal dressing at 50 kg ha^{-1} and found that the plants responded to N but not to P fertilization.

Application of micro-nutrients on growth and yield: Studies on micro-nutrients showed that application of manganese (0.5%) and zinc (0.25%) at Bapatla, zinc (0.5%) at Kalyani, molybdenum (0.1 %) at Jabalpur and manganese (0.5%) at Bhubaneswar improved the leaf yield. Application of micronutrients influenced the leaf yield of betelvine with highest yield of 2045 leaves per hill with 0.50% zinc sulphate sprays compared to 1906 leaves in control obtained in cv. Vellaikodi (Arulmozhiyan *et al.* 1993).

Efficacy of biofertilizers in betelvine: Various bio fertilizers like azotobacter, phosphobacter and *Azosprillum* were applied in combination with other organic manures like vermicompost and inorganic fertilizers to study the efficacy of bio-fertilizers on growth, yield, shelf life and organoleptic quality of betelvine. Two levels of azotobacter (5 kg and 10 kg), azotobacter (5 kg) + phosphobacter, vermicompost, MOC + urea (1:1) were applied in combination with NPK to betelvine for their effect on vine growth, yield and keeping quality of betel leaf at ANIP on betelvine centres. At Sangli, application of azotobacter 5 kg ha^{-1} along with phosphobacter at 5 kg ha^{-1} resulted in increased vine growth, leaf yield and shelf life and improved the organoleptic quality with highest economic return. At Pusa, application of vermicompost registered the highest production of crop in term of total number of leaves, fresh weight of hundred leaves, and leaf area and all other treatments did not result in appreciable increase in leaf yield. It was also noted that increase in urea dose (200 kg ha^{-1}) resulted in maximum disease incidence and poor keeping quality of leaves.

Nutrient uptake in betelvine: Nutrient uptake studies carried out at different centres showed that the application of nitrogen in the form of FYM or oilcake equal to recommended dose of N provided better crop performance with superior betel leaf quality. At Kalyani, the results showed that yield and growth parameters were maximum in cases of nutrient dose NPK (kg ha^{-1}) = 150:50:50 (N = oilcake). Chemical analysis of plants showed that plants from treatment – NPK (kg ha^{-1}) = 200:100:100 (N= oilcake + urea) contained highest percentage of N & P. But where NPK (kg ha^{-1}) = 200:100:100 (N = FYM) were applied, plants contained highest K. Soil analysis showed that lowest residual P & K were obtained in treatment with NPK (kg ha^{-1}) = 150:50:50 (N = oilcake + urea) was applied. Low residual N in soil was found in treatment - NPK ((kg ha^{-1}) = 200:100:100 (N = oilcake + urea).

At Jabalpur, N, P and K uptake was highest under the treatment where NPK was applied at the rate of 200 (oil cake) :100:100 kg ha^{-1} . The uptake of N, P_2O_5 and K_2O were 156.25, 68.56 and 82.55 kg ha^{-1} whilst they were lowest (120.25, 38.25 and 48.56 kg ha^{-1}) under NPK application at 150 (FYM): 50: 50 kg ha^{-1}. Application of NPK at 200:100:100 kg ha^{-1} as FYM resulted in highest uptake of nutrients. N, P and K uptake were 272.30, 45.20 and 136.76 kg ha^{-1} respectively. However, soil nutrient status was maximum under the application of NPK at 200:100:100 kg ha^{-1} as oilcake : urea. The treatment receiving nutrient dose of 200:100:100 as N, P_2O_5 and K_2O produced significantly superior yield.

At Sirugamani, the treatment consisting of 150 kg N as FYM , 50 P_2O_5 and 50 K_2O kg ha^{-1} application recorded the highest leaf yield of 40.19 lakh leaves per ha and recorded maximum organic carbon content (0.53%) during second year. The available N was high in the treatment having NPK of 150 (oilcake + urea): 50 : 50. kg ha^{-1}. Arulmozhiyan and Thamburaj (1998) reported that application of 150 kg N ha^{-1} (urea + FYM), a pre-planting dip of *Azospirillum* (1 kg ha^{-1}) for 10 min + soil application of *Azospirillum* (2 kg ha^{-1}) on 50th day, and a foliar spray of triacontanol (cv. Vellaikodi) resulted in the highest uptake of N, P, K, Ca and Mg.

Soil organic carbon content in betelvine cultivation: The balance of organic carbon in the soil is of pivotal importance in maintaining soil properties and dynamics of soil micro flora in the betelvine cropping system. Assessment of organic carbon content in the soil is carried out to find out the optimum level for sustainable cultivation of betelvine in various regions of our country where betelvine is cultivated commercially.

At Jorhat, optimum level of organic carbon was assessed in different cultivation practices followed in Assam *i.e.*, closed type, semi closed type and open type in three locations (Ambagan, Lengeri, Borhola) at fifteen different sites. Per cent organic carbon varied from 0.56 to 0.78 in different betelvine gardens of Assam and it was medium in terms of available nitrogen. Soil type at Borhola village was predominantly silty clay loam with high organic carbon content (0.67 to 0.78%). The available P_2O_5 (43.8 to 48.8 kg ha^{-1}) and K_2O (105.5 to 108.2 kg ha^{-1}) were highest among the locations.

A survey was conducted at Bhander Khola, Dist. 24 Parganas (N) and soil samples were collected from those barejas for analysis as per schedule. The farmers of Bhander Khola, mainly used mustard oil cake. The organic carbon (%) content, total N (%), total P_2O_5 kg ha^{-1} and total K_2O kg ha^{-1} of different borojas ranged from 0.49-0.78%, 0.014- 0.042%, 4.4-196.46 kg ha^{-1} and 168.3 – 382.8 kg ha^{-1} respectively. The pH ranged from 6.78 – 8.13. At Jabalpur, it was found that betelvine when applied nitrogen in the form of urea and oil cake to the tune of 265 kg ha^{-1} which resulted in maximum organic carbon content (1.3%) among the locations tested and got maximum leaf yield (42.52 lakh ha^{-1}).

Irrigation management

Irrigation schedules and methods on growth and yield of leaves: Application of irrigation water at an IW/CPE ratio of 1.00 with irrigation depth of 5 and 3 cm at Pusa and Kalyani respectively, were found to be better for growth and leaf yield. However, irrigation did not influence keeping quality of leaves, incidence of bacterial leaf spot and uptake of major nutrients at Pusa. Furrow irrigation after each row in Bapatla and after two rows in Sangli was reported to be superior methods for higher leaf yield. Irrigation methods did not have any effect on keeping quality of leaves and disease incidence.

Drip irrigation on growth and leaf yield: At Jabalpur, 100% replenishment of pan evaporation rate through drip irrigation produced highest leaf yield (25.55 lakh ha^{-1}). However, at Sangli, 125% evaporation replenishment produced highest yield (42.32 lakh ha^{-1}) (Fig. 3). Water saving was to the tune of 34.26 per cent in this treatment.

Plant population: At Bapatla, plant population of 10 plants m^{-2} (1 lakh plants ha^{-1}) found to be optimum for betelvine as it recorded higher leaf production and better cost-benefit ratio. The leaf yield was highest in the plant population density of 1, 25,000 per ha (108.54 lakhs ha^{-1}). However, the cost benefit ratio was 1: 6.23 compared one lakh plant population which gave 1: 9.10. At Jabalpur, maximum number of leaves ha^{-1} (23.65 lakh) was noted with 2.0 lakh plants ha^{-1}. It was at par with 1.75 lakh plants ha^{-1} (23.35 lakh). Plant population density did not affect keeping quality of leaves and per cent of disease incidence significantly. At Islampur (RAU), amongst four plants spacing /plant populations, maximum vine elongation, populations (9.35), no. of branches (18.35) and no. of leaves ha^{-1} (26.75 lakh ha^{-1}) was recorded with 1.5 lakh ha^{-1}plant population. The *Phytophthora* foot rot incidence increased with increasing plant population. At Bhubaneswar, leaf yield was significantly highest (55.6 lakhs ha^{-1} yr^{-1}) in 2 lakhs plant population ha^{-1} followed by 1.75 lakh ha^{-1}. At Sirugamani, among the 4

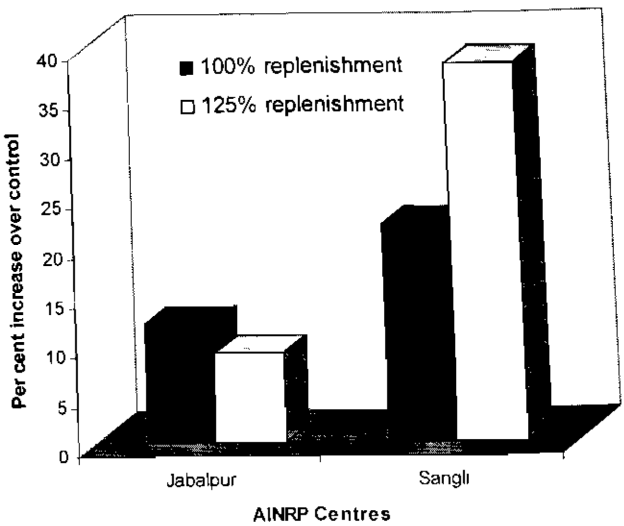

Fig. 3. Effect of drip irrigation on leaf yield of betelvine

different spacing/population adopted, the population of 75,000 plants ha^{-1} gave the best growth and yield performance.

Crop regulation through staggered lowering: To increase the harvest of betel leaves in the lean period, a technique named staggered lowering was standardized. The results showed that significant improvements in crop growth and yield were noticed by this technique in various centres. At Jorhat, there was no significant difference in vine elongation, number of branches per plant, fresh weight and keeping quality of the leaves. However, significant difference was observed in yield, disease incidence and net return during February & September lowering and July & November lowering compared to other lowering periods. February & September lowering gave highest net return (2.49 lakh ha^{-1} yr^{-1}). At Kalyani, the results showed that leaf yield was found highest (33.30 lakh ha^{-1}) in treatment where July & November lowering was done and it was statistically at par with February & June lowering. The lowest (27.81 lakh ha^{-1}) leaf yield was recorded in August & December lowering and it was statistically at par with September & January lowering. The lowest (6.66%) leaf spot disease was recorded in September & January lowering and it was at par with February & June lowering (8.02%).

Bio-regulators on yield and keeping quality of leaves: Triacontanol, a primary alcohol has been shown to increase the growth and/or yield of major crops and several forest species. Triacontanol (0.05%) sprayed thrice at 30 days interval had favourable influence on growth and yield parameters in all the centres (Fig. 4). However, an increase in keeping quality of leaves with the triacontanol spray was observed only in Sangli, Bhubaneswar and Sirugamani. A significant increase in cost benefit ratio was also observed in Sangli and Pusa. Pawar *et al.* (2001) found that threc sprays of 0.5% triacontanol at 30-day intervals resulted in the highest values for vine length (4.11 cm), number of leaves ha^{-1} (84.22) and 100-leaf weight (250.50 g), while the two sprays resulted in the highest number of laterals per vine (19.14) and gave the highest values for leaf shelf life (18.25%) and benefit: cost ratio (1.89). Three sprays of triacontanol (0.05%) at 30 days interval was beneficial to betelvine which resulted in highest leaf yield (32.476 lakh ha^{-1}) at Jabalpur (Sengupta *et al.* 2001). Chatterjee (1999) found that n-triacontanol application increased leaf yield by 12-18%, and reduced the effects of water stress in betelvine and it increased leaf oil content particularly in cv. Bangla.

Integrated crop management

Integrated crop management involving optimum nutrient management and management of pest and diseases of the crop became focus point for sustainable crop production.

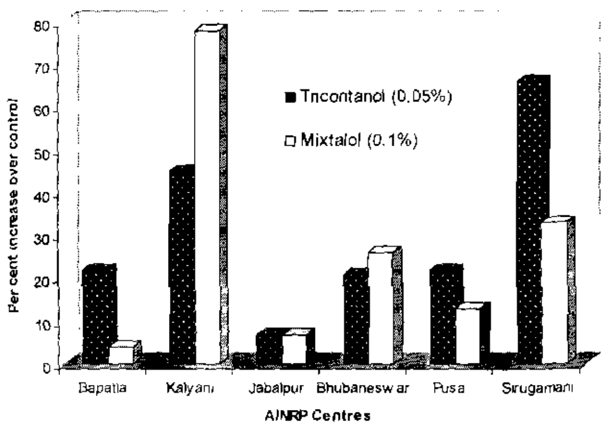

Fig. 4. Effect of growth regulators on leaf yield of betelvine

At Jorhat, the incidence of the disease was significantly less in the treatments where *Trichoderma spp* and Bordeaux mixture as applied. Final soil status indicated the fixation of phosphorus as well potash in the soil leading to soil build up of both the nutrients. The retention of K was higher in plant population with combination of *Trichoderma* and Bordeaux mixture. The farmers' practices resulted in lower return compared to INM and IPM approaches because of adopting lower plant population as well poor disease, nutrient and irrigation management aspects.

At Bapatla, results showed that the treatment consisting of optimum plant population (1,00,000 plants ha^{-1}) + recommended fertilizers (neem cake + urea (1 : 1) at 200 kg N, 100 kg P_2O_5 and 100 kg K_2O ha^{-1}), irrigation (100% replenishment of CPE) and application of Bordeaux mixture (4 drenches and 8 sprays) recorded significantly higher leaf yield of 39.15 lakhs ha^{-1}. At Kalyani, highest fresh mass of 100 leaves (407.14 g) and leaf yield (44.44 lakh ha^{-1}) were recorded in treatment consisting of plant population of 1.5 lakh vines ha^{-1} with application of 200kg N in splits of organic form + 100kg P_2O_5 + 100 kg K_2O + Irrigation at 100% replenishment of CPE + Bordeaux mixture application (4D + 8S) + recommended insecticides. In the same treatment, lowest incidence of leaf and foot rot caused by *Phytophthora* sp. and leaf spot caused by *Colletotrichum capsici* was observed. At Jabalpur, maximum vine elongation per month (15.58) number of leaves (36.25 ha^{-1}), length of inter node (7.54 cm) and weight of 100 leaves (618.65 g) were observed with treatment consisting of best plant population + 200 kg nitrogen in four splits in organic form + 100 kg P_2O_5 + 100 kg K_2O + irrigation at 100 %

replenishment of CPE + 4 applications of *Trichoderma viride* + sanitation + recommended insecticides. The maximum disease incidence (15.30%) and minimum keeping quality (9.82days) of leaves were noted in farmers practice. At Bhubaneswar, application of 150 kg nitrogen + 100 kg P_2O_5 +125 kg K_2O + irrigation at 100% replenishment of CPE + Bordeaux mixture application (4D +8S) + recommended insecticides gave higher vine elongation (28.2 cm), number of laterals (2.0) and the leaf yield (45 lakhs ha^{-1}) with larger leaves (14x11 cm), fresh weight of 100 leaves (292 g) and less disease incidence. The shelf life of leaves was better in farmers practice with an organoleptic rating of 2.6. At Pusa, the treatments having 50 lakh plants ha^{-1} + 200: 100:100kg ha^{-1} N:P_2O_5: K_2O (4 -splits) as organic + irrigation + 4 application of *Trichoderma viride* + sanitation+ organic insecticide and 1.50 lakh plants ha^{-1} +200: 100:100kg ha^{-1} N:P_2O_5: K_2O (4 -splits) as organic + irrigation + 3 drenchings of Bordeaux mixture(1%) and 6 sprays of Bordeaux mixture (0.5%) + sanitation + organic insecticide gave superior yield.

Evaluation of live support crop

Superiority of *Moringa* sp. as live support crop was recorded uniformly in two locations. *Sesbania grandiflora* was also good when growth parameters were compared. S. *sesban* was not found suitable since it started producing branches from the base of the plants and also had slow growth rate.

Packing and storage

As the betel leaves are perishable in nature the storage and packing for better keeping quality and least damage during storage and transit were investigated in different centres. Packing of leaves without petiole was found to be a better practice for improving shelf life when compared to packing with petiole in all the centres. In general, keeping quality during storage was better in winter than summer and rainy seasons. Under all storage conditions, depetiolation prolonged storage life, and the most effective storage treatment was in banana leaves (Saikia & Dutta 1993). The storage life of leaves varied with cultivar; leaves from the local Bangla cultivar exhibited the longest storage life (92.9% healthy leaves after 14 days storage in banana leaves). Singh *et al.* (1990) showed that treatment of mature harvested betel leaves after depetiolation with 5 mg BA l^{-1} for 6 h and storage in conventional baskets would be most suitable for prolonging the shelf-life of the leaves. The least spoilage (66% on day 21) was observed for leaves (cv. Vellaikodi) packed by the hollow method using fresh plantain leaves in the months of July-August.

References

Arulmozhiyan R, Manuel R W W & Velmurugan S 2002 Effect of organics vs. inorganics on betelvine cv. Vellaikodi in open system cultivation. South Indian Hort. 50 (1-3): 169-172.

Arulmozhiyan R, Nagalakshmi J, Jonathan E I, Ayyamperumal A & Padmanabhan D 1993 Effect of micronutrients on the growth and yield of betelvine cv. Vellaikodi. South Indian Hort. 41(5): 305-306.

Arulmozhiyan R A & Thamburaj S 1998 Integrated nutrient management in betelvine (*Piper betle* L.) on nutrient uptake. South Indian Hort. 46 (3-6): 185-191.

Chatterjee S K 1999 Water stress effect on betelvine (*Piper betle* L.) and its alleviation by n-triacontanol. Acta Hort. *(ISHS)* 502:93-98.

Kadam A S , Nakat R V & Pawar A B 1993 Effect of organic and inorganic sources and graded levels of nitrogen on yield of betelvine (*Piper betle* L.). Maharashtra J. Horticulture 7(1): 60-63.

Kumar N 1999 Betelvine (*Piper betle* L.) cultivation: A unique case of plant establishment under anthropogenically regulated microclimatic conditions; Indian J. Hist. Sci. 34 :19–32.

Maiti S, Sengupta K, Punekar L K, Saikia L, Kadam A S, Babu M L K, Das J N, Singh S P, Biswas S R & Reddy K M 1997 Nitrogen management in betelvine by split application. J. Plantation Crops 25 (1): 83-87.

Mishra S K, Chaurasia R S & Balasubrahmanyam V R 1995 Effect of graded levels of slow release fertilizers on the yield and quality of betel leaves. J. Plantation Crops 23(1): 48-51.

Mishra S K, Rawat A K S, Gurunath S, Chaurasia R S & Balasubrahmanyam V R 1993 Effect of potash application on the yield, disease incidence, quality, and essential oil composition of betel leaves (*Piper betle* L.). J. Potassium Research 9 (2): 166-170.

Nambiar K K M & Abrol I P 1989 Long term fertilizer experiments in India- a review. Fertilizer News 34: 11-20.

Pal P 1987 Effect of different levels of nitrogen and phosphorus application on the yield of *Piper betle* cv. Bangla. South Indian Hort. 35 (6): 429-432.

Pawar V P, Kathmale D K & Patil B K 2001 Effect of bio-regulators on yield and shelf-life of betelvine. J. Maharashtra Agricultural Universities 25 (3): 262-263.

Rabindran R, Marimuthu T, Sivakumar M & Natarajan S 1987 Role of graded doses of potash on the incidence of *Phytophthora* wilt of betelvine. J. Potassium Research 3(4): 155-159.

Roy J K, Sengupta D K, Dasgupta B & Sen C 2002 Effect of organic and inorganic fertilizers on yield and disease incidence of major diseases of betelvine. Horticultural J. 15 (3): 59-69.

Saikia L, Bhuyan C K & Dutta P K 1995 Study on growth, yield and keeping quality of betelvine (*Piper betle* L.) cv. Local Bangla as influenced by source and level of nitrogenous fertilizers. Indian Cocoa, Arecanut and Spices J. 19 (2): 46-50.

Saikia L & Dutta P K 1993 Varietal response of betel leaves to petiolar regulation under different storage systems. Indian Cocoa, Arecanut and Spices J. 16 (3-4): 123-124.

Sengupta S K, Bhatt J, Chaurasia R K & Bhatt J 2001 Effect of certain bioregulators on growth and yield of betelvine leaves (*Piper betle* Linn.). Advances in Plant Sci. 14 (1): 163-167.

Singh K K, Balasubrahmanyam V R & Kochhar V K 1990 Effect of different packing methods, temperature conditions, treatment with chemicals on the senescence and storage behaviour of betel (*Piper betle* L.) leaves. J. Plantation Crops 18 (1) : 23-28

Processing, packaging and marketing of betel leaf (*Piper betle* L.)

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Introduction

Betel vine is (*Piper betle* L.) belongs to the family Piperaceae. The plant yields deep green heart shaped leaves popularly known as *Paan*. The leaves are also synonymously known as Nagaballi, Nagurvel, Saptaseera, Sompatra, Tamalapaku, Tambul, Tambuli, Vaksha Patra, Vettilai, Voojangalata *etc.* in different parts of the country (CSIR 1969; Guha 2006). The vine is a dioecious, shade loving perennial root climber. There are about 100 varieties of betel vine in the world, of which about 40 are found in India and 30 in West Bengal (Guha 1997; Maiti 1989; Samanta 1994). Malaysia is considered to be the place of origin of betel vine by most of the workers (Chattopadhyay and Maiti 1967) but the leaves are much more popular in India than in any other country of the world. This is obvious from its high acreage (55000ha) and annual production (Rs 9000 million) in the country (Guha 2000). Significance of the leaves is known traditionally in Indian society since the time immemorial. A well-prepared betel quid is still regarded as an excellent mouth freshener and mild vitalizer, routinely served on the social, cultural and religious occasions. It is also offered to the guests in order to show respect and for such traditional use, the leaf really stands without any parallel even today (Mehrotra 1981; Guha and Jain 1997; Guha 2006). In fact, this edible leaf has also achieved an esteemed position in several other countries of the world particularly in Bangladesh, Burma, China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, South Africa, Sri Lanka, Thailand *etc.* (Jana 1996; Khoshoo 1981; Samanta 1994; Sharma *et al.* 1996; Guha 2006) where leaves are traditionally used for chewing in their natural raw condition along with many other ingredients like sliced areca nut, slaked lime, coriander, aniseed, clove, cardamom, sweetener, jelly, piper mint, flavouring agent, fruit pulp *etc.* (CSIR 1969 ; Guha 2006).

The strikingly high demand of the fresh leaves can be explained by the fact that it is a cheap, natural and easily available appetizer, digestive, mild stimulant, aphrodisiac and refreshing mastication. Chewing of betel leaves impart a sense of well-being, increased alertness, salivation and energetic feeling with exhilaration. It also increases the capacity to perform physical and mental functions more efficiently for a comparatively longer duration over control (without betel leaf chewing). These beneficial properties can be explained by the nutritional composition of the leaves which are good source of minerals and vitamins.

Processing of betel leaf

Processing is a very wide term but when it is applied to food science, engineering or technology it means application of all the small and big methods and techniques (processes) applied/ performed on the raw materials or unfinished products to introduce some desirable properties like long storability, attractive colour, taste, flavour, texture, chewability, particular shape, size, cleanliness, safety *etc.* so that a new product is obtained with better utility and economy. The most common processing techniques are: peeling, slicing, mincing, macerating, liquefaction (fruit juice), fermentation, emulsification, extraction, cooking (boiling, broiling, frying, steaming, baking, grilling *etc.*), mixing, addition of gas, proofing, drying, dehydration, applications of /manipulation by physical forces (light, electromagnetic waves *etc.*), pasteurization, chemical treatments *etc.* This list however, is not exhaustive since new techniques are coming up every year and some of them are specific to particular novel product.

It is clear that when applied properly, processing may minimize losses of the raw materials which cannot be stored for long time under ordinary conditions, for example betel leaf is a very perishable commodity and therefore, always subject to wastage by quick spoilage due to dehydration, microbial infection, dechlorophyllation *etc.* This may cause post-harvest losses ranging from 10 to 70% during transport and storage (Guha & Jain1997; Rao & Narasimham 1977) amounting over Rs 900 million every year in monetary terms. So much is the wastage that the surplus leaves are fed to the cattle and also buried in the ground (Guha 2007). In view of such alarming losses, attempts have been made to minimize the wastage by adopting some processing techniques like extracting essential oil (Guha 2007), drying of the leaves (Ramalakshmi *et al.* 2002), depetiolation (Mishra & Gaur 1972), chemical treatments, manipulation of storage temperature, adopting better packaging materials and methods (Guha 2004; Rao & Narasimham 1977) besides curing/bleaching of the leaves (Dastane 1958; Sengupta 1996). Commercialization of betel leaf-tincture and betel leaf-gargle is also under progress (Khanra 1997). That apart, formulation of beverages/drinks from fermented betel leaf has been taken up for scientific study but no specific information is available since the inventors from Jadavpur University of West Bengal are trying to get a patent on the novel product. Description of some important processing technologies is given below:

Extraction of essential oil from betel leaves

This was attempted with Clevenger apparatus but its performance was not satisfactory due to various drawbacks. Therefore, research work was undertaken to design and develop an apparatus for extraction of essential oil from betel leaves minimizing the drawbacks. As a result, betel leaf oil extractor was developed, the drawbacks were minimized and rapidity in the extraction process was achieved with a consequential saving of time and energy to the tune of 43.8 % and 29.8 %, respectively and increase in oil recovery to the tune of 16.2 % compared to Clevenger apparatus (Guha 2008). With this apparatus essential oil can be extracted from the stranded or unsold leaves, be it fresh or stale or dechlorophylled or even partially decayed and rejected for consumption. The essential oil extracted with this apparatus clearly revealed that the Mitha, Bangla and Sanchi varieties of betel leaves contained about 2.0%, 1.7% and 0.8% essential oil respectively, on dry weight basis. This oil of Bangla variety was constituted by a mixture of about twenty-one different compounds of which eugenol was the chief ingredient constituting about 29.5 % of the oil (Guha 2003). Similarly, the essential oil and its constituents of most of the other varieties show a comparable trend but in some varieties terpenyl acetate is the chief constituent. However, these constituents may vary qualitatively and quantitatively as well due to several factors like variety, soil, climate and the agronomic practices followed to raise the crop, *etc.* like any other essential oil yielding crops (Garg & Jain 1996; Gunther 1952; Kanungo 1996; Ramalakshmi *et al.* 2002; Sankar *et al.* 1996; Sharma *et al.* 1981). In fact, these constituents are the sources of the medicinal, aromatic, stimulant, tonic and various other useful properties found in the leaves (Khanra 1997). Such useful properties of the oil indicate a promising industrial future for it as a raw material for manufacturing skin emollients, tooth pastes, tooth powders, *paan masala*, perfumes, room fresheners, de-odorants, soaps, face creams, antiseptic creams and lotions, cold drinks, chocolates, incense sticks, appetizers, carminative mixtures, digestive agents, tonics, medicines *etc.* (Guha 2000).

Fig. 1. Betel leaves essential oil extractor

The cost of a 20- litre size oil extractor is about Rs 20000/ and that of the 10-litre size is Rs 10000/, which is well within the affordable limits of the betel leaf growers. Therefore, the farmers themselves at a rural industry can take up such oil extraction and product development work. The 20-litre size oil extractor can easily process 200-400 leaves/batch and about 800-1600 leaves /day, whereas the daily production of the leaves may not normally exceed 500 leaves/ boroz of average size *i.e.*, 0.02 ha. Therefore, in all accounts a small oil extractor of 20-litre capacity would be sufficient to process the surplus leaves on any day. Similarly, a single unit can also be shared by several farmers to make this rural technology more cost effective. Such oil extraction may provide employment opportunities to the family members of the cultivators and business opportunities to the industries.

Curing of betel leaves

In food processing, curing refers to various preservation and flavoring techniques, particularly for meat or fish, by the addition of salt, sugar, nitrate and nitrite singly or in combination. Some curing techniques also involve smoking. So far as curing of betel leaf is concerned it refers to heat and smoke (rich in carbon mono oxide) treatment of the leaves for removing green colour (chlorophyll), pungency and undesirable traits and thereby improving taste, appearance and other qualities. Thus, curing imparts a unique colour to the leaves ranging from yellow to white (with slight yellow tinge) through one kind of gradual bleaching action. Moreover, removal of pungency makes it consumer acceptable especially to those who suffer badly after consumption of fresh betel leaves, particularly from swelling of tongue and loss of taste. Unfortunately, not much scientific studies have been carried out on this aspect. Cured leaves had higher essential oil and reducing sugars percentages but lower starch, tannin and non-reducing sugar percentages compared to fresh leaves (Dastane *et al.* 1958).

The workers in Bengal, follow two methods for curing (Guha & Jain 1997): Bhati method and Dabano method (Pressure method) as described below:

Bhati method: In this method a brick and mud built room of approximately 2.0 X 1.4 X 1.7 m size is made with one small door which is kept closed with thick gunny curtain to make the chamber air tight as much as possible. In one corner of the room, a small oven is kept with 2-2.5 kg of wood charcoal. Baskets containing the betel leaves (with or without petioles) are placed on floor of raised beds made of bamboo. The baskets are lined with sal (*Shorea robusta*) leaves and gunny sheets and are kept covered with moist gunny bags. The charcoal is burnt for about 3 hours/firing and temperature of the chamber ranges from 36-45°C (Sengupta 1996). The leaves are reshuffled every 6-12 hours and the defective and /or decaying leaves are removed and the rest are transferred to another basket outside the curing chamber for 30-36 hours before retreatment. Due to absence of light and presence of heat and smoke, the leaves gradually loose chlorophyll and become light yellow/white in colour. Such change in colour may be attributed mainly to the modified atmospheric condition consisting of carbon mono oxide, darkness and heat. It takes about 8-15 days in summer and 15-25 days in winter to complete the curing process. At a time 16-20 thousand leaves can be cured in summer while in winter the number may be as high as 24-30 thousands. This method is practiced mainly during the months of September to March when raising the chamber temperature becomes essential. The baskets containing the leaves are kept a little away from the oven to avoid direct heating. Betel leaves grown in Birkuli, Ramnagar and Mohanpur areas of Midnapore district of West Bengal give best results by this method while the other varieties may not give good results. However, the method has not been standardized and hence, number of firings of the oven, arrangement of the leaves in the baskets, arrangement of the baskets in the curing chamber, selection of the leaves for this purpose *etc.* are still a matter of personal experience. Recently, Rayaguru *et al.* (2007) has conducted a survey study in Orissa on curing of betel leaves. The study reveals that the same processing technique is also being adopted in Orissa as previously reported by Guha & Jain (1997).

Dabano method (Pressure method): This method is practiced mainly during the summer months, April to August when atmosphere is warm and moist. No oven or additional heat source is required. The betel leaves are arranged in larger baskets which are placed one over the other and are reshuffled every 24 hours. It takes about 7-10 days for completing the process in summer while in winter it takes about 15-20 days or a little more, possibly according to the pressure mounted on the leaves.

Drying of betel leaves

Drying is a simple process for removal of moisture from any substance although in many cases it is performed through sophisticated techniques like microwave drying. It helps in increasing shelf life of the product since scarcity of water in the product restricts or even prevents microbial growth responsible for spoilage of most of the edible substances. So far as betel leaves are concerned, needless to reiterate that a very limited work has been done on the subject. However, Ramalakshmi *et al.* (2002) have studied the impact of drying on quality of betel leaves. They found that solar drying gave better results compared to shade drying, mechanical drying and microwave drying since in the latter methods there was substantial loss of volatile oil which is responsible for improving quality of the product.

Depetiolation of betel leaves

Depetiolation means removal of the petioles partly or fully from the leaves. The farmers pluck the leaves along with the petioles and sell them to the retailers or whole sellers who in turn carry out the processing work. In most of the places it is done manually with the help of a piece of a blade, scalpel or sharp sickle before packaging for transportation to final destination. By doing so, about 10-25 percent weight of the leaves are reduced besides shedding off the total length of the leaves by about 10-40 percent. Such processing has many advantages like delaying senescence (Mishra & Gour 1972), reduction in weight of the bundles of betel leaves facilitating transportation, reduction in space requirement for storage and transportation, reduction in requirement of packaging materials, minimization of chances of early necrosis which starts mostly from the base of the petioles and thereby increasing shelf life, *etc.*

Packaging of betel leaves

Packaging is the science, art and technology of enclosing/covering a product (with some substance like paper, polythene, plastic, cloth, tin or aluminum foil, card boards, soft wood, glass *etc.*) for promoting its storage, distribution, marketing and use. It gives physical (shock, vibration, compression, temperature, dust, contaminants *etc.*), chemical (oxygen, water vapour, *etc.*) and biological (microbes) protection by creating barrier. It helps in marketing by providing information (labels) and creating attraction. Packaging is also done for creating convenience in handling, transportation and use. Currently, not much work has been done on packaging of betel leaves and therefore, sophisticated packaging for the leaves is not available. However, presently packaging of the leaves is done in bamboo baskets of different sizes having diameter of 25 to 50 cm and depth of 50 to 75 cm in the following manner (Guha & Jain 1997). A basket of proper size for housing about 4000 to 10000 leaves is taken and lined with moist straw. Over this, a moist cloth is stretched to cover up the straw. On such moist cloth pieces the leaves are arranged in a circular manner keeping the base/petioles uniformly towards the centre or outside. In the centre, however, a piece of ice slab weighing about 1.5 to 4.5 kg is kept and the ice piece is kept closed inside a plastic bag to avoid over moistening of the leaves. The ice piece absorbs the heat generated by respiration of the leaves and keeps them cool and thus, delays decaying. Usually the petioles are completely removed before packing but some times 1 to 2 cm length is retained according to the choice of the consumers of the locality whereto the consignment is dispatched.

Marketing of betel leaves

Before stating the marketing aspects it would be appropriate to mention the economic significance of the crop which actually provides foundation for marketing of the leaves like all other commodities. To start with the initial cost of cultivation of betel vine, it may be stated that the cost may range from Rs 1-2 lakh/ha at the minimum during the first year which may come down to about Rs 0.5-0.6 lakh/ha in the subsequent years. A minimum net profit of Rs 0.5-1.0 lakh/ha/year or more (Rs 5.02 lakh/ha/year in one case as reported by ICAR 2000) is easily attainable under ordinary conditions (Bhowmick 1997; Guha & Jain 1997; ICAR 2000; Lahiri 1991; Samanta 1994; SDAMM 1996). Further, a small Boroj of even 10-15 decimals may provide sufficient net profit for maintaining a small rural family of five members (Jana 1995; SDAMM 1996). Such a Boroj may be termed as a household bank since the leaves can be plucked and sold straight in the market as and when hard cash is required and this may continue for 10-30 years or more (Chattopadhyay 1981; Jana 1995). Moreover, the leaves may also be retained on the vines up to about six months without any deterioration of leaf quality (Bhowmick 1997) and this may provide an opportunity to escape the dull markets. Interestingly, the annual yield of a good crop is about 60-70 leaves/ plant and 6-7 million leaves/ha. This may constitute a gross production of the leaves worth about Rs 9000 million every year in the country where the crop is grown on about 55,000 ha of land. On an average about 66% of such production is contributed by the state of West Bengal where it is cultivated on about 20,000 ha of land encompassing about 4-5 lakh Boroj employing about the same number of agricultural families (Guha 2006).

The vast marketing potentiality of the crop can be adequately established by the fact that about 15-20 million people consume betel leaves in India on a regular basis (Jana 1996) besides those in other countries of the world which may include over 2 billion consumers (Jeng *et al.* 2002). The crop provides a national income to the tune of Rs 6000-7000 million every year. It also provides an income of Rs 800-1000 million to the state of West Bengal. In addition to this, the Eastern Railways earn about Rs 100 million every year from transporting betel leaves from West Bengal to different parts of India (Jana 1995; Samanta 1994). The leaves are also in great demand in several other countries of the world. Consequently, leaves worth about Rs 30-40 million are exported to the countries like Bahrain, Canada, Great Britain, Hong Kong, Italy, Kuwait, Nepal, Pakistan, Saudi Arab and many other European countries (Jana 1996; Singh *et al.* 1990). The available export details are shown in the table 1.

Table 1. Export of betel leaves from India during 1968-91 (Jana 1996)

Year of export	Quantity (MT)	Value (in thousand rupees)
1968-1969	208	566
1969-1970	210	580
1970-1971	372	940
1971-1972	461	1182
1972-1973	391	1398
1973-1974	209	716
1974-1975	253	1084
1975-1976	249	1040
1976-1977	304	2292
1977-1978	932	8007
1978-1979	1347	13226
1979-1980	402	3429
1980-1981	435	4002
1981-1982	574	6162
1982-1983	740	8200
1983-1984	1116	15100
1984-1985	717	11000
1985-1986	NA	NA
1986-1987	582	9190
1987-1988	814	12541
1988-1989	1063	16446
1989-1990	NA	NA
1990-1991	884	14801

NA: Data not available

Rayaguru *et al.* (2007) have also highlighted the export potential of the crop but the data provided by them are much less and therefore, do not match with those provided by Jana (1996).

So far as the marketing channels of betel leaf are concerned, it is very simple and traditional ones. The leaves are generally plucked in the evening for marketing during the next morning. After plucking, sorting for damaged, deformed, diseased, off sized or otherwise undesirable leaves are done during the following night or next early morning. Thereafter, the leaves are graded in to different sizes, large, medium and small (which are sold at different prices in decreasing order). The rinsing of the leaves are done in the near by ponds at convenient time, after plucking or grading. Depetiolation is rarely done by the farmers at home unless there are specific instructions from the retailers or whole sellers since depetiolated leaves are looked upon doubtfully as stale leaves. This is because petiole tips dry up quickly showing staleness of the leaves and a recent cut may impart a misleading fresh look to the leaves. After all these steps are covered, the leaves are counted and arranged in lots of 50 or 100 in a circular manner according to the prevailing procedure of the locality. The leaves are then bundled in plant leaves, like banana, sal (*Shorea robusta*) or palas (*Butea monosperma*) leaves overwrapped with cloth or gunny pieces. Rarely bamboo baskets are also used at this stage. The sizes of the bundles are not fixed and may vary according to the availability of transportation methods but they are always kept in multiples of 1000 for easy counting. Thus, the steps followed while sending the leaves from the vineyards to the nearby markets may be summarized as: Plucking, rinsing, sorting, grading, (depetiolation), counting, arranging and bundling. After bundling, the leaves are taken to markets by head loads, cycles, motor bikes, trolleys and other locally available means. After reaching the markets, particularly whole sale markets, the bundles are opened for inspection by the prospective buyers. The leaves are then auctioned by bidding (by professional callers) and the highest bidders buy the leaves. But so far as payment to the farmers are concerned, part of the payment is released on the spot, rest amount is paid after thorough inspection and complete sale of the leaves. In most of the cases the farmers however, do not get the actual price offered/fixed by biddings. In fact, the local whole sellers purchase the leaves, do a little bit of processing and packaging and then transport the bundles to another whole seller located at a distant place and on receipt of payment from him the local whole seller makes payment to the farmers. This process consumes 15-30 days or more causing financial loss to the farmers besides creating other troubles. Not only this, a portion of the payment is always curtailed on flimsy grounds like presence of rotten leaves (due to faulty transportation), small leaves, fluctuation in price, *etc.* It is true that price fluctuation in betel leaf is undesirably high but the farmers should not suffer from it particularly when the leaves are sold by auction. In the prevailing marketing system either the local whole seller or someone else plays the role of middleman between the farmer and the final buyer who actually makes the payment and therefore, there is no direct and immediate full payment. The summary of two channels of marketing of betel leaves may be shown as: (1) Vineyard——farmer—retailer—consumers; (2) Vineyard—farmer—local whole seller/middleman—whole seller/middleman at a distant location—retailers—consumers.

Transportation of the leaves within the country is done mainly by rail. It is also done by road (trucks) to the destinations not connected with rail. It takes about 3-7 days to reach the final destination anywhere in the country. On the other hand transportation of the leaves outside the country is done only by air at present and the consignment reaches the final consumers within about 3 days.

Problems in marketing of betel leaves

- Betel leaf is a highly perishable commodity,
- Betel leaf producers are not organized and therefore, subjected to exploitation,
- Adequate wagons are not available in trains, particularly during the peak period of production,
- Refrigerated wagons/vans/trucks are not available for transportation of betel leaves,
- Producers do not get proper price of the leaves,
- During rainy season excessive marketable surplus is wasted.
- There is no export promotional activity,
- Marketing intelligence is not available,
- Alternative uses of the leaves are not known,
- Proper facility for storage of unsold leaves are not available,
- Lack of proper efforts to neutralize cancer propaganda on betel leaf.

Conclusion, recommendations and suggestions for future work

- It may be concluded from the present study that wastage of betel leaves worth millions of rupees may be minimized by adopting appropriate processing technologies.
- It may also be concluded that the present marketing system does not support the actual betel leaf producers properly and therefore, it needs overhauling.
- It is recommended that essential oil of betel leaves be used in cottage industry for manufacturing of different commercial products particularly the non-tobacco based Gutkha (Paan Masala).
- Search for novel formulations/products made of betel leaf singly or in a combination with other ingredients are required to be taken up.
- Studies on alternative uses of the leaves and essential oil are required to be taken up.
- Research work on by-product utilization can be considered as the mandate of the current time.
- Research work on mechanization of depetiolation should be taken up for saving time, energy and money.
- Scientific studies should be taken up for studying curing of betel leaf.
- Research work on the marketing systems and intelligence and allied aspects relevant to the crop are required to be initiated to safeguard the wild and unwarranted fluctuation in price of betel leaves.
- In view of the controversial claims about presence of carcinogen in betel leaf, it becomes imperative to carry out conclusive biochemical and genetic investigations together with clinical trials and demographic studies to protect the marketing potentialities of the crop.

- The foreign exchange earning potentiality of the crop may be improved through proper research on export systems and intelligence besides modulation of the export-policy-decisions.
- Studies should be taken up to solve all other marketing problems of betel leaf, like quick perishability, lack of proper storage of unsold leaves, lack of refrigerated and adequate number of wagons *etc.*
- The betel leaf growers should be encouraged to form proper professional association for addressing their own problems.

References

Bhowmick S 1997 Paan: Anadrita Laxmi In Bengali. "Betel leaf: The neglected goddess of wealth" Moyna Prakashani, Calcutta-9.

CSIR Council of Scientific and Industrial Research, New Delhi. The wealth of India 8: 84-94. CSIR, New Delhi.

Chattopadhyay T K 1981 Betel vine cultivation in West Bengal, pp. 121-124, In: Proc. of Group Discussion on improvement of betel vine cultivation. S D Khanduja & V R Balasubrahmanyam (Eds.). National Botanical Research Institute, Lucknow, India.

Chattopadhyay S B & Maiti S 1967 Diseases of betel vine and spices. ICAR, New Delhi.

Dastane N G, Patil R G & Chaugule B A 1958 This bushiness of bleaching betel leaves, Indian Farming, 7(10): 10-12.

Garg S C & Jain R 1996 Chavicol rich essential oil of *Piper betle* L., Cutivar Sagar Bangla. Euro cosmetics 5: 27-28.

Guha P 1997 "Paan Theke Kutir Silpa Sambhabana" (In Bengali). "Exploring betel leaves for cottage industry", pp. 15-19, In: Krishi, Khadya-O- Gramin Bikash Mela –A Booklet published by the Agricultural and Food Engineering Department, IIT, Kharagpur, India.

Guha P 2000 Commercial exploitation of oil from betel leaves, pp. 56-57, In: Proc. Sixth Regional Workshop on oil seeds and oils. IIT, Kharagpur (Eds.). Agricultural and Food Engineering Department, IIT, Kharagpur, India.

Guha P 2003 Extraction of essential oil from betel leaves grown in and around Midnapore District, pp.15-23, In: Annual Report of All India Coordinated Research Project on Post Harvest Technology (ICAR). IIT, Kharagpur (Ed.). Food and Agricultural Engineering Department, IIT, Kharagpur, India.

Guha P 2004 Development of technology for enhancing shelf life of betel leaves (*Piper betle* L.), pp. 39-56, In: Annual Report of All India Coordinated Research Project on Post Harvest Technology (ICAR). Food and Agricultural Engineering Department, IIT, Kharagpur, India.

Guha P 2006 Betel leaf: The neglected green gold of India. J. Hum. Ecol. 19(2):87-93.

Guha P 2007 Extraction of essential oil: An appropriate rural technology for minimizing wastage of surplus betel leaves. AMA 38(4):47-50.

Guha P 2008 Design, development, testing and comparative evaluation of betel leaf oil extractor. Communicated to AMA.

Guha P & Jain R K 1997 Status Report on Production, processing and marketing of betel leaf *Piper betle* L. Agricultural and Food Engineering Department, IIT, Kharagpur, India.

Gunther E 1952 The essential oils, 5: 160-161. D. Van Nostrand & Co, Inc. New York.

ICAR Indian Council of Agricultural Research, New Delhi 1997 Annual Report of All India Coordinated Research Project on Betel vine (ICAR), Indian Institute of Horticultural Research, Hessarghatta, Bangalore, India.

ICAR Indian Council of Agricultural Research, New Delhi 2000 Annual Report of All India Coordinated Research Project on Betel vine (ICAR). National Research Centre for Medicinal and Aromatic Plants, Boriavi, Gujarat, India.

Jana B L 1995 Gram Banglar Arthakari Phasal-Paan (In Bengali). "Betel leaf: A cash crop of villages of Bengal". Asaboni, Flat 203, 184, B B Chatterji Road, Calcutta-12.

Jana B L 1996 Improved technology for betel leaf cultivation. A paper presented in the " Seminar-cum-Workshop on betel leaf marketing", held at State cashew nut farm, Directorate of Agricultural Marketing, Digha, Midnapore (W. B.), India, June 5-6, 1996.

Jeng J H Chen, S Y Liar, C H Tung, Y Y Lin, B R, Hahn L J& Chang M C 2002. Modulation of platelet aggregation by areca nut and betel leaf ingredients: Roles of relative oxygen species and cyclooxygenase. Free radical biology and medicine 32 (9): 860-871.

Khanra S 1997 Paan Vittik Silpakendra (In Bengali). "Betel leaf based industry". Nabanna Bharati 30 (2): 169.

Kanungo, S P 1996 Package of practices and agronomic manipulations in *Cymbopogan* species, pp.13-16, In: CSIR Technology Utilization for Rural Development (Aromatic and Spice Plants). RRL, Bhubaneswar (Ed.).

Khoshoo T N 1981 Welcome address pp. xvii-xx, In: Proc. of Group Discussion on improvement of betel vine cultivation. Khanduja S D & Balasubrahmanyam V R (Eds.). National Botanical Research Institute, Lucknow, India.

Lahiri D 1991 A study of betel leaf marketing in Midnapore District, West Bengal. A Report on an Ad-hoc research project (ICAR), Rural Development Centre, IIT, Kharagpur.

Maiti S 1989 Extension Bulletin: The Betel vine. All India Coordinated Research Project on Betel vine, Indian Institute of Horticultural Research, Hessarghatta, Bangalore, India.

Mehrotra R S 1981 Fungal diseases of betelvine and their control, pp. 3-12, In: Proc. of Group Discussion on improvement of betel vine cultivation. Khanduja S D & Balasubrahmanyam V R (Eds.). National Botanical Research Institute, Lucknow, India.

Mishra S D & Gaur B K 1972 Control of senescence in betel leaves by depetiolation. Exptl., Gerant. (7): 31-35.

Ramalakshmi K, Sulochanamma G, Rao L J M, Borse B B & Raghavan B 2002 Impact of Drying on quality of betel leaf (*Piper betle* L.). J. Food Sci. Technol. 39 (6): 619-622.

Rao, V M & Narasimham B 1977 Prolonging storage life of betel leaves, Indian J. Hort. 34 (2): 175-182.

Rayaguru K, Sahoo G, Khan, Md. K & Pal U S 2007 Post harvest practices of betel leaves in Orissa, India. AMA 38(3):33-37

Samanta C 1994 Paan chaser samasyabali-o-samadhan: Ekti samikkha (In Bengali): "A report on the problems and solutions of betel vine cultivation". A booklet published by Mr H R Adhikari, C-2/16, Karunamoyee, Salt Lake City, Kolkata-64 (WB), India .

Sankar C R, Sridevi D & Babu M K 1996 Studies on essential oil and oil constituents of betel vine cultivars. The Andhra Agric. J. 43 (1): 24-26.

DAMM Superintendent, Directorate of Agricultural Marketing, Midnapore 1996 Paaner Kotipoy Tathya (In Bengali). "Some aspects of betel leaf." A paper presented in the " Seminar-cum-Workshop on Betel leaf Marketing", held at the state cashew nut farm, Directorate of Agricultural Marketing, Digha, Midnapore (W. B.), India, June 5-6, 1996.

engupta K 1996 Pan Patar Sangrakkhan (In Bengali). "Preservation of betel leaves." Nabanna Bharati 28 (12): 580-82.

Sharma M L, Rawat A K S, Balasubrahmanyan, V R & Singh A 1981 Essential oil of betel leaf (*Piper betle* L.) cv. Kapoori, pp. 161-164, In: Proc. of Group Discussion On Improvement of Betel vine Cultivation. Khanduja S D & Balasubrahmanyam V R (Eds.). National Botanical Research Institute, Lucknow, India.

Sharma M L, Rawat A K S, Khanna R K, Chowdhury A R & Raina R M 1996 Flavour characteristics of betel leaves. Euro cosmetics 5:22-24.

Singh K K, Balasubrahmanyam V R & Kochhar V K 1990 Effect of different packing methods, temperature conditions, treatment with chemicals on the senescence and storage behaviour of betel (*Piper betle* L) leaves. J. Plant. Crops 18 (1): 23-28.

Research on betel vine diseases under AINP on betel vine

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Introduction

Betel vine is mainly cultivated in East and North of India under artificially erected structure known as Boroj, Bareja or Bheet, which is a kind of protected cultivation. The sides and roof are made of jute sticks or straw on a light bamboo frame work. Where as in South, it is grown under open system with live support of fast growing trees (*Moringa, Sesbania, etc.*). In spite of the tremendous potentiality of the crop, cultivation of betel vine is un remunerative because of its susceptibility to several diseases, aggravated by moist and humid growing conditions, which are prerequisites for growth and yield. Obviously the major constraint in cultivation is diseases that eventually damage all plant parts such as root, stem and foliage. The serious diseases reported are foot rot (*Phytophthora parasitica,* var. *piperina*, *Phytophthora nicotianae* var *parasitica, Rhizoctonia spp, Pythium spp.* and *Sclerotium rolfsii)* and leaf rot (*Phytophthora parasitica*, *Phytophthora palmivora)*, leaf spot and stem anthracnose (*Colletorichum capsici*) and bacterial leaf spot and stem rot (*Xanthomonas campestris* pv. *Betlicola)*. Among the pathogens, *Phytophthora, Colletotrichum,* bacterial stem rot and leaf spot causess extensive damage both under field and storage conditions.

Research work carried out under All India Coordinated Research Project on Betelvine on various aspects of disease management *viz*., disease survey, epidemiology, varietal resistance, disease control and integrated disease management are presented here with

Symptomatology

Phytophthora foot rot and leaf rot

Dastur (1935) reported an accurate description of the disease symptoms. In *Phytophthora* induced foot rot, wet rot associated with wilting of vines is common. In leaf rot, circular brown to black water soaked spots develop on the leaves that enlarge fast and extend to petiole and stem. Leaves are subsequently shed. Under intermittent wet and dry conditions, clear zonations were seen on leaves giving a wavy appearance due to shrinkage or collapse of cells (Maiti & Sen 1977).

Foot rot

The leaves and shoots turn yellow, wither and finally dry out to a pale brown colour. In diseased plants, fine young roots are infected first, gradually it spreads through older roots and reaches to collar region.

In a severely diseased plant, completed rotting of the whole root portion can be noticed. The soft tissues of old roots and inter nodal portion are completely decomposed leaving only the fibrous portion.

Leaf rot

The initial symptoms appear in the form of water soaked spots which enlarge rapidly in size on mature leaves near the soil. The spots are of two types, first one is of circular, necrotic, deep brown in colour with distinct grey-brown zonation and thc second one is of expanding, circular, dark-brown necrotic spot without any zonation. The central rotten portion of the spot drops out leaving a hole with irregular edges. In both these types, the symptoms develop on any part of the leaves, including tips and margins.

Leaf spot and stem anthracnose (*Colletotrichum spp.*)

Leaf spot

On the leaves, the disease is characterized by the presence of spots which are usually circular with brownish-black centre surrounded by yellowish halo. These spots often coalesce to form large lesions. The infected regions gradually become thin and dry and do not undergo any rotting. When the spots are present on the margin of the leaves, the leaf blade tend to droop owing to the shrinkage of tissues. The infected leaves may fall off prematurely (Roy 1948). Hector (1925) described the disease as yellow discolouration and wilting of leaves. Narasimhan (1938) described the disease as blackish spots on leaves and vines, latter drying and withering of foliage. Maiti & Sen (1979) observed more than one spot on each leaf. The spots are irregular in size and shape, light to dark brown or black in the center and surrounded by a diffuse chlorotic yellow halo. Dasgupta (1982, 1998); Roy (2002) reported that leaf spots developed as minute necrotic spots with a narrow bright yellow halo around them. The spots enlarged and coalesce and appeared as light to dark brownish black spot in the centre surround by a diffuse, chlorotic yellow halo. The spots are developed on margins, tips and both inter and intra-veinal areas and was in variably surrounded by a yellow halo irrespective of its position. In severe cases the margins and tips develop a burnt appearance.

Stem anthracnose

Stem anthracnose developed as minute spots, dark brown in colour. The spots enlarge and coalesce to form narrow elongated dark brown lesions of 7.0 – 10.0 x 1.5 – 2.3 mm in size and ultimately the stem is girdled. Numerous acervuli developed on such lesions (Dasgupta 1982; Roy 2005).

Bacterial leaf spot and stem rot

Leaf spot

The infection starts as minute water soaked lesions spread to all over the leaf blade delimited by veins. Several of them coalesce to form bigger irregular browinish spots surrounded by translucent water soaked area on the lower surface and yellow halo on the corresponding upper surface. The leaves defoliate prematurely. The symptoms are found to vary with varieties (Chattopadhyay & Maiti 1990).

Stem rot

Bacterial stem rot develop as water soaked lesions on the internodal areas near the soil surface. The lesions enlarge rapidly, coalesce and form brownish water soaked lesions. The infected areas become sticky, leaf turn yellow and fall off and as a result entire vine may die.

Disease survey

Survey was conducted during pre and post monsoon period. Results revealed that disease incidence was recorded maximum during post monsoon period that is just after the rainy season. In most of the locations, *Phytophthora* leaf and foot rot, anthracnose, bacterial leaf spot and stem rot and basal rot were important and causes heavy losses. Powdery mildew was recorded only in MPAU, Maharashtra. Disease pressure was low in AAU, Assam and RAU, Bihar. Maximum disease incidence was recorded in BCKV, West Bengal and TNAU, Tamil Nadu.

Varietal resistance

The results (table 1) revealed that the varieties available at different centres were screened under artificially created epiphytotic condition against important diseases. Multiple resistance was observed in Halisahar Sanchi against *Phytophthora* rot (stem and leaf), anthracnose, bacterial leaf/stem infection and basal rot. Pachaikodi and Karappu showed high resistance to *Phytophthora* leaf and foot rot and bacterial leaf/stem infection at JNKVV, Jabalpur. All Kapoori varieties showed resistance to powdery mildew at IIHR.

Table 1. Varietal resistance in betel vine against diseases

Disease	Resistant cultivars	Location of testing
Anthracnose	Halisahar Sanchi, Awani pan, Alupatria	Kalyani, Bhubaneswar Kalyani, Bhubaneswar
Phytophthora leaf and stem rot	Pachaikodi, Karappu	Jabalpur
Bacterial leaf/stem infection	Pachaikodi, Karappu, Bangla (Mandsur) Halisahar sanchi, Alupatria	Jabalpur, Bhubaneswar
Basal rot	Halisahar sanchi, Alupatria	Bhubaneswar
Powdery mildew	All Kapoori cultivars	Hessarghatta

Epidemiological studies

Temperature, relative humidity and rainfall played an important role in development of both the diseases (Anonymous 2000-2006; Maiti & Sen 1982).

Disease management

Phytophthora foot rot - chemical control

The experiments were conducted for three consecutive years to evaluated fungicides against foot rot caused by *Phytophthora* spp. Treatments includes phosphorus acid (Akomin, Rallis India @ 4 ml/l); chlorothalonil (Kavach, Sandoz @ 0.18% a.i.); fosetyl – Al (Aliette 80 WP, Rhone-Poulnec @ 0.24% a.i.); Bordeaux mixture (1% copper sulphate preparation); and water spray as control. All the treatments were applied at monthly interval between June and September. The disease incidence results of pooled data of three years showed that the highest foot rot were recorded in control in all the centres. The best control of foot rot was recorded in fosetyl-Al (3g/l) at monthly interval treatment at AAU and TNAU which was also at par with Bordeaux mixture (1%). At BCKV, the best control of foot rot was recorded in Bordeaux mixture and it was statistically at par with fosetyl-Al (3g/l). The results of disease incidence at APAU was non significant. The highest leaf yield was recorded with fosetyl-Al at AAU (41 lakh/ha), TNAU (25 lakh/ha) and BCKV (58 lakh/ha). Bordeaux mixture treatment was also at par with fosetyl-Al in all the three centres. Results on leaf yield was non-significant in APAU. Fresh weight of 100 leaves was non-significant except in BCKV. AT BCKV, the highest fresh weight (212 g/100 leaves) was recorded with phosphorus acid (4g/l) and it was statistically at par with all other treatments except control and chlorothalonil (2.5 g/l). The highest cost:benefit ratio was recorded in Bordeaux mixture (1%) applied at monthly interval treatment at BCKV (1:8.01) and TNAU (1:3.59) centres.

Spray schedule for *Phytophthora* foot rot control

The results showed that in all the centres the lowest disease was recorded in 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively treatment (June, July, Aug., Sept.) and it was statistically inferior to all other treatments except at JNKVV centre where three drenchings and six sprayings of Bordeaux mixture @ 1% and 0.5% respectively (July, Aug., Sept.) treatment. The highest foot rot was recorded in control treatment and it was statistically superior to all other treatments.

In all the centres the highest leaf yield was recorded in 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively treatment (June, July, Aug., Sept.). and the lowest leaf yield was recorded in control treatment.

The highest fresh weight of 100 leaves was recorded in treatment where 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively (June, July, Aug., Sept.) were made. The lowest fresh weight of 100 leaves was recorded in control treatment.

Spray schedule for *Phytophthora* leaf rot control

The experimental results showed that in all the centres the lowest disease was recorded in 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively treatment (June, July, Aug., Sept.) and it was statistically inferior to all other treatments except at BCKV centre where three drenchings and six sprayings of Bordeaux mixture @ 1% and 0.5% respectively (July, Aug., Sept.) treatment. The highest foot rot was recorded in control treatment and it was statistically superior to all other treatments except at BCKV centre where single drenching and two sprayings of Bordeaux mixture @ 1% and 0.5% respectively treatment (June).

In all the centres the highest leaf yield was recorded in 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively treatment (June, July, Aug., Sept.). and the lowest leaf yield was recorded in control treatment.

The highest fresh weight of 100 leaves was recorded in the treatment where 4 drenchings and eight sprayings of Bordeaux mixture @ 1% and 0.5% respectively (June, July, Aug., Sept.) were made. The lowest fresh weight of 100 leaves was recorded in control treatment.

Biological control of *Phytophthora* foot rot

The results (table 2) showed that in all the centres the lowest disease was recorded in 4 drenchings and eight sprayings of Bordeaux mixture treatment and it was statistically on par with the treatment where antagonists were applied at quarterly interval at AAU and TNAU centres. At BCKV centre, *Trichoderma* treatment was the second best treatment after Bordeaux mixture.

The highest leaf yield was recorded in treatment where four drenchings and eight sprayings of Bordeaux mixture were applied at all the centres. However, it was statistically on par with quarterly application of *Trichoderma* at AAU and TNAU centres. The lowest leaf yield was recorded in control treatment and it was statistically on par with the treatment where *Trichoderma* was applied at pre-monsoon at TNAU centre. In other centres, AAU and BCKV, leaf yield was minimum in control and other treatments were statistically superior to control treatment.

The highest fresh weight of 100 leaves was recorded in treatment in Bordeaux mixture treated plots in all the locations. At AAU and TNAU centres, the treatment differences were statistically non-significant. At BCKV centre, the above treatment was statistically superior to all the treatments. The lowest fresh weight of 100 leaves was recorded in control treatment (table 2).

Table 2. Biological control of *Phytophthora* foot rot in betel vine

Treatment	Per cent disease incidence			Leaf yield (lakh/ha)			Fresh weight of 100 leaves (g)		
	AAU	BCKV	TNAU	AAU	BCKV	TNAU	AAU	BCKV	TNAU
One application of *Trichoderma* inoculated oil cake @ 500 kg/ha at premonsoon + three applications of *Trichoderma* uninoculated oil cake @ 500 kg/ha applied at quarterly interval	16.19 (24.32)	20.31 (26.58)	38.39 (38.12)	27.55	34.43	27.56	333.67	205.20	215.12
Two applications of *Trichoderma* inoculated oil cake @ 500 kg/ha at pre and post monsoon + two application of *Trichoderma* uninoculated oil cake @ 500 kg/ha applied at quarterly interval	9.67 (18.08)	16.57 (23.90)	32.77 (34.65)	36.70	38.22	29.96	333.64	213.93	219.95
Four applications of *Trichoderma* inoculated oil cake @ 500 kg/ha inoculated oil cake at quarterly interval	4.59	13.37	24.39	41.68	41.09	34.57	337.17	220.65	225.29
Bordeaux mixture (4 drenches + 8 sprayings at monthly and fortnightly intervals, respectively) @ 1% as soil drench and 0.5% as foliar spray + four split doses of oil cake @ quarterly intervals.	4.05	10.29	21.48	42.16	45.43	35.23	335.21	249.77	226.34
Control	21.23 (27.45)	28.94 (32.08)	43.43 (39.48)	18.04	27.60	25.28	326.46	197.86	213.45
SEm ±	0.82	0.53	1.29	1.79	0.90	1.09	3.42	4.03	3.46
CD (P=0.05)	2.42	1.46	3.88	5.37	2.49	3.27	NS	11.10	NS

(figures in parentheses are the angular transformed values)

Integrated management of foot rot and leaf rot

The results showed that the treatment where sanitation, Bordeaux mixture and *T. harzianum* were integrated, gave the best control of foot rot and leaf rot of betelvine. It was also found that this combination gave the better yield of leaves (lakh/ha) and fresh weight of 100 leaves. The economic analysis showed that application of Bordeaux mixture along with *T. harzianum* and sanitation may be of great practical implication due to its favourable effect on leaf yield and fresh weight.

Chemical control of anthracnose

The lowest disease incidence and disease index was recorded in Bordeaux mixture 1% sprayed treatments at AAU centre, copper oxy chloride 0.2% a.i sprayed treatment at BCKV centre and Baycor (Bitertanol) 0.05% a.i sprayed treatment at OUAT and TNAU centre. The highest disease was recorded in control treatment (table 3).

The highest leaf yield was recorded in treatment where Bordeaux mixture 0.5% was sprayed in the entire centre. The lowest leaf yield was recorded in control treatment.
The highest fresh weight of 100 leaves was recorded in Bordeaux mixture 0.5% sprayed treatment in all the centres except of BCKV, centre where highest fresh weight was recorded in copper oxychloride 0.2% a.i sprayed treatment. The lowest fresh of 100 leaves was recorded in control treatment (table 3).

Bacterial leaf spot control

In all the centers the lowest disease was recorded in streptocycline 250 ppm sprayed treatment when percent disease index and percent disease incidence were recorded except in TNAU centres where lowest percent disease incidence was recorded in Bacterinol 0.1% + copper oxychloride 0.1% a.i sprayed treatment although where treatment differences were not significant.

The highest leaf yield was recorded in streptocycline 250 ppm sprayed treatment at BCKV, OUAT,RAU Centre, copper oxycloride o.1% a.i sprayed treatment at AAU centre and Bordeaux mixture 0.5% sprayed treatment at TNAU centre although where treatment differences were not significant.

The highest fresh weight of 100 leaves was recorded in copper oxychloride 0.1% a.i sprayed treatment at AAU centre although where treatment differences were not significant (Table 11). At BCKV centre highest fresh weight of 100 leaves was recorded in streptocycline 250 ppm sprayed treatment. At OUAT centre, highest fresh weight of 100 leaves was recorded in Bactrinol 0.1% a.i + copper oxychloride 0.1% a.i sprayed treatment. Where as at RAU and TNAU centre, the highest fresh weight of 100 leaves were recorded in Bractinol 0.1% a.i + Bordeaux mixture 0.5% sprayed treatment.

Table 3. Chemical control of anthracnose *(Colletotrichum capsici)* in betelvine

Treatment	Per cent disease index				Per cent disease incidence			
	AAU Jorhat	BCKV Kalyani	OUAT Bhubaneswar	TNAU Sirugamani	AAU Jorhat	BCKV Kalyani	OUAT Bhubaneswar	TNAU Sirugamani
Copper oxychloride 0.1% a.i.	24.77 (29.82)	7.34 (15.69)	15.00 (22.80)	53.83 (47.20)	14.49 (22.32)	8.19 (16.59)	12.30 (20.53)	27.92 (31.71)
Copper oxychloride 0.2% a.i.	14.44 (22.32)	6.42 (14.64)	10.03 (18.47)	48.33 (44.13)	11.70 (20.46)	5.59 (13.67)	8.44 (16.89)	25.30 (30.12)
Baycor (Bitertanol) 0.02% a.i.	19.50 (26.29)	9.65 (18.06)	10.80 (19.19)	45.50 (42.41)	13.12 (21.22)	7.74 (16.12)	10.25 (18.69)	23.77 (29.22)
Baycor (Bitertanol) 0.05% a.i.	15.05 (24.81)	9.13 (17.55)	7.66 (16.08)	37.83 (37.93)	11.54 (19.94)	7.74 (16.12)	5.39 (13.42)	22.30 (28.10)
Cuman L 0.1% a.i.	22.16 (28.16)	8.72 (17.17)	9.98 (18.41)	57.0 (49.05)	12.55 (20.72)	13.66 (21.45)	7.44 (15.83)	34.57 (35.94)
Mancozeb 0.1% a.i.	10.16 (18.14)	11.49 (19.80)	8.80 (17.25)	58.83 (49.01)	10.48 (18.97)	17.30 (24.43)	6.65 (14.96)	31.11 (35.39)
Bordeaux mixture 0.5%	6.00 (14.44)	7.03 (15.36)	9.07 (17.53)	49.67 (44.81)	8.57 (17.10)	6.34 (14.43)	6.90 (15.13)	24.33 (29.29)
Control	39.00 (38.70)	15.01 (22.79)	19.00 (25.83)	70.33 (57.49)	27.22 (31.58)	22.87 (28.42)	15.47 (23.16)	40.35 (39.30)
SEm ±	1.07	0.92	0.94	2.50	0.39	2.74	2.60	1.27
CD (P=0.05)	3.25	1.97	2.03	5.08	1.20	5.88	NS	2.58

(figures in parentheses are the angular transformed values)

Conclusion

The research conducted under AICRP on betelvine and different workers have generated information on management strategies to control major diseases of betelvine particularly *Phytophthora* diseases. But there are gaps and require much more detailed study to make them fruitful to the farmers.

There is ample scope in the field of bio-control research. Although, *Trichoderma* was found to be an effective antagonist under *in-vitro* conditions which is probably due to poor rhizosphere competence and less secretion of antifungal enzymes. These problems may be over come by the use of genetically engineered strains of *Trichoderma* sp. In bio-control of these diseases, application of bio-protectant may be effective on the foliage and also in the collar region which is very much responsive to foot rot pathogens.

To get the better results in IDM programmes, the source of initial inoculum need to be identified along with possibilities of their elimination. There are several reports that some co-lateral hosts harbour the pathogens. The irrigation water from the adjoining ponds may also be the source of inoculum. The growers usually wash the infected material in nearby reservoirs and irrigate their crops with the same water, thus enabling the recurrence of the disease. So, the actual means of survival within and in the immediate vicinity should be identified first and then factors influencing inoculum build-up and their dispersal need to be studied. The strategy thus obtained should be confirmed under *in situ* farmer's plot demonstrations.

References

Anonymous 2000-2001 Annual Report, All India Net Working Project on Betelvine. National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand, Gujarat, India, p 137.

Anonymous 2001-2002 Annual Report, All India Net Working Project on Betelvine. National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand, Gujarat, India, p 152.

Anonymous 2002–2003 & 2003-2004 Biennial Report, All India Net Working Project on Betelvine. National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand, Gujarat, India, p 157.

Anonymous 2004–2005 & 2005-2006 Biennial Report, All India Net Working Project on Betelvine. National Research Centre for Medicinal and Aromatic Plants, Boriavi, Anand, Gujarat, India, p 168.

Chattopadhyay S B & Maiti S 1990 Diseases of betel vine and spices. New Delhi, Indian Council of Agricultural Research (ICAR), p 160.

Dasgupta B 1982 Studies of leaf spot and anthracnose of betel vine caused by *Colletotrichum capsici* (Syd.) Butler and Bisby. Ph. D. thesis. BCKV, Kalyani, India, p 57.

Dasgupta B 1998 Proceedings National Training on Recent Advances in Betel vine cultivation, B.C.K.V., Kalyani, West Bengal, Dec. 1-8, 1998, p 50.

Dastur J R 1935 Disease of pan (*Piper betle*) in the Central Provinces. Proc. Indian Acad. Sci. 1(11): 26-31.

Hector G P 1925 Appendix 1. Annual report of the Economic Botanist to the Government of Bengal for the year 1923-24. Ann. Rept. Dept. of Agric. Bengal, pp. 1-5.

Maiti S & Sen C 1977 Leaf and foot rot of *Piper betle* caused by *Phytophthora palmivora*. Indian Phytopath. 30 : 438-439.

Maiti S & Sen C 1979 Fungal diseases of betel vine. PANS 25: 150-157.

Maiti S & Sen C 1982 Incidence of major diseases of betel vine in relation to weather. Indian Phytoph. 35: 14-17

Narasimhan M J 1938 Annual Report of the Mycological Department for the year 1936-37, pp. 169-173.

Roy T C 1948 Anthracnose disease of betel vine (*Piper betle* L.) caused by *Colletotrichum dastur*; Roy, in Bengal. J. Indian Bot. Soc. 27: 96-102.

Roy J 2002 Management of two important diseases of betel vine (*Piper betle* L.) with special emphasis on biological control. Ph. D. thesis. BCKV., Nadia.

Roy Sandip 2005 Epidemiological studies of leaf spot of betel vine (*Piper betle* L.) caused by *Colletotrichum capsici* (Syd.) Butler and Bisby, and its management. M.Sc.(Ag.) Dissetation. BCKV., Mohanpur, West Bengal.

Insect pests and mites of betelvine and their management

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Introduction

India is the largest producer of betel leaves in the world and the leaf area expansion is high in India (Arulmozhian *et al.* 2005). In India more than 100 types of betelvine are reported to be in cultivation and most of them are synonyms and confusing one. The crop is damaged by pests and diseases at one time or other and cause economic loss to the tune of several crores. The common betelvine pests recorded are whitefly, mealybugs, blackfly, scales, spider mites, *Spodoptera litura etc.*

Status of betelvine pests in India

- In Assam incidence of whitefly, mealybug and mites were observed in betelvine gardens. Whitefly infestation was in peak during April to July.
- In Andhra Pradesh, severe damage by *Spodoptera litura* (up to 30%) and red spider mite (up to 8%) was observed during October months. An incidence of 5-15% mirid bug (*Disphinctus politus*) was recorded around Tuni area during monsoon months which caused 40-50% damage during post monsoon months in Vishakapatnam District.
- In West Bengal, blackfly was observed to be serious in Midnapur and Bankura districts.
- In Orissa, whitefly and red spider mite were prevalent during summer months, whereas betelvine bug, aphids and jassids were confined to winter months.
- In Tamil Nadu, incidence of scales (*Lepidosaphas cornutus*) red spider mite, mealybug and *Spodoptera litura* were observed.

Population fluctuation of insects of betelvine

- In APAU, tobacco caterpillar incidence started during the second fortnight of September and was maximum during November-December months. Infestation was nil from January onwards. Build up of white mite started during second fortnight of November and was maximum during December-January months. Lower temperature was favourable for the development of the pest.
- At BCKV the population of white and black fly was maximum during August-September and June-August respectively. The second peak in population of white and black fly was also observed during December-January and September-November respectively.

- Highest scale insect population was seen during April-May in TNAU. Mite population was high during March. Both scale and mite population were positively correlated with maximum and minimum temperatures.

Betelvine pest management in India

Tobacco caterpillar : The experiments carried out at Acharya NG Ranga Agricultural Univerisity, Bapatla showed the effectiveness of the neem oil 0.5 % in the management of the tobacco caterpillars. Effective management of the pest resulted in monetary benefit to the tune of Rs 14,115 (in two months) and the cost benefit ratio was 1:9.4. There was 27 % leaf loss in unmanaged plots.

Red spider mite : The mites infestation was managed effectively by the spray of wettable suphur at 0.3 % at two times during the month of December. Effective management of the pest resulted in monetary benefit to the tune of Rs 20,175 (in two months) and the cost benefit ratio was 1:16.8. The reduction in leaf yield was 22.9 % in unmanaged plots.

At Mahatma Phule Krishi Vidyapeeth, Sangli, dicofol 0.05 % was effective in managing mites on betelvine leaves. The monetary benefit earned through increased leaf yields in well managed betelvine garden was Rs. 34,3866/- which was 38.69 % more than the unprotected garden.
At Tamil Nadu Agricultural University, Sirugamani, the mite infestation was effectively checked by spray of wettable sulphur 0.15 % + neem seed kernel extract 5 % or wettable sulphur 0.15 % + neem oil 2% or wettable sulphur 0.15 % + Azadirachtin 0.03 %. The monetary benefit was Rs. 33,044/-, Rs.34144/- and Rs. 40,327/- respectively.

White fly : The research conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani confirm the effectiveness of Imidachloprid 0.003% sprayed at an interval of one and half months for the management of whitefly. The leaf yield showed reduction to the tune of 12.18 % and monetary loss was high *viz.*, 34.13% in unprotected plots.

Newer technologies

Fixing of ETL for linear scale insect : The experiments conducted at Tamil Nadu Agricutural University at Sirugamani on betelvine crop with *Lepidosaphus cornutus* with population of 1,3, and 5 vine^{-1} seem to tolerate infestation. The leaf yield vine^{-1} in 5 scales vine^{-1} was 60.0 compared to that of 60.60 and 61.33 leaves in 1 and 3 scales^{-1} vine respectively. Control plot (0.04% chlorpyriphos spray) recorded only 2% damage and the leaf yield was highest (62.67 leaves vine^{-1}) in plants released with initial load of 1,3 & 5 scales respectively.

Mohammed Jalaluddin (2007) also reported that the leaf yield recorded from vine released with 5 linear scales was drastically lower and on par with 1&3 scales vine^{-1}. The leaf yield recorded from vines released with 7 & 10 scales was significantly lower than 5 scales vine^{-1}. The leaf yield was on par with the sprayed crop during the first week (exposed and treated crop recorded 13.67 lakh leaves/ha and 13.48 lakh leaves /ha respectively). The loss of leaf and the monetary loss followed from the second week onwards and lasted till seven weeks even in 1 scale vine^{-1}. Hence the control measures should be started before the threshold level of 1 scale vine^{-1} for effective suppression of linear scale insect (table 1).

Table 1. Economics of linear scale control at varying levels of exposure

Exposure (weeks)	Linear scales (mean no./ vine)	Leaf yield Avg/ month (lakh/ha)	Total cost of protection (Rs.)	Increase yield over control (lakh/ha)	Gross monetary profit (Rs.)
0	1.75	13.67	2220.00	10.59	37886.00
1	7.31	13.48	1942.50	10.40	37213.50
2	31.00	11.75	1665.00	8.67	28541.00
3	68.13	11.61	1387.50	8.53	28418.50
4	84.37	9.49	1110.00	6.41	18076.00
5	84.94	8.59	832.50	5.51	13873.50
6	94.88	7.67	555.00	4.59	9551.50
7	127.60	6.07	277.50	2.99	1820.50
Unprotected control	163.00	3.08	—	—	—

0-7 (0-complete protection & 1 to 7 - weeks exposures with scales)

Fixing ETL for mites: The population levels of mite, *Tetranychus cinnabarinus*, cause damage to the betel vine leaves and the feeding results in poor development and finally bronzing of leaves. The populations of 1 and 3 mites vine^{-1} recorded 0 and 0.89 mean damage grade index and yield was 51.33 and 50 leaves vine^{-1}. The population of more than 3 showed mean grade of more than 1 .5 and resulted in leaf yield loss (table 2).

Table 2. ETL for mite *Tetranychus cinnabarinus* at Tamil Nadu Agricultural University, Sirugamani

Population (mites/ vine)	Weeks after release 1	2	3	Mean DGI	Mean leaf yield /vine (no.)
1	1	0	0	0.0	51.33
3	0.33	0.67	1.67	0.89	50.00
5	0.67	1.0	3.00	1.56	37.00
7	1.00	2.33	4.33	2.55	32.67
10	2.33	3.00	4.33	3.22	32.00
25	3.00	3.67	5.67	4.11	31.00
50	3.67	4.35	6.33	4.78	30.00
100	4.33	5.00	7.67	5.67	29.33
Control (monocrotophos 0.05 %)	0	0	0	0	52.67
Mean (weeks)	1.70	2.22	3.67.		

CD values: for treatment - 0.70; for weeks - 0.04; for yield - 2.67

Management of tobacco caterpillar by biocontrol agents: The experiments conducted at Acharya NG Ranga Agricultural University, Bapatla, confirmed the effect of the neem seed kernel extract 5 % and neem oil 0.5 % which recorded highest leaf leaf yield of 4031/ha and 3906/ha respectively during 2004-05 and 3125/ha and 3000/ha respectively during 2005-06. This was followed by *Beaveria bassaiana* @ 5 g which recorded leaf yield of 3843/ha and 3333/ha respectively for the two years (table 3).

Table 3. Management of tobacco caterpillar in betel vine garden at Acharya N G Ranga Agricultural University, Bapatla during 2005-06

Treatment	Pretreatment leaf damage	Mean of two sprays	Leaf yield per plot (32 m^2)	No. of bundles* per ha
NSKE 5 %	12.8	11.4 (19.9)	7.5	3125
Neem oil 0.5 %	12.5	11.3 (18.2)	7.2	3000
NPV @ 500 LE /ha	11.3	15.1 (22.8)	6.2	2583
B.t @ 1.0 kg/ha	11.5	14.3 (21.9)	7.1	2958
B. bassiana @ 5 g/l of water	09.2	15.4 (23.0)	8.0	3333
N. rileyi @ 5 g /l of water	9.4	10.4 (18.6)	6.5	2708
Pongamia soap spray @ 10 g / l of water	14.0	18.2 (25.1)	7.8	3250
Chlorpyriphos 0.05 % spray + neem oil 0.5 % and NSKE 5 %	10.7	11.2 (19.4)	10.1	4208
Untreated	09.9	29.8 (33.0)	5.8	2416
S.E.	12.0	1.5	0.4	
C. D.(0.05)	-	3.1	0.8	

* Each bundle is equal to 100 leaves. Figures in parentheses are the transformed values

New pests identified

*At Bidhan Chandra Krishi Viswavidyalaya, Kalyani in West Bengal, a new scale insect and black fly were traced. The white fly species *Dialeurodes pallida* Singh and black fly species, *Aleurocanthus rugosa* occurring sympatrically.

*A new species of white scale insect, of Diaspididae was reported to be occurring in higher populations in Borejas at Nadia.

Future thrust

The new and safer biocontrol agents are to be tested for the management of pests. The natural enemies of the pests are to be identified, conserved and released in the betelvine garden. Application of neem products and neem formulations *viz.*, Azadirachtin 0.03 % is to be tested for the efficacy.

References

Arulmozhiyan R, Chitra R, Prabhakar K, Mohammed Jalauddin S & Packiaraj D 2005 SGM. BV. 2- An Improved variety of betel vine. Indian J. Arecanut, Spices and Medicinal plants 7 (1) :12-14

Mohammed Jalaluddin S & Padmanabhan D 2004. Tamil Nadu Agricultural Unversity, Sirugamani. Linear scale insect. p 124. In : All India Networking Project Report on Betelvine, Boriavi 387310, Anand, Gujarat, India,. pp.1-157

Mohammed Jalaluddin, S & Padmanabhan D 2006 Tamil Nadu Agrcicultural University, Sirugamani. Linear scale insect. p 145. In : All India Networking Project Report on Betelvine, Boriavi 387310, Anand, Gujarat, India, pp.1-168

Mohammed Jalaluddin S 2007 Fixing ETL or linear scale insect P. 60. In: The Annual Report 2006-2007 National Research Centre for Medicinal and Aromatic Plants, Boriavi 387310, Anand, Gujarat, India, pp.1 - 74.

Under-exploited species of Piperaceae and their uses

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The genus *Piper* belongs to the family Piperaceae with over 1000 species distributed in both the hemispheres, of which 110 are of Indian origin. The distribution of *Piper* ranges from sea level to the high ranges of Andes and Sub Himalayas. Trans-Gangetic region and the South Deccan are considered to be the two independent centers of origin of the genus *Piper* in India. The sub mountainous tracts of the Western Ghats are believed to be the centre of origin of black pepper, *Piper nigrum* L. More than 1000 species are included in the genus *Piper*, of which 110 are of Indian origin. *Piper*, the most diverse genera among basal lineages of angiosperms, is an important structural component of the forest under storey. *Piper* species occurring in South India are economically important, as they are closely related to the cultivated black pepper. *P. betle* L. is another economically important species which is mainly used in the pan industry. Several species of *Piper* are used as important medicinal plants. *P. longum*, *P. cubeba*, *P. retrofractum*, *etc.* are some of the species used in indigenous medicine system. The first report of *Piper* species of the Malabar region was by Van Rheede in his *Hortus Indicus Malabaricus* wherein he described five types of wild peppers including black pepper and long pepper. The major floristic study on *Piper* species for North Eastern India was done by Hooker as early as in 1886. Rama Rao (1914) in his 'Flowering Plants of Travancore' listed 14 species of *Piper* from the Western Ghats. Fischer (1921) described six species from Annamalai hills. The most authentic floristic study of South Indian *Piper* was that of Gamble (1925) who described 14 species in his 'Flora of the Presidency of Madras'. New taxa were reported by Ravindran *et al.* (1987); Velayudhan & Amalraj (1992); Nirmal Babu *et al.* (1993). Chromosome number of *Piper* species occurring in the Western Ghats, range from $2n = 26$ to 195, and this indicates the existence of a polyploid series (Ravindran *et al.* 2000). Most of the chromosome studies could trace to the basic chromosome number, $x = 13$.

The *Piper* species have high commercial, economical and medicinal importance. Black pepper (*Piper nigrum* L.) is the most economically important species of the genus, since it is the source of white and black pepper. There are other species having commercial value. A narcotic beverage popularly known as kawa-kawa is produced in Oceania from the roots of *P. methysticum*. Several species of *Piper* are grown domestically as house plants for their foliage. Besides this, there are a few *Piper* species identified for disease resistance (*e.g.*, foot rot disease caused by *Phytophthora capsici*), insect resistance ('pollu' beetle infestation) *etc.* and these species are being utilized in the crop improvement programme.

The species of *Piper* are used medicinally and in cosmetics in various form in different countries (table 1). *Piper* species are reputed in the Indian Ayurvedic system of medicine for their medicinal properties and in folklore medicine of Latin America and West Indies. Long pepper (*Piper longum* L.) forms an important Ayurvedic preparation *viz.*, 'Trikadu'. The tribal of India consider *P. betle* as a useful ingredient in treating madness, strangulation of intestine, venereal sore *etc.* (Jain & Tarafder 1970). *P. silvaticum* roots are used as an effective antidote to snake poison in the indigenous system of Indian medicine. *P chaba* roots and fruits find numerous applications in Ayurvedic and Unani medicine systems. In particular, they are useful in asthma, bronchitis, pain in abdomen *etc.* (Kirtikar & Basu 1933). *P. aduncum* and *P. hispidium* are listed as remedies for stomach ache and insect repellents in Jamaica (Asprey & Thorton 1954).

The fruits of *P. guineense*, popularly known as West African black pepper are used as a flavorant while preparations of leaves, roots and seeds have been used internally as medicinal agents for the treatment of bronchitis, gastro intestinal diseases, venereal disease and rheumatism (Irvine 1961; Parmer *et al.* 1997). *Piper* plants are most commonly used as food flavoring by local Thai people. *P. nigrum* and *P. sarmentosum* are the most famous ethno economic species of Thailand (Chaveerach *et al.* 2006). They are common nation wide for cuisine flavoring and are grown in many home gardens and crop plantations of Thailand.

Distribution

The distribution of *Piper* species ranges from sea level to the high ranges of Andes and to the sub Himalayas. Trans – Gangetic region and the South Deccan are considered to be the two independent centers of origin of the genus *Piper* in India. However, the studies conducted by Rahiman (1981) states that there are three major centers for *Piper* in India, *viz.*, the sub-Himalayan and North East Indian centre, the Western Ghat centre and the Eastern Ghat centre.

The *Piper* species originated from the southern Asia are of more importance since the important species like *P. nigrum* (black pepper), *P. betle* (betel vine) *P. longum* (long pepper), *P. chaba* (Java long pepper), *P. cubeba* (cubeb) *etc.* have originated from this region. The distribution of *Piper* is denser along footpaths, animal tracts, riversides and towards the periphery of the forests, wherever there is a good penetration of light. However, in disturbed forests they occur in good number even in interior due to the increased light availability.

Table 1. *Piper* species used for medicine and in cosmetics in various countries

Botanical name	Uses
Piper aduncum L.	Macerated leaves and stem are used for medicament for sores. Whole plant is used for herbal bath
P. alatabaccum T & Y	Used for skin washing

P. amalago var. medium Y	Flower infusion, used as vermifuge
P. arboretum Aublet	Heated leaves are used as band-aid around joints. Macerated leaves and stem are used as antivenom
P. attenuatum Buch- Ham. Ex Wall	Dried roots are macerated and used as diuretic
P. angustum Rudge	Whole plant decoction is used for heart diseases. Stem and leaf decoction is retained in the mouth to heal bleeding gums
P. avellanum (Miq) CDC	Leaf is used in cramps, snake bite and stomach aches
P. betle L.	As a masticatory, it is aromatic, digestive, stimulant and carminative.
P. chaba Hunter	Used in place of *P. longum* for the Ayurvedic preparation of "thrikadu"
P. cubeba L.	The powdered fruits are used for the treatment of dysentery, catarrh and as an aromatic stimulant, local irritant, carminative and sedative.
P. cyriopodon (Miq) CDC	Leaves used for skin rashes
P. glabrescens (Miq) CDC	Leaf extract is used as antivenom against snake bite
P. hapnium Ham.	Used in place of *P. longum.*
P. hostmannianum Gorts & Kramer	Whole plant infusion with other herbs is used to treat rattlesnake bite
P. kadsura (Choisy) Ohwi	Podered roots are used for the treatment of asthma and arthritis
P. longum L.	Widely used in Ayurvedic and Unani systems of medicine, particularly for diseases of respiratory tract.
P. methysticum F.	Roots are used for the preparation of "kava-kava"- a non alcoholic drink of Polynesia
P. mullesua Ham.	The roots are used in the treatment of asthma, bronchitis, dyspepsia *etc.*
P. nigrispicum CDC	Leaves are used for snake bite
P. nigrum L.	The root, in the form of ghee, powders and balms is used to treat abdominal tumors. Powdered form of black pepper along with other herbs used to treat adenitis, cholera, cold *etc.* A heavy dose of pepper with bamboo shoots is said to produce abortion.
P. obliquum Ruiz & Pavon	Cut stem is used to treat hernia. Warmed leaves are used for treating muscular pain.
P. peepuloides Roxb.	Used in place of *P. longum*

Diversity and conservation of under-exploited *Piper* species in India

India is one of the centers of origin of the genus *Piper*. The Western Ghats of South India and the North Eastern India are the two independent centers where genetic diversity of *Piper* is occurring besides A & N Islands. The species diversity of *Piper* in South India, their salient features and distribution are given in table 2. Some species of *Piper* are most affected by deforestation and many of the taxa are now confined to a few locations and may soon be extinct, if not collected and conserved. *Piper barberi, P. hapnium, P. silentvalleyensis, P. wightii* and *P. schmidtii* are extremely rare and are probably on the verge of extinction. Local cultivar diversity is the richest in Kerala, followed by that in Karnataka. Unlike the wild forms of P. *nigrum* which are mostly dioecious, most cultivated ones are bisexual. Earlier, there were specific local cultivars, associated with every major pepper-growing tract but by the turn of the 20th century; there was a lot of human migration to the Western Ghats and its foothills. This led to the selective spread of some of the better yielding genotypes, and they became popular throughout the pepper-growing areas. Intracultivar variability has also been reported in certain extensively grown local cultivars.

Table 2. Species diversity of *Piper* in Western Ghats, India

Species/ 2n chromosome number	Salient features
P. argyrophyllum (36, 39, 52)	Occurs at medium elevations in the peripheral areas of evergreen forests, rare species.
P. attenuatum (26, 39, 36, 52)	A common wild *Piper* species, occurs at low and medium elevations.
P. barberi (52)	Included in the Red Data Book as endangered species, occurs in Thirunelveli forests.
P. betle (26, 42, 52, 58, 64, 78, 195)	Cultivated species but also occurs in forest.
P. galeatum (40, 52)	Occurs at medium elevations, bold fruits.
P. hapnium (52)	Very rare, endangered species occurring at low elevations.
P. hookeri (60, 104)	Closely related to *P. hymenophyllum*, but less pubescent.
P. hymenophyllum (104)	Occurs at medium to high elevations, pubescent species.
P. longum (24, 26, 48, 52, 60, 96)	Distributed all over India at low elevations, has creeping habit, medicinal value.
*P. psuedonigrum**	Related to *P. nigrum* and very similar to *P. sugandhi* var. *brevipilis*.
P. schmidtii (96)	Endangered species, occurs at high elevation above 1500 m

*P. silentvalleyensis**	New species, extremely rare, has bisexual flowers and minute fruit.
P. sugandhi (52)	Closely related to *P. nigrum* and *P. pseudonigrum*
P. sugandhi var. *brevipilis* (52)	Similar to *P. sugandhi*
P. trychostachyon (52)	A medium elevation species resembling *P. galeatum.*
P. wightii (48)	The pepper of hill tops of Nilgiris, occurs only at high elevation around 2000 m.
P. sp. *(unidentified)	Newly discovered species from Nilgiris, related to *P. mullesua,* is bisexual and extremely rare.

Ravindran *et al.* (2005); * Chromosome number not reported

Indian Institute of Spices Research, Kozhikode, Kerala is the nodal institute for conducting spices research in India. This institute has played a key role in spices research and for better improvement of the crops. Collection, conservation, cataloguing and utilization are given high priority in this institute. Systematic surveys of pepper growing areas and the forests of Western Ghats were conducted to collect the genetic variability in pepper. At present, the germplasm holding of black pepper at IISR, is the largest in the world. The germplasm conserved in different centers are listed in tables 3 & 4.

Table 3. Germplasm conservation of *Piper* species in India

Germplasm centre	Cultivated accessions	Wild & related species	Total
IISR, Calicut (Kerala)	1300	1275	2575
NBPGR, Regional Station, Thrissur (Kerala)	183	67	250
Horticultural Research Station, Yercaud (Tamil Nadu)	106	0	106
Pepper Research Station, Panniyur (Kerala)	105	90	195
Pepper Research Station, Sirsi (Karnataka)	75	21	96
Regional Agricultural Research Station, Chintapalli (Andhra Pradesh)	26	29	55
Other AICRP on Spices centres	23	1	24

Ravindran *et al.* (2005)

Table 4. Under-exploited *Piper* species with important traits

Species conserved	No. of accessions		Center of Origin	Important trait
	IISR Calicut	NBPGR Thrissur		
Piper arboreum	1	1	Brazil	Resistant to foot rot
P. attenuatum	88	3	India	Insect resistance
P. barberi	2	-	India	Insect resistance
P. betle	29	8	Indo-Malaya	Masticatory, medicinal
P. chaba	2	2	Moluccas	Medicinal use
P. colubrinum	1	1	Brazil	Resistant to foot rot discase
P. hapnium	8	-	India	Medicinal usc
P. hymenophyllum	44	4	India	Insect resistance
P. longum	53	27	India	Medicinal value
P. mullesua	35	-	India	Medicinal value
P. magnificum	1	1	-	Ornamental purpose
P. ornatum	1	1	-	Ornamental purpose
P. peepuloides	1	-	India	Medicinal value

In vitro conservation of *Piper* germplasm is also being carricd out at IISR and NBPGR. A total of 26 accessions of *P. nigrum, P. colubrinum* Link, *P. barberi, P. schmidtii* Hook. f., *P. silentvallyensis, P. longum, P. attennatum* Buch.-Ham. ex Miq, *P. betle, P. chaba* Hunter, non Blume, *P. cubeba* and *P. mullesuar* are being maintained at IISR. *In vitro* repository of NBPGR is conserving seven species of *Piper*, namely, *P. nigrum, P. colubrinum, P. arboreum, P. betle* L., *P. barberi, P. hapnium and P. longum* (Tyagi & Yusuf 2000; Tyagi *et al.* 2000a). North-East, tropical and subtropical Himalayas, Eastern Ghats and Western Ghats up to Northern end are the areas to be explored for further collection of germplasm.

Characterization of pepper germplasm based on morphological and chemical characters have been carried out at IISR and at the Kerala Agricultural University (KAU), Pepper Research Station, Panniyur (Ravindran *et al.* 2000). Based on isozyme studies, Sebastian *et al.* (1996) showed three groups of closely related species: (i) *P. nigrum, P. pseudonigrum* C. DC., *P. bababudani* and *P. galeatum* (ii) *P. chaba, P. hapnium, P. colubrinum, P. argyrophyllum* and *P. attenuatum* and (iii) *P. longum* and *P. betle*. But in these species, *P. colubrinum* is grouped with two other species which are morphologically and cytologically very distinct. Molecular characterization based on Randomly Amplified Polymorphic DNA (RAPD) and Amplified Fragment Length Polymorphism (AFLP) patterns, are being carried out at IISR and KAU. The germplasm is being used through clonal selection, hybridization *etc.* Such crop improvement work led to the release of many elite cultivars of pepper. In addition, in long pepper, cultivar Viswam was developed as a clonal selection for cultivation in irrigated coconut gardens of the coastal areas.

Utilization of wild species in crop improvement

Wild relatives of crop plants constitute a part of crop genepool, which possess genes that have great potential for their utilization in crop improvement programmes. Systematic characterization and screening of *Piper* germplasm resulted the identification of resistant sources from the secondary genepool. Foot rot disease caused by *Phytophthora capsici* and 'slow wilt' caused by nematodes (*Meloidogyne incognita* (root knot nematode) and *Radopholus similis* (burrowing nematode) are the major threats for black pepper cultivation. *P. colubrinum,* an introduced species from Brazil is found resistant to both these lethal diseases. This species is used in the crop improvement programme by using it as a root stock. Vanaja *et al.* (2008) developed a partly fertile interspecific hybrid having partial resistance to the dreaded disease *Phytophthora* foot rot through hybridizing *Piper nigrum* with the wild species *Piper colubrinum.* Hybridity of interspecific progenies was established through morphology, anatomy, cytology, and molecular studies. This hybrid has large number of spikes/unit area and long spike but low berry setting.

Similarly, wild species like *P. attenuatum* and *P. barberi* are found to be resistant to 'Pollu' beetle which is a major insect pest of black pepper in India. The insect damages the berries and tender leaves. The larvae feed on tender berries, spikes and also the terminal buds and shoot tips. Sasikumar *et al.* (1999) developed two inter specific hybrids from the cross combinations of *P. nigrum x P. attenuatum* and *P. nigrum x P. barberi* (both wild species used as male parent are 'pollu beetle' resistant). The F_1 progenies are characterized based on anatomy, cytology (2n=52), isozymes and function (reaction to 'pollu' beetle) to identify the hybridity. They inherited the 'pollu' beetle resistance from the male parent as revealed by the 'pollu' beetle resistance screening. Field performances of the hybrids are not encouraging though they grow well under nursery conditions.

Economically important *Piper* species

***Piper nigrum* (black pepper)**

Black pepper (*Piper nigrum*) is the most important species of the family Piperaceae. It is the dried, mature fruit of the perennial climber, and is the most important and widely used spice. The major black pepper producing countries are India, Indonesia, Vietnam, China, Brazil, Sri Lanka and Thailand. In India, pepper is cultivated in approximately 181,000 ha, the annual production is about 65,000 tons and about 60 per cent of which is exported. Black pepper is a native of the humid tropical forests of the Western Ghats, from where it has spread throughout the tropics. Genus *Piper* has over 1,000 species of which about 110 are of Indian origin (Ravindran 2000). In India, the North-Eastern and the South-Western (Western Ghats) regions are recognized as two independent centres of diversity. About 16 species are reported from the forests of Western Ghats, while most of the other species are from North-Eastern region of India. Black and white peppercorns are the dried berries obtained from a creeper with woody stems and oval heart shaped leaves. Tiny white flowers appear in pendulous spikes, followed by spherical red berries. It is common to South and East India. Black pepper contains essential oil (up to 3.5%) and 5 - 10% pungent acid-amides with piperine as well as piperyline, piperoleines and piperamine, while the oil contains sabinene, pinene, phellandrene, linalool and limonene. Piperine is known as a central nervous system depressant and has good anticonvulsant and antimicrobial properties. It stimulates both the digestive and circulatory system and, apart from this, has insecticidal properties.

Uses

Green pepper is the whole fresh berry that is frozen or preserved, while white pepper is the fully matured fruit from which the outer fleshy layers have been removed before drying and black pepper is the almost mature complete berry that is dried and separated from their stalks.

It is used to aid digestion, relieve gas, and in Chinese medicine to treat food poisoning, stomach chills, cholera, dysentery, vomiting caused by hypothermia. It is also used in Ayurvedic medicine to stimulate the digestive system and is used for treatment of nausea, lack of appetite and other dyspeptic complaints. A common myth in the European countries is that pepper cannot be digested and remains in the digestive tract for 7 to 8 years. This is just a myth and contrary to the working of the digestive system, as the digestive tract has no way of treating pepper differently from any other food substance consumed. Pepper is absorbed and eliminated by the body in exactly the same way as any other food. Pepper, white or black, is very common and is used to flavor most dishes, meats, chicken, fish, dressings sauces, pickles and cheese. Unripe, fresh green berries are also used in sauces and to flavor various savory dishes. Ayurvedic medicine uses pepper mixed with ghee (buttery type of compound) to treat nasal congestion, sinusitis, skin eruptions and epilepsy. Black pepper essential oil is used for pain relief, increasing circulation, muscular aches, exhaustion and fevers. It can also be used to treat toothache, rheumatic pains and for ecto-parasites. It is analgesic, antiseptic, anti-spasmodic, cardiac, carminative, digestive, diuretic, laxative, stimulant and a tonic. Since it helps to increase circulation, it can be successfully used in any problem where poor circulation plays a part, and for this reason, it is included in a variety of products. Excessive topical use of the essential oil may over stimulate the kidneys. It should be avoided during pregnancy and it may also cause redness to the skin.

This species has been exploited a great deal but there are a few other species having commercial value either as an one of the ingredients in the pharmaceutical industry, cosmetics or ornamental value. Brief descriptions are given *Piper* spp. other than black pepper.

***P. betle* (betel vine)**

Piper betle (betel vine) is cultivated throughout India except the dry North Western parts (Guha 2006). It is believed to be originated from the Indo-Malayan region and known to occur only under cultivation

(Ravindran 2000). However, it is found growing wild under natural habitat in Andaman and Nicobar Islands. Cultivated extensively in India, Bangladesh, Pakistan, Malaysia and Indonesia, mainly for its leaves which are used as masticatory for chewing (together with lime, betel nut and tobacco). The cultivated betel in India is usually the male plant selected from certain races. Several types are grown in different parts of India (table 5) showing variation in size, shape and color of the leaves, their taste and aroma (Anon 1969). The benzene extract of betel leaves yield β sirosterol, Ò-sirosterol, hentriacontane, n- triacontanol, stearic acid, chavicol and 3,5 dinitrobenzoate (Deshpande *et al.* 1970). The betel leaf contain an essential oil varying from 0.10 to 1% . About 52 compounds are identified in the betel leaf oil.

Table 5. Common cultivars of betel leaf in India

Cultivar	Pungency	Keeping quality (days to 50% rotting)
Bangla (Madhya Pradesh)	Pungent	13
Bangla (Uttar Pradesh)	Pungent	13
Bangla Nagaram (Uttar Pradesh)	Pungent	13
Culcutta (West Bengal)	Pungent	19
Calcutta Bengal (West Bengal)	Pungent	17
Desi Calcutta (West Bengal)	Pungent	19
Desawari Mahoba (Uttar Pradesh)	Mild pungent	13
Ghanghatte (West Bengal)	Pungent	13
Ghodi Bangla (Orissa)	Pungent	13
Halisahar Sanehi (West Bengal)	Pungent	13
Kakir (Bihar)	Pungent	13
Kalipatti (Maharashtra)	Pungent	13
Kapoori (Bihar)	Non pungent	10
Kapoori (Orissa)	Non pungent	10
Karapaku (Andhra Pradesh)	Pungent	13
Karpooi (Tamil Nadu)	Non pungent	10
Kuljedu (Andhra Pradesh)	Non pungent	10
Maghai (Bihar)	Pungent	13
Meetha pan (West Bengal)	Sweet	10
Nov Bangla (Orissa)	Pungent	13
Ramtek Bangla (Maharashtra)	Pungent	13
SGM-1 (Tamil Nadu)	Mild pungent	13

Sachi pan (Assam)	Pungent	13
Sangli Kapoori	Non pungent	10
Tellaku (Andhra Pradesh)	Non pungent	10
Vellai kodi (Tamil Nadu)	Non pungent	10

(Ravindran 2000)

Uses

Betel leaves are traditionally known to be useful for the treatment of various diseases like bad breath, boils and abscesses, conjunctivitis, constipation, headache, hysteria, itches, mastitis, leucorrhoea, ring worm, swelling of gum, rheumatism, abrasion, cuts and injures *etc.*, as folk medicine, while the root is known for its female contraceptive effects (Chopra *et al.* 1956; Khanra 1997; Guha 2006). The essential oil from the leaves possess antibacterial, anti protozoan and antifungal properties. A cultivar called Thulasivettila is commonly used in certain indigenous medicinal preparations. This variety is having the flavor of tulsi (*Ocimum tenciflorum*), is an important ingredient in many indigenous medicinal preparations used in a variety of skin diseases, in head ache, sinusitis *etc.*

Betel leaves possess anti-oxidant action. When leaves are heated with fats and oils rancidity is checked. Leaves are effective in preserving refined oils of ground nut, mustard, sesame, coconut and sunflowers. This anti-oxidant action is due to phenol especially hydroxy chavicol (Ravindran 2000). Chewing of betel laves produce a sense of well being, increased alertness, sweating, salivation, hot sensation and energetic feeling with exhilaration. It also increases the capacity to exercise physical and mental function more efficiently for a longer duration, but it may produce a kind of psycho active effect causing a condition of mild addiction leading to habituation and withdrawal symptoms (Chu 2001; Garg & Jain 1996). Further the leaves are very nutritive and contain substantial amount of vitamins and minerals and it is told that six leaves with a little bit of slaked lime is comparable to about 300 ml of cow milk especially for the vitamin and mineral nutrition (Guha 2000).

Piper longum (The Indian long pepper)

A slender aromatic shy climber, dioecious, occurring widely in the low altitude evergreen forest, occurring in sub Himalayan hills, Assam, Khasi region and Western Ghats and is cultivated in the tribal belts of Assam, Tamil Nadu and Andhra Pradesh. It is distributed throughout in India, Sri Lanka, Myanmar, Malaysia and other south Asian counties, but most widely distributed in India. Vegetative branches creep and spread on the ground; fruiting branches erect; young branches hairy; hairs minute and multi-cellular. Older branches glabrous. Leaves are distinctly dimorphic; petiolate up to 3 cm long, cordate with acute leaf base and acrodromous type of veining and elliptic, lanceolate leaves, base unequally cordate with pronounced auricle in fruiting branches. Tip acuminate, 3-4 pairs of lateral ribs arise from the base, slightly hairy when young. Leaves adnate or shortly petiolate. Spike cylindrical, erect, creamy white to yellowish white when young. Peduncle 1-2 cm long, downy, female spike 2-3 cm long, male spikes are longer about 6 - 10 cm, yellow on maturity. Bracts peltate, orbicular, glabrous. Flowers bracteate laterally fused, unisexual and naked. Stamens 3-4, dithecous. Ovary obovate, style absent, stigma 3-4 lobed, short- papillate. Fruits very small, laterally fused, spicy and pungent; fruits turn green to black when ripen, seeds very small. Viswam is an improved variety of *Piper longum* from Kerala Agricultural University, Thrissur, Kerala.

On steam distillation, the spikes yield an essential oil (0.7 to 0.8%) consist of n- hexadecane, n-hepta decane, n-octa decane, n- nona decane, n- ciocosane, n-hencosane, α- theyne, terpenolene *etc.* A pellitorine type of alkaloid (CH-isobuty deca-trans-4-dienamide) isolated from long pepper and *P. peepuloides* is reported to exhibit significant anti tubercular activity against mycobacterium. The essential oil of long pepper showed antibacterial activity against *Bacillus, Mycobacterium, Streptococcus, E coli, Salmonella* and *Vibrio chloerae.*

Uses

Piper longum is widely used in Ayurvedic and Unani systems of medicine, particularly for diseases of respiratory tract. The fruit, commonly known as pippali and its root, called as pippali mula are used for medicinal purpose. Pippali is seldom used externally, in case of painful and swollen conditions, wherein its paste is applied. Though it has mild antiseptic property, it is an irritant to the skin and produces allergic reactions. The root is used for bronchitis, stomach ache, diseases of the spleen and tumors. It also improves appetite. An infusion of the root is prescribed after past nutrition to induce the expulsion of the placenta. Long pepper is and important ingredient in the Ayurvedic preparation such as Trikadu (dry ginger-long pepper- black pepper) and panchakolam. True Indian long pepper is derived from the wild grown plants distributed in Assam, West Bengal, Nepal, North Eastern region, Bihar, Uttar Pradesh, Kerala, Tamil Nadu, Andhra Pradesh, *etc.* It is also cultivated in Kerala, Andhra Pradesh and Maharashtra in a small scale. The root of long pepper is also attributed with several medicinal properties. The extract is used in cough syrups and as a counter irritant in analgesics and for all other ailments.

Internally, pippali is invaluable in vast range of diseases. Pippali is the best drug recommended in the disorders of the spleen. It is a powerful stimulant for the digestive and respiratory systems. It is strongly heating and removes cold, congestion and ama – the undigested toxic elements and revives the weakened organic functions. It is also a rejuvenative to lungs and kapha dosha. Trikatu is the most popular formulation used to mitigate the diseases due to kapha dosha. It increases the bioavailability of the drug, when it is used as a complementary medicine.

Pippali effectively reconciles the digestive functions and is used with benefit in anorexia, indigestion, flatulence, abdominal pain, hyperacidity, piles *etc.* It works well with honey to combat hyperacidity. The decoction or its medicated milk can be used for the same. Pippali is beneficial, when given with amalaki in the treatment of anemia. For treating any type of fever, the medicated ghee of pippali is very useful. In chronic fever and tuberculosis, the preparation Vardhamana pippali is more effective. In fact, Vardhamana pippali is a regimen, praised in ancient scriptures in which the doses of pippali are increased gradually. On the first day, an infusion of 3 pippalis, boiled for a few minutes in a mixture of milk and water is taken (4:1). Then for 10 successive days the dose is increased by 1 pippali everyday. After 10 days, the dose is gradually decreased by 1 pippali daily. During this regimen only milk is consumed as a diet. This method is useful in treating chronic respiratory ailments, anemia, recurrent fevers, piles and digestive problems. It strengthens the immune system of the body.

Pippali is beneficial as a brain tonic and in the diseases of vata. The decoction is effectively used in sciatica and hemiplegia. Being the best rejuvenative, pippali sidda ghrita is useful in tuberculosis, cough and with the ghee and honey, it reduces the frequency of paroxysms in bronchial asthma. It also helps controlling hiccup, when given with honey. It boosts the reproductive system too, hence, is used as an aphrodisiac. It also works well in amenorrhea.

Piper chaba syn. *P. retrofractum* (The Java long pepper)

Java long pepper, also called gaja thippali or bengla thippali is a perennial, glabrous, fleshy climber with adhesive roots, native to Moluccas and found in hot and moist climate. It is considered as a minor forest produce. There is no evidence on organized cultivation of *P. chaba.*

The plant is a dioecious vine, reaching a height of 2-4 meters. The leaves are short, petioled, oblong, oblong - ovate or elliptic lanceolate, 6 – 7.5 x 3.2 – 6.5 cm with oblique base. The male spikes are 3.2 to 8.5 cm long. The female spikes are red, fleshy when mature and 3-6.5 cm long and 6.5 to 11 mm diameter. The rachis is smooth and the bracts are peltate. The fruit is more or less united partly or wholly embedded in the rachis. Owing to its medicinal use, recently it is gaining popularity and grown as intercrop in areca nut/coconut plantation and avenue trees. Kandiannan *et al.* (2005) conducted an experimental trial to study the feasibility of intercropping *P. chaba* with areca nut and the yield recorded are given in table 6. Petroleum ether extract of stem yields piperine, pipalartine and β- sirosterol. The root yielded sylvatine and piperlongumine. Preliminary pharmacological study of aqueous and alcoholic extracts of fruits produced hypertensive and sooth muscle relaxant effects (Tewari *et al.* 1964). Alcoholic extract of stem exhibited antifungal activity. Alcoholic extracts of roots enhanced the bio availability of sulphadiazine (in dogs and rats) and tetracycline hydrochloride in rats (Ravindran 2000).

Table 6. Summary of statistics of *Piper chaba* yield (mature fresh fruit, g/vine)

Year	Range	Mean	Median	S.D
1997	20-980	320.0	250.0	235.5
1998	30-1700	555.5	490.0	405.4
1999	50-800	215.3	180.0	179.6
2000	20-1700	559.0	500.0	387.9
2001	70-2530	752.3	660.0	498.0
2002	20-1500	492.5	400.0	386.1
2003	50-1320	498.2	450.0	308.8

Kandiannan *et al.* (2005)

Uses

The fruits are used as spice and also in pickles and preserves. They have pungent pepper like taste and produce salivation and numbness of the mouth. They are used all over India as long pepper for the same purpose for which Indian long pepper is used.

Piper cubeba (tailed pepper or cubeb)

Cubeb or tailed pepper is indigenous to tropical monsoon forests of Malaysia and Indonesia. It is cultivated in Indonesia and Malaysia where its fruits have long been used by local people as a condiment and herbal medicine. Cubeb is wholly a small holder crop. Unlike black pepper there are no cubeb plantations, and vines are grown as a supplementary crop on shade trees grown on plantations. *P. cubeba* is a perennial, woody climber. The leaves are coriaceous, glabrous, entire with round base, tip acuminate, oblong to ovate oblong in shape, 8-15 x 2-9 cm and the petiole is 0.5-2.0 cm long. Inflorescence is a spike, 5-10 cm bearing clusters of dioecious flowers. The female flower has an oblong bract up to 5 x 8 mm and three to five stigmas. Male flowers are with oblong-ovate bract up to 2 x 1 mm and 3-5 stamens. The fruit is small, 6-8 mm diameter, reddish yellow drupe drying to black with a coarsely reticulated surface. The base of the pericarp extends into a pedicel like formation and the globose seed is usually free from the pericarp. Berries separated from the spike retain the pedicel (stalk), hence the name tailed pepper and this is a distinguishing feature of the fruits.

Cubebs contain 5-20 % essential oil and about 6-8% resinous matter. The essential oil of cubeb showed antibacterial activity against bacteria such as *Bacillus subtilis, Vibrio cholerae, Salmonella typhimurium, Clostridium diplithereae etc.* Oil of cubebs is used in flavoring certain brands of sauces and also in perfumery to impart an exotic note.

Uses

The major products of the cubeb vine are the dried fruit, tailed pepper and cubeb oil. Cubebs are used as a drug and as a spice. The powdered fruits are used for the treatment of dysentery, catarrh and as an aromatic stimulant, local irritant, carminative and sedative. The most commonly used preparation of cubeb is the 'cubeb oleoresin' which is prepared by extracting cubeb with alcohol or ether. The dried fruits are used in herbal medicines and are stated to be antiseptic, diuretic, a stimulant, an expectorant and a carminative. They were formerly used in the production of asthma-alleviating cigarettes in the USA. In Malaysia, powdered dry fruits are used to treat amoebic dysentery and in Java, as a popular aphrodisiac.

The main use for cubeb fruits outside producing countries is as raw material for distilling cubeb oil, produced mainly on demand in Europe and North America from imported material. Cubeb oil is a viscous, pale greenish to bluish yellow liquid. The oil has a camphoraceous, spicy smell with a bitter but not pungent or peppery taste. The main use of cubeb oil is in perfumery and in soaps, medicines, some beverages and bitters.

Piper methysticum (kava pepper)

Kava pepper (*P. methysticum)* is a perennial shrub growing up to 3 m with bright green, cordate leaves about 15-20 cm long. It produces small flower on spikes, but they are sterile. It is distributed in the South Pacific Melanesia (including Fiji, Papua New Guinea, the Solomon Islands and Vanuatu), Micronesia and Polynesia. Kava is mainly found occurring on rich- well drained soil mountain area (referring shade when young and full sun when established). The active principles are found in the roots and underground rootstocks. The roots contain alkaloids such as methysticin, yangonin, dihydro methysticin and di hydro kawain.

Uses

The pacific Islands have been using the roots of this plant for making the potent beverage called kava-kava. Kava- kava has a central place in the culture and social customs of this region (Laird 1999). Herbalists have traditionally used kava- kava as a remedy for nervousness, urinary problems, asthma, whooping cough, stomach ache and headache. It is also used in muscle relaxant for the relief of spasms and cramp. It is applied externally to treat fungal infections and the inflammation of skin. Kava-kava drink is non intoxicating. It does no dull mental processes but it is a narcotic. It induces euphoric state of tranquil well being that eventually leads to a deep dreamless sleep.

The roots of *P. sylvaticum* Roxb. are widely used in indigenous medicine as an effective antidote for snake poison. In Peninsular Malaysia, the decoction made from the leaves of *Piper sarmentosum* Roxb. is used for curing pains in bones and applied to the foreheads of children suffering from headaches. *Piper umbellatum* (stomach ache, cough) and *P. poryphyrophyllum* (leprosy, stomach ache and skin diseases) are the other two *Piper* species used in Peninsular Malaysia. *Piper kadsura* (Choisy) Ohwi, a native of Taiwan is used for the treatment of asthma and arthritis in Taiwan (Linn & Lu 1996). Recent studies indicated that this plant has got inhibitory properties on hepatitis B.

Besides these economically important species, there are some *Piper* species having ornamental value having attractive foliage. *P. auritum, P. borneense, P. decurrens, P. magnificum, P. metallicum, P. ornatum, P. porphyrophyllum, P. rubronodosum, P. rubrovenosum etc.* are valued for ornamental purpose (Mark Greiffith 1992).

References

Anonymous 1969 The Wealth of India- Raw Materials Vol. 8. CSIR, New Delhi.

Asprey G F & Thornton P 1954 Medicinal plants of Jamaica. West Indies Medicinal J. p17.

Chaveerach A, Mokkamul P, Sudmoon R & Tanee T 2006 Ethnobotony of the genus *Piper* (Piperaceae) in Thailand. Ethnobotany Research and Applications 4: 223-231.

Chopra R N, Nayar S I & Chopra I C 1956 Glossary of Indian medicinal plants. CSIR, New Delhi, p 194.

Chu N S 2001 Effects of betel chewing on the central and autonomic nervous system. J. Biochemical Sci. 8 (3) : 229-236.

Deshpande S M, Upadhyaya R R & Sing R P 1970 Chemical study of *Piper betle* leaves. Curr. Sci. 37: 372.

Fischer C E C 1925 Piperaceae In: Gamble J S (Ed.) Flora of Presidency of Madras. Botanical Survey of India, Calcutta.

Gamble J S 1925 Piperaceae. In: Flora of the Presidency of Madras, London, pp. 1202–1210.

Guha P 2000 Commercial exploitation of oil from betel leaves, pp. 56-57, In: Proc. Sixth Regional Workshop on oil seeds and oils. IIT, Kharagpur (Eds.). Agricultural and Food Engineering Department, IIT, Kharagpur, India.

Guha P 2006 Betel leaf: The neglected green gold of India. J. Hum. Ecol. 19 (2) : 87-93

Garg S C & Jain R 1996 Chavicol rich essential oil of *Piper betle*. L. cultivar *Sagar Bengla*. Euro Cosmetics 5: 27-28

Hooker J D 1886 The Flora of British India Vol. 5. L. Reeve and Co., London.

Irvine F R 1961 Woody plants of Ghana. Oxford University press. London, p 40.

Jain S K & Tarafdar C R 1970 Medicinal plants-lore of the sandals. Economic Botany 24: 241.

Kirtikar K R & Basu B D 1933 In: Indian medicinal plants Vol. III, p 2130.

Kandiannnan K, Thankamani C K, Korikanthimath V S & Mathew P A 2005 Performance of Java long pepper (*Piper chaba* Hunter non Blume syn *P. retrofractum* vahl.) intercropped with Arecanut. J. Plantation crops 33(1): 77-78.

Khanra S 1997 Betle leaf based industry. Nabanna Bharati 30 (2): 169.

Laird A 1999 The botanical medicine industry In : The commercial use of bio diversity access to genetic resources and benefit sharing. Ten Kate K & Laird S A (Eds.) Earth scan, London.

Linn T T & Lu S Y 1996 Piperaceae. In: Flora of Taiwan. 2nd ed. Editorial committee of the flora of Taiwan. Vol. II, pp. 624-631.

Mark Greiffith 1992 Index to Garden Plants. Mc Millon, p 900.

Nirmal Babu K, Naik V G and Ravindran P N 1993 Two new taxa of *Piper*, Piperaceae from Kerala, India with a note on their origin and interrelationship. J. Spices and Aromatic Crops 2: 26-33

Parmer S V, Jain S C, Bisht S K, Ranjini Jain, Taneja P, Jha A, Tyagi O D, Ashok K P, Jesper W, Carl E O & Per M B 1997 Phytochemistry of the genus *Piper*. Phytochemistry 46(4): 597- 673.

Rahiman B A 1981 Biosystematics studies in varieties and species of *Piper* occurring in Karnataka region. Ph.D thesis, University of Mysore, Mysore.

Rama Rao, R S M 1914 Flowering plants of Travancore, Trivandrum.

Ravindran P N 2000 Other economic important species of piper. In: Black pepper - ***Piper nigrum***, Ravindran P N (Ed.) Hard wood Academic Publishers, pp. 497-509.

Ravindran P N, Nair M K & Nair R A 1987 New taxa of *Piper* (Piperaceae) from silent valley forest, Kerala. J. Eco. Tax. Bot 10: 167-169.

Ravindran P N, Nirmal Babu K, Sasikumar B & Krishnamurthy K S 2000 Botany and crop improvement of 'black pepper'. pp. 23 - 142. In: Ravindran P N (Ed.) Black pepper – *Piper nigrum*. Harwood academic publishers.

Ravindran P N, Nirmal Babu K, Peter K V, Abraham Z & Tyagi R K 2005 Spices In: Plant Genetic Resources: Horticultural crops. Dhillon B S, Tyagi R K, Saxena S & Randhawa G J (Eds.), Narosa Publishing House Pvt Ltd. New Delhi, pp.190-227.

Sasikumar B, Chempakam B, Johnson George K, Remashree A B, Devasahayam S, Damayanthi K P M, Ravindran P N & Peter K V 1999 Characterization of two interspecific hybrids of *Piper*. J. Horticulture Science and Biotechnology 75 (1): 125-131.

Sebastian A, Sujatha V S, Nybe E V, Nair G S & Augustine A 1996 Isozyme variation and species relationships in the genus Piper. J. Tropical Agric. 34 : 85-92.

Tawan C S, Ipor I B, Fashihuddin B A & Sani H 2002 A brief account on the wild *Piper* (Piperaceae) of the Crocker Range, Sabah. ASEAN Review of Biodiversity and Environmental Conservation (ARBEC), July- September.

Tewari J P, Dutta K C & Mishra S S 1964 Preliminary pharmacological examination of P*iper chaba* Hunt. Labadev. J. Sci. Technol. 2: 1118.

Tyagi R K & Yusuf A 2000 Direct regeneration and conservation of two wild species of *Piper – P. colubrinum and P. hapnium.* In : Proc. Int. Conf. on managing natural resources for sustainable agricultural production in the 21st century, Vol.2, Natural Resources, Indian Agricultural Research Institute, New Delhi, India, pp. 818-819.

Tyagi R K, Yusuf A & Dua P 2000 *In vitro* conservation of *Zingiber, Curcuma* and *Piper* species at NBPGR. In : Proc. Nat, Symp. on prospects and potentials of plant biotechnol. in India in the 21st century, Department of Botany, Jai Narain Vyas University, Jodhpur, p 172.

Vanaja T, Neema V P, Mammootty K P & Rajesh R 2008 Development of a promising interspecific hybrid in black pepper (*Piper nigrum* L.) for *Phytophthora* foot rot. Euphytica 161: 437-445.

Velayudhan K C & Amalraj V A 1992 *Piper pseudonigrum*- a new species from Western Ghats. J. Eco. Tax. Bot. 16: 247-250.

Uses of Piperaceae plants in Ayurvedic medicine

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The botanical sources

Piper nigrum, *Piper longum* and *Piper betle* are herbs of the Piperaceae family that figure prominently in the literature of Ayurveda. *Piper brachystachyum* and *Piper cubeba* are also other herbs in the Piperaceae family used in the tradition of Ayurveda.

These herbs have been introduced into the Ayurvedic pharmacopoeia at a very early period in its evolutionary history. The earliest text books on Ayurveda *viz.,* Caraka Samhita and Susruta Samhita, (dating a few centuries BCE) have documented the uses of these herbs. Over thousands of years, the nomenclature, morphology, properties and applications of these herbs have been elaborated and codified in the literature of Ayurveda.

When studying herbs mentioned in Ayurveda with a continuity of several thousands of years, we need to look at the Ayurvedic drug identities independently before correlating them with specific botanical sources that we know of today. This is because one plant may have become associated with many names in Ayurveda over a period of time and the same name may be applicable to many plants in different texts. Also different plants are used in the same name in different parts of the country and often there is substitution and adulteration. Therefore, many botanical sources may be equated with one Ayurvedic drug identity and vice versa.

The ayurvedic drugs

When we examine the Ayurvedic nomenclature of the Piperaceae herbs, seven herbal drugs emerge for discussion. First and foremost comes *marica* or pepper (*Piper nigrum*), which is a very popular spice as it is a medicine. The next is pippali or long pepper (*Piper longum*), which is an ingredient of many Ayurvedic formulations.

There is also mention of pippalimula or root of long pepper, which could be the root of *Piper longum* itself or may refer to a wild variety of long pepper as many local names suggest (kattutippaliveru) and also as some lexicons indicate (vanadi pippali). In the raw drug market, several varieties of long pepper spikes are available and may belong to variants of *Piper longum*. The fourth identity is cavika or cavya which has been identified as *Piper brachystachyum*.

Table 1. Ayurvedic herbal drugs and their botanical sources

Ayurvedic drug identity	Botanical source
Maricam	*Piper nigrum* - fruits.
Pippali	*Piper longum* - fruits.
Pippalimula	*Piper longum* - roots.
Tambula	*Piper betle* - leaves.
Cavya	*Piper brachystachyum* - roots. *P. chaba, P. retrofractum, P. attenuatum and P. hymenophyllum* are also considered as sources.
Gajapippali	*Scindapsus officinalis* - fruits. This plant belongs to Araceae but some texts recommend use of fruits of *P. brachystachyum*.
Kankola	*Piper cubeba* - fruits

Scholars have debated on the botanical identity of cavya. There is an opinion that the spikes of cavya is gajapippali. However, in practice, *Scindapsus officinalis*, belonging to the family Araceae, is accepted as the source of gajapippali. Then, we have tambula, which is identified as *Piper betle*. And finally, there is kankolam, the botanical source for which is *Piper cubeba*.

Varieties mentioned in the Ayurvedic texts

Depending on the stage in which the pepper fruits are harvested, they are either green (raw), red (ripe) or black (dried). Dehusked pepper fruits are white in color. Ayurveda predominantly makes use of the dried black pepper. Some Ayurvedic texts refer to white pepper, which is probably the dehusked pepper.

Ayurvedic texts distinguish between the properties of raw and dried spikes of long pepper. In practice, several varieties are distinguished like the small (cerutippali), big (vantippali) and chinese (cinatippali) types. The root of a wild variety of long pepper is also mentioned in the name of pippalimula. One of the lexicons, Raja Nighantu, lists four additional varieties of pippali, making it five in all inclusive of pippali as such.

The varieties of betel leaf plant have been described in the Raja Nighantu, but it has been emphasized that the variations are due to soil, climate and not essentially a species variation. There is no discussion on the varieties of cavika. No varieties have been documented in the case of kankolam either.

Table 2. Varieties of drug identities of Piperaceae in Ayurveda

Drug identity	Criteria	Varieties
Maricam (Pepper)	Color of dried fruits	Black (with skin) and White (dehusked) varieties
Pippali (Long pepper)	Size of dried fruits and source of market samples	Large, small and china varieties
	Classification in Raja Nighantu of additional varieties	Gajapippali (fruit of *Piper brachystachyum* or *Scindapsus officinalis*), saimhali (unidentified), vanadi (wild variety) and granthika (root of *Piper longum*)
Tambala (Betel vine)	Based on ecological variations as listed in Raja Nighantu	Srivati, amlavati, satasa, saptasira, amlasara, patulika, hvesaniya

In this paper, nomenclature, varieties, properties and clinical uses of maricam, pippali, cavya, tambula and kankola are discussed. Pippalimula and gajapippali are considered in the discussion on pippali and cavya respectively.

A very rich nomenclature is available for these herbs in the Ayurvedic texts. In Ayurveda, a polynomial system of nomenclature has been used for herbs and drugs and each herb or drug is referred to with many names. These names point to morphological features and medicinal properties of the herbs and help in identification of the herb to some extent. The multiplicity of names also cause confusion in identity at times.

Maricam (*Piper nigrum*)

The plant maricam (*Piper nigrum*) has at least twenty names in Ayurvedic literature. Each name gives some clue about some feature of the plant. The name marica itself means that which kills worms and germs. The names krsna, meaning black, vrttaphalam, meaning globose fruit, vallijam, meaning that which sprouts on a creeper and sirovrntam, meaning stalk located on the top indicate morphological features of the plant. The names usanam meaning hot, katukam meaning pungent, tiksna meaning sharp and ruksa meaning dry are names that describe its properties in general. Marica is also known as dharmapattana (grows in the Travancore region of Kerala) and yavanesta (liked by Europeans). It is an important spice (sakanga) and useful in the management of diseases caused by kapha (kaphavirodhi).

Ayurvedic texts have distinguished the properties of raw and dry pepper. Raw pepper is not so hot, has a sweet post digestive taste, does not aggravate pitta, enhances mucus secretions and is heavy to digest. Dry pepper is hot and pungent, light to digest and a digestive stimulant as well. In large quantities, pepper can adversely affect male fertility. It is, however, an appetizer and dispels worms. It is useful in the management of asthma and pain. It pacifies vata and kapha, but increases pitta.

Pepper is listed in the group of dipaniya (digestives), sulaprasamana (analgesics), krmighna (anthelmentics) and sirovirecanopaga (errhine) drugs.

The powder of pepper taken along with sugar candy, ghee and honey is useful in management of cough. A pinch of pepper take with a spoon of turmeric is an ideal combination for regular use to boost immunity and prevent diseases. The powder of pepper mixed with buttermilk is an effective remedy for many digestive disorders. Pepper is recommended in management of common cold but is not advisable when there is high fever.

Trikatu or the triad of pungents, comprises of dry ginger, pepper and long pepper. This combination is very popular in Ayurvedic pharmaceuticals and is an ingredient of many important formulations. Another combination of six ingredients known as sadusanam has pepper as one of the ingredients too. Trikatu is a major ingredient in Dasamulakatutrayam kasayam indicated in the management of respiratory diseases and vyosadi vatakam indicated in management of sinusitis and upper respiratory disorders.

Pippali (Piper longum)

Pippali (*Piper longum*) is variously known as kana (fruits are very small berries), saundi (the fleshy spike resembles an elephant's trunk, used in distilleries and bars), krsna (fruits are black when dried), upakulya (grows near water streams). The names kola, usana and tiksnatanula denote the pungent nature of the fruits. This herb is also known as magadhi (that which grows in the magadha region) and vaidehi (that which grows in the Videha region). The word pippali itself indicates the ability of the dried fruits of this herb to nourish and rejuvenate the tissues of the body. Indeed, pippali is an important rejuvenative used in Ayurvedic treatment.

Just as in the case of pepper, the texts distinguish between the properties of raw and dried fruits of long pepper. The raw and green fruits of long pepper are cool in potency, heavy to digest, with a sweetish taste, unctuous and provokes mucous secretions. On the other hand, the dried fruits are light to digest, sweet in the post digestive taste, neither hot nor cold in potency and pungent in its taste. The dried long pepper fruits pacify vata and kapha, improves appetite, enhances fertility and have rejuvenating properties. They stimulate digestion and metabolism and have a benign effect on the cardiovascular system. Long pepper is useful in the management of bronchial asthma, cough, abdominal distention, hemorrhoids, splenomegaly, fever and ascites. It is considered to be a very effective single drug for the management of disorders of the spleen. So also for the management of bronchial asthma. There is also an opinion that long pepper has a balanced impact on the three dosas and if used carefully can restore their normalcy. Dried fruits of long pepper are burnt into ashes and mixed with water. The alkaline filtrate is considered to be an effective remedy for management of bronchial asthma.

Like pepper, long pepper is also an ingredient in the combinations trikatu and sadusana. Additionally its roots and fruits are ingredients of the group of five herbs known as paricakola, which is a powerful digestive. Pippalyadi Ghrtam, Pippalyadi anuvasana tailam, Yakrtpliharilauha and Pippalyadyasavam are important formulations used in Ayurvedic practice with long pepper as the main ingredient.

Difference between pepper and long pepper

Long pepper has a sweet post digestive taste and is not hot in potency like pepper. Pepper can adversely affect male fertility but long pepper actually enhances it. Not only that, long pepper can be used as a rejuvenative tonic unlike pepper, which is mainly used as a spice in food and medicine for specific diseases.

However, the classical texts advises us to exercise caution when using long pepper on a long term basis. Pepper is a spice that can be part of one's regular diet in limited quantities. It can also be used as a medicine when required. But long pepper should not be used on a regular basis. When consuming long pepper for a long period, one must strictly adhere to the rejuvenative regimen, which imposes certain restrictions in diet and behavior. If the regimen is not followed, long term use of long pepper can result in undesired side effects. A very common method of using long pepper for rejuvenation is to gradually increase its dose day by day and after reaching the highest dose, to taper it to the starting dose before withdrawing it completely. This treatment called as vardhamana pippali rasayana is indicated for the management of chronic bronchial asthma and disorders of the spleen. The Caraka Samhita lists long pepper as one of the three substances that should not be used regularly. The other two are salt and alkali. Regular use of these substances can have debilitating effects on the health of the individual.

Pippali and Pippalimula

Although derived from the same plant, the roots and dried fruits of long pepper are considered as different drugs with different properties. It is interesting to note that a Malayalam equivalent for vanadi pippali by the name kattutippali is prevalent in Kerala, thereby indicating that the tradition distinguished between the cultivated and wild forms of long pepper. Perhaps, in the Kerala tradition, the roots were harvested from the wild form of long pepper and the fruits from the cultivated variety. The roots of long pepper are pungent and hot, pacifies kapha, eliminates worms, stimulates digestion, increases appetite and aggravates pitta. long pepper root is also useful in the management of neurological disorders.

Tambula (*Piper betle*)

Betel leaves hold a special place in the Indian tradition. They are used in rituals and when offering daksina (offering to one's teacher at the end of studies). Additionally, chewing betel leaves was part of the daily routine of the people of ancient India. Ayurvedic texts recommend chewing of betel leaves with spices, but it is important to note that the practice of chewing tobacco along with betel leaves does not have its origin in the classical Ayurvedic texts. Though ascribed with certain benefits, abstaining from chewing betel leaves was also considered as a virtue. The great iatrochemist in the Ayurvedic tradition, Nagarjuna, was honored with the epithet bhadanta, meaning one whose teeth are white and lustrous because he does not chew betel leaves.

The Astariga Sarigraha advises that one who is desirous of preserving appetite, removing viscosity and bad odor in the oral cavity should chew betel leaves mixed with nutmeg, cloves, camphor, java pepper, pepper and areca nut, acacia wood and lime. Chewing of betel leaves is recommended either on waking up or after food or after taking bath or after vomiting. It should be avoided by people whose blood and pitta are deranged, those who are recovering from injuries, those who suffer from diseases of the eye, those who are afflicted with poison or are under the influence of alcohol and those who are emaciated. We can say that betel leaf chewing represents one of the earliest instances of the use of mouth freshener in the history of humankind.

The betel vine is known in Sanskrit as the snake vine (nagavalli). The basis for this association is not clear and could be with respect to its morphological features. Other names having the same meaning are nagavallari and patalavasini. The betel leaf has also been associated with auspiciousness, for which reason it has been used in rituals. The names like bhadra, amrta and kamada indicate this. Betel vine is also considered to be a sexual stimulant and hence known as kamajanani and not recommended for use by those who have taken to a spiritual life.

Betel leaf has a mixture of bitter, astringent, alkaline and pungent tastes. It is hot in potency, light to digest and stimulates appetite. It improves strength but deranges pitta and blood. It loosens bowels, improves speech and removes the sliminess and bad odor in the mouth.

The varieites listed by Raja Nighantu are srivati, amlavati, satasa, saptasira, amlasara, patulika and hvesaniya. These varieties have variations in morphological appearances as well as in their properties. For example, srivati is cool in potency while amlavati is hot and can even cause ulcerations in mouth. The properties of all the seven varieties have been described in the Raja Nighantu.

The paste of seven betel leaves mixed with boiled water and salt is said to be an effective remedy for filariasis. Betel leaf is an ingredient of popular Ayurvedic formulations like murivenna (an oil used in management of fractures, wounds and ulcers) and tambulalehyam (medicated jam indicated in management of bronchial asthma).

Cavya (*Piper brachystachyum*)

Cavya is considered to be the wild variety of pepper in the Ayurvedic tradition. *Piper brachystachyum, P. chaba, P. retrofractum, P. attenuatum* and *P. hymnenophyllum* are variously used as the botanical sources for cavya.

It is known variously as cavika, kolavalli, maricalata and vanaja and these names point to the identity of this herb as wild pepper. The officinal part used is the root.

Wild pepper roots have almost the same properties of long pepper roots, but is especially effective in the management of hemorrhoids. It has a pungent and bitter taste, is hot in potency, light to digest, improves appetite and stimulates digestion. But the majority opinion is that is pacifies vata and kapha and increases pitta. Its leaves pacify pitta and kapha but slightly aggravates vata. Its flowers are especially useful in management of artificial poison, flatulence, splenomegaly and ascites. Wild pepper is useful in the management of bronchial asthma, cough, colic and emaciation. It also has anthelmintic properties.

According to many lexicons, the fruit of cavya is known as elephant pepper or gajapippali. The fruits are ascribed with slightly different properties than the roots. However, in actual practice Scindapus officinalis belonging to the family Araceae is used as the official source of gajapippali. Therefore, its properties are not being discussed in this paper.

Cavya is listed in the groups trptighna (removes satiety), arsoghna (anti-hemorrhoid activity), dipaniya (digestive stimulants) and sulaprasamana (analgesics). The leaves of wild pepper are effective in diarrhoea. The roots are effective in management of ascites. Cavya is an ingredient of the herbal combination known as pancakola in Ayurveda. So also in the combination known as sadusana. Cavikasavam is an important formulation of cavya used in the management of bronchial asthma, cough and digestive disorders. It is also an ingredient of the formulation karikayana vati used in management of hemorrhoids.

Kankola (*Piper cubeba*)

Kankola or tailed pepper is another important herb from the Piperaceae family used in the tradition of Ayurveda.

Various synonyms of this plant highlight the peculiar shape of its fruit with its stalk projecting like a tail after harvesting. In appearance it resembles pepper to some extent (sthulamaricam). The other names are karkola, krtaphala, katukam phalam, rudrasammitam, vidvesyam and maricam.

Paste of cubeb berries are applied to male and female genitals to increase pleasure during coitus. Tailed pepper is bitter and pungent in taste, hot in potency, light to digest, digestive stimulant, appetiser, mouth freshener and pacifies kapha and vata. It is useful in the management of heart diseases, intestinal worms and disorders of digestion.

Table 3. Herbal formulations with herbs from Piperaceae

Formulation	Ingredients
Trikatu (Three pungents)	Pepper, long pepper and dry ginger
Pancakola (The five pungents)	Long pepper fruit, long pepper root, wild pepper root, *Plumbago rosea* and dry ginger
Sadusanam (The six hot drugs)	The above mentioned herbs along with pepper.

The discovery of piperine

Modern research has provided spectacular insights into the special properties of some of the alkaloids present the herbs of Piperaceae. These insights support the Ayurvedic practice of adding especially pepper and long pepper as additives in many formulations. Both these herbs have been discovered to contain an alkaloid called piperine, which has the ability to increase the bioavailability of other drugs. Using pepper and turmeric together can enhance the bioavailability of curcumin in turmeric, which has anti cancer properties. Twenty mg of piperine can enhance bioavailability of piperine twenty fold. It has also been observed that piperine may enhance bioavailability in humans by 2000%.

Piperine has been found to stimulate the activity of amino acid transporters in the intestinal lining, decrease the intestinal production of glucuronic acid and inhibit p-glycoprotein, a protein that removes substances from cells. This helps more quantity of drugs to enter the body in an active form and reach and remain in target cells for prolonged periods. This ability of piperine has both benefits and risks. It can make a therapeutic drug toxic and at the same time, a marginally therapeutic drug into a very effective one. Its ability to increase bioavailability and intracellular residency time should be utilized wisely and with caution in clinical practice. This is an important point to be borne in mind when using Ayurvedic formulations containing Piper species along with allopathic medications. The herb-drug interactions can have desirable or undesirable consequences. Piperine is known to enhance the bioavailability of many modern drugs like barbituares, ethambutol, rifampicin, isoniazid and theophylline. It is also known to increase the brain's production of beta-endorphins as well as serotonin and provides relief from pain. It checks acidity in the stomach and stimulates production of enzymes from the pancreas.

It is pertinent to note that many of the modern research findings corroborate well with the the observations made in Ayurvedic texts. It is interesting to note that piperine is ascribed with anti-ageing properties while Ayurveda uses long pepper for the same purpose. The effects of piperine on the digestive system and on absorption and bioavailability are also well documented in the classical Ayurvedic texts.

A brief profile of the five species of herbs in the Piperaceae family used widely in Ayurveda has been outlined in this paper. This discussion is only an index to the rich information that is available in both the literature and oral traditions of Ayurvedic practice that offers fresh ground for research.

References

Khajuria A, Zutshi U & Bedi K L 1998 Permeability characteristics of piperine on oral absorption — an active alkaloid from peppers and a bioavailability enhancer. Ind. J. Exp. Biol. 36:46-50.

Ojha Jharkhandle & Misra Umapathi 1996 Dhanwantari Nighantu (Ed.) Chaukhambha Vidyabhavan, Varanasi.

Pei Y Q 1983 A review of pharmacology and clinical use of piperine and its derivatives. Epilepsia 24:177-182.

Ram Prasad 1998 Vaidyopadhyaya Comm. In: Hindi, Madanapala's Madanapala Nighantu, Shri Krishna Dass proprietors, Shri Venkateshwar Press, Mumbai.

Sastri Viswanath Dwivedi. 1998 Bhavaprakasa Nighantu, Motilal Banarasidas, Delhi.

Sharma P V & Sharma G P 1979 Kaiyadeva Nighantu Chaukhambha Orientalia, Varanasi.

Sharma P V 2000 Namarupajnanam, First Edition, Satyapriya Prakashan, Varanasi.

Shastry J L N 2004 Illustrated Dravya Guna Vijnana, Vol. II, Chaukhambha Orientalia, Varanasi.

Shoba G, Joy D, Joseph T, Majeed M, Rajendran R & Srinivas P S 1998 "Influence of piperine on the pharmacokinetics of curcumin in animals and human volunteers". Planta Med. 64 (4): 353–6. PMID 9619120.

Sivarajan V V 2002 Indira Balachandran, Ayurvedic drugs and their plant sources, Reprint, Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi

Sreekumari K P (Ed.) 1982 Vagbhataa's Ashtanga Samgraha, Sutrasthana with "Sasilekha comm. by Indu, Ayurveda College, Thiruvananthapuram, Kerala.

Srikantha Murthy K R (Ed. Eng Trans), Vagbhataa's Astanga Hridaya, Sustrsthana 2004 Chaukhamba Krishnadas Academy, Varanasi.

Tripathi Indradeo (Edition with Hindi Commentary) Raja Nighantu of Pandit Narahari 1998 II nd Edition, Chaukhamba Krishnadas Academy, Varanasi.

Warrier PK *et al.* 2003 Indian Medicinal Plants: A compendium of 500 species, Orient Longman, Chennai.

Yadavji Trikamji Acharya (Ed.) 2002 Caraka Samhita, Chaukhambha Surabharati, Varanasi.

Yadavji Trikamji Acharya (Ed.) 1994 Susruta Samhita, Chaukhambha Surabharati, Varanasi.

Government initiatives in strengthening the production of *Piperaceae* crops

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The Western Ghats stretching across the southern states, is home to a number of plant species, belonging to the family Piperaceae, of which the commercially important ones are *Piper nigrum* (black pepper – the spice), *Piper longum* (thippali – the medicinal plant) and *Piper betle* (betel vine- the stimulant). Black pepper or the black gold, the spice of commerce, was the most important of them all, which brought many seafarers to the shores of India from the ancient times. It was one spice, the trade of which has become an important part of the world history, which lead to the great adventure, exploration, conquest and naval rivalry.

The organized cultivation and development of black pepper began with the setting up of a high – level Spices Enquiry Committee by the Planning Commission way back in 1951, due to the significant role the spices played among the agricultural commodities produced in the country. The committee in its report in 1953, stressed the need for better planning, research and coordinated effort for the development of spice crops.

The Government of India, accepted the recommendations of the Spices Enquiry Committee and provided necessary funds to Indian Council of Agricultural Research (ICAR), for implementing various schemes on research, development and marketing in all the regions of the country. In 1961, an ad-hoc, Central Spices and Cashewnut Committee, a semi autonomous body consisting of government officials and representatives of growers and traders was set up to look into the problem confronting the development of spices crops.

Based on the report of Agricultural Research Review Team, appointed by Government of India, Central Spices and Cashewnut Committee was abolished in 1965. The responsibility of research was given to ICAR. Development and marketing of spices was to be dealt by the Regional Office of the Ministry of Agriculture, Government of India, which subsequently lead to the creation of the present Directorate of Arecanut and Spices Development as a subordinate office under the Ministry of Agriculture, Government of India on 1st April, 1966 at Calicut in Kerala. Simultaneously, the Indian Spices Development Council was also constituted to continue the association officials and non-officials for continued advise on the development programmes of these crops. The Directorate served as the secretariat of the development council. Spices Export Promotion Council was also promulgated for the export promotion activities in spices.

The Cardamom Board, created under Cardamom Act, 1965 and the Spices Export Promotion Council were later merged together in 1986 to form the present Spices Board to look after the export promotion activities of all spices and the crop development and research activities of cardamom as was done by the erstwhile Cardamom Board.

Development programmes and financial outlay

No systematic programme for development of spices was undertaken in the first Five Year Plan (1951-56). The second Five Year Plan (1956-61) contained provision to the tune of Rs.15.49 lakh while the third Five Year Plan (1961-66) had an outlay of Rs. 35 lakh for spices development with which planting material production was taken up for the development of major spices in the important growing states. In the fourth Five Year Plan (1969-74) development programmes were concentrated for large scale production and distribution of high yielding varieties of important spices with a financial provision of Rs. 13.9 lakh.

A well organized effort for spice development was mooted in the fifth Five Year Plan (1974-79) with a plan provision of Rs.175 lakh with a stress for the development of major spices alone that too, confined to traditional centers of cultivation. In this plan period a special component plan costing over Rs. 30 lakh was also taken up for the development of spices cultivation in the Andaman and Nicobar Islands. In the sixth Five Year Plan (1979-84) the development programmes on spices were assigned to state governments as their mandate on the recommendations of the National Development Council. However, Central Sector Scheme was continued in the Union Territories and autonomous organizations like State Agricultural Universities and ICAR Institutes with the limited financial resources made available. Majority of the state governments however continued the development programmes on spices mostly confined to planting material production so as to encourage area expansion with high yielding varieties released by the research stations. The above arrangements were continued till 1986-87.

As this mode of implementation of the scheme was found inadequate in view of the growing demand for spices for domestic consumption and export, it was felt necessary to pay more attention towards spices development with adequate central assistance. Thus Centrally Sponsored Scheme for Spices Development was revived during VII Plan period (1985-90) with the launching of an Integrated Programme for Development of Spices (IPDS) with an outlay of Rs.435 lakh with a central share of Rs. 240 lakhs for providing 50% of the financial requirement in respect of the schemes to be implemented by the state governments and 100% requirements for the schemes implemented in Union Territory administrations and autonomous organizations.

In the Annual Plans 1990-91 and 1991-92, centrally sponsored schemes for the development of spices were intensified by increasing the financial outlay to the tune of Rs. 244 lakh and Rs. 574 lakh, respectively, by providing cent per cent financial requirements.

The major thrust in development activities in spices was received during eighth and ninth Plans with an objective of increasing area under spices by 4% and production by 8%. The IPDS was further intensified in the VIII Plan (1992-97) with a financial outlay of Rs. 125 crores comprising programmes for the overall development of 27 commercially important spice crops grown in India and the developmental activities were extended throughout the country particularly to the non traditional areas.

In the IX Plan the outlays were increased to Rs 142.50 crores and the area of operation was widened, so that due attention was given to every nook and corner of the country which have potential for development of any of the spices crops. Major programmes implemented during these two plan periods for the development of pepper were as follows:

Production and distribution of planting material: The programme was aimed at large scale production and distribution of planting material of high yielding varieties to meet the requirement of area expansion programme. The nucleus planting material of released high yielding varieties obtained from research stations were utilized for large scale multiplication in the government farms of the State Agriculture/ Horticulture Departments adopting rapid multiplication techniques.

Rehabilitation of pepper gardens: In order to encourage rehabilitation of old and unproductive gardens, incentives were given to the pepper farmers to the extent of 50% of the total input cost.

Adoption of plant protection measures against foot rot disease: The programme was to encourage farmers to adopt plant protection measures against foot rot disease on compact area basis. As an incentive, plant protection chemicals were supplied at 50% subsidized cost.

Eradication of little leaf/phyllody disease: This disease assumed serious proportion in Wynad and Idukki districts of Kerala, the two major pepper production centres. Compensation at the rate of Rs. 25 for cutting and removing the diseased vine was given to the farmers besides the supply of rooted cuttings of high yielding varieties free of cost for replacement.

Field demonstration plots: The programme was intended to convince and motivate farmers to take up the cultivation of new varieties of pepper adopting scientific package of practices. Each plot consisted of 50 standards/vines. The cost of inputs for establishing and maintaining each demonstration plot was provided.

Large scale demonstration of high production technology: Under the scheme, assistance was provided for the establishment of large scale demonstration plots in the farmers fields for the demonstration of high production technology developed by the Indian Institute of Spices Research.

Area expansion programme: The programme was intended to encourage monocropping of pepper of the desired varieties. The farmers were given financial assistance to bring new area under pepper.

Though the intended objective of increasing the area and production by 4% and 8% respectively, was achieved for spices as a whole, this did not hold true for black pepper. With regard to pepper, lot of variations were noticed and on an average the area of black pepper recorded an increase of 2% and production by 4% annually.

During the fag end of ninth Plan, macromanagement mode of implementation was adopted by the Ministry of Agriculture and central funds were released directly to the state governments for development of spices as per the regional requirements. This mode of implementation of Central Sector Scheme was continued during the tenth Plan. During the year, 2005-06 of the tenth Plan, National Horticulture Mission (NHM) was introduced with increased financial outlays. Under NHM, State Horticulture Missions were established in each states for implementing Central Sector Schemes proposed by each states as per their local requirements. Following are the major development programmes under National Horticulture Mission, which could be utilized for development of black pepper.

- Production and productivity improvement
- Production and distribution of planting material
    - Model nurseries
    - Small nurseries
- Tissue culture units
- Seed infrastructure
- Rejuvenation / replacement of senile plantations
- Promotion of integrated nutrient management/integrated pest management
    - Disease forecasting units
    - Plant health clinics
    - Biocontrol labs
    - Leaf/tissue analysis labs
- Technology dissemination through demonstrations/ front line demonstration
- Post harvest management

Government of India has already sanctioned a pepper rehabilitation and rejuvenation programme proposed by the State Horticulture Mission of Kerala state with a financial outlay of Rs 45.98 crores for the year 2008-09 covering 30,655 ha.

The Directorate of Arecanut and Spices Development has been entrusted with the responsibility of overall coordination and monitoring of the implementation of NHM programmes on spices in the country. Besides, the Directorate directly implements NHM programmes including nucleus planting material production programme, technology dissemination through frontline demonstration plots and conduct of national seminars and workshops.

Development programmes on betel vine and *Piper longum*

Considering the importance of betel vine in the national culture and heritage, self employment opportunities for rural farm families, a Central Sector Scheme was implemented by this Directorate during the VIII Plan with a financial utilization of Rs 2.00 crores. Major programmes implemented were:

- *Establishment of demonstration plots for the dissemination of technologies developed under All* India Coordinated Research Project on Betel vine
- Assistance for construction of conservatory / trellies
- Assistance for developing water sources
- Distribution of plant protection chemicals

Programmes implemented during IX Plan were production and distribution of planting materials of betel vine and transfer of technology programmes. The Central Sector Scheme on betel vine was discontinued in macromanagement mode of implementation and now the development of the crop is entrusted to respective State Horticulture Missions.

Assistance for *Piper nigrum* was covered under the Central Sector Scheme on medicinal and aromatic plants during VIII and IX Plans. Major components under the scheme were production of quality planting material and establishment of herbal gardens. Now, the Directorate implements a programme on nursery centre for medicinal plants for production and distribution of quality planting materials of medicinal plants including *Piper nigrum.*

Conclusion

In spite of all the development activities undertaken for black pepper, the production has been reported to have come down from 2005-06 to 2007-08. The productivity of pepper has not shown any remarkable improvement from the past years, probably due to non adoption of high production technology developed by research institutes and poor coverage of area under high yielding varieties. The important centres of production *viz.* Idukki and Wynad districts of Kerala hints at a decline in production due to the problems of pest and diseases, which could not be controlled effectively. It is time that various government institutes concerned with development of pepper adopt some aggressive measures to revive the lost grounds in pepper production so that the country retains its past supremacy in black pepper production and trade.

Role of State Horticulture Mission in black pepper and betel vine production

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The State Horticulture Mission (SHM) is a registered society set up under the Travancore Cochin Literary, Scientific & Charitable Societies Registration Act, 1955 to implement the National Horticulture Mission program, a centrally sponsored scheme, introduced during the financial year 2005-2006. This scheme envisages an end to end development of the horticulture sector covering production, post harvest management, processing and marketing. SHM provides assistance for plantation crops like cashew, cocoa, arecanut, betel vine, pepper and intercrops in plantation crops include pine apple, banana, spices, tuber crops, medicinal and aromatic plants.

State Horticulture Mission interventions in black pepper and betel vine production

Production and distribution of planting material

Model nurseries

Production and distribution of good quality seeds and planting material is an important component of the Mission. Model nurseries are intended to serve as a model for the production of superior quality planting materials on a commercial basis. To meet the requirements of planting material for bringing additional areas under improved varieties of horticultural crops and for rejuvenation programme in old/ senile plantations, assistance would be provided for setting up of new nurseries under public as well as private sector.

To meet the requirement of planting material for bringing additional areas under improved varieties of pepper & betel vine and for rejuvenation programme for old/senile plantations, assistance would be provided for setting up new nurseries under the public as well as private sector.

Infrastructure for model nurseries would include the following:

- Mother stock block maintenance under polycover with a maximum area of 500 m^2 to protect from adverse weather conditions
- Raising root stock seedlings under net house conditions
- Propagation house - a maximum of 500 m^2 tropical polyhouse with ventilation having insect proof netting in the sides and fogging and sprinkler irrigation systems.
- Hardening/maintenance in insect proof net house maximum of 2000 m^2 with 35% light screening properties and sprinkler irrigation systems.

- Pump house to provide sufficient irrigation with peak load of 5 mm per day and water storage tank to meet at least 2 days requirement.
- Soil sterilization -steam sterilization system with boilers.

It has been estimated that a model nursery with an area of 4 ha would cost Rs.18.00 lakhs per unit. The model nurseries, which would be established under the public sector, will be eligible for 100 per cent assistance of maximum of Rs. 18.00 lakhs per unit. It would be the responsibility of the nurseries to ensure quality of the planting material. The nursery will be laid out in a compact area of 4 ha. For model nurseries in the private sector the assistance will be 50 per cent of the cost subject to a maximum of Rs.9.00 lakhs per unit.

Regarding establishment of model nurseries in the department farms separate action plan for each nursery will be prepared by concerned farm superintendent or agricultural officer and scrutinized by the district level Deputy Director of Agriculture (Horticulture), [DDA (H)]. District Level Committee (DLC) of State Horticulture Mission (SHM) will approve the action plans.

Similarly in the case of private farms the action plans submitted by the entrepreneurs will be approved by DLC after scrutiny by the DDA (H) of the districts concerned following the instructions issued earlier. Registers should be maintained showing the calendar of operations as well as action taken weekly during the nursery preparation. Periodical inspection has to be done by the scientists of nearby stations of KAU and Principal Agricultural Officers of the district may record comments then and there. A team comprising of PAO, DDA (H), Professor of KAU, and Scientists from ICAR/CSIR should visit periodically and certify the quality of the planting materials produced before its distribution.

The model nurseries will produce 4 lakh plants per year. In the case of public sector nurseries 25% of the cost will be released after demarcating the land for the nursery. Further release of funds will be based on the completion of work and on verification of results. In the case of private nurseries funds will be released only as back-ended subsidy on loans availed for the purpose or based on the completed work utilizing own resources.

Small nurseries

Small nurseries, covering area of about one ha, will have infrastructure facilities to hold 60,000 to 80,000 plants. These plants will be maintained for a period of approximately 9 months. Small nurseries would cost Rs. 3 lakhs per unit. The assistance will be to the extent of 100% of the cost for the nurseries under public sector and 50% of the cost limiting to Rs. 1.5 lakhs for the nurseries in the private sector. The small nurseries would produce at least 60000 plants per year.

In the case of public sector nurseries 25% cost will be released as advance on demarcating the land for the purpose in the departmental farms or agencies under public sector. The remaining amount will be released in three equal installments based on the completed work. The release of assistance to private sector nurseries will be on the basis of completed work in four stages.

It would be the responsibility of the nurseries to ensure quality of the planting material through self accreditation. Nurseries will also be regulated under the legislation in force relating to seeds and planting material. The nurseries could be multi-crop or crop specific depending upon the requirements of planting material in the locality/project area. Hence, the type of nursery proposed to be established should be clearly indicated in the action plan. The plan should also contain an assessment of the existing nurseries, the number of planting material being produced, crop wise and the additional requirement of nurseries. *e.g.*, For pepper and betel vine - cuttings will be produced in the small nurseries by following serpentine method of propagation as far as possible.

Item	Assistance (Rs. in lakhs)	
	Public sector (100%)	Private sector (50%)
Model nursery (4 ha)	18	9
Small nursery (1 ha)	3	1.5
Rehabilitations of tissue culture lab	8	4

Infrastructure for nursery would include the following

- Raising two node cuttings under net house conditions. A net house of 2000 m^2 to screen 35% light. The floor of the net house will be covered with mulching sheet to control weed and ground pathogens.
- Suitable irrigation system will be provided.
- The nurseries will also have provision for solar sterilization of soil media.
- Purchase of newly evolved nucleus planting materials from KAU, IISR, research institutions *etc.*
- Any other infra structure with the approval of the DLC.

Tissue culture units

No new Tissue Culture (TC) units will be set up under the Mission. However, since a large number of TC units already exist, some of which need strengthening/rehabilitation, assistance would be provided for rehabilitation/ strengthening of existing TC Units subject to a maximum ceiling of Rs.8.00 lakhs for the TC Units in the public sector and 50% of the cost with a ceiling of Rs.4.00 lakhs for the TC units in the private sector.

Establishment of new gardens

The Mission envisages coverage of large areas under improved varieties of horticultural crops. A farmer will be eligible for receiving assistance, normally, for one crop. The assistance for cultivation will be spread over a period of three years in the ratio of 50:30:20 in the first, second and third year. Assistance for the second year will be subject to 75% survival of the new gardens and for the third year the assistance will be subject to 90% survival of the plants. The cost of raising new plantations will vary from crop to crop.

Crop	Assistance (%)	Assistance per ha (Rs.)	Period (years)	Maximum limit
Pepper	75	11250	3 (50: 20:30)	2 ha
Betel vine	75	11250	3 (50: 20:30)	4 ha

Rejuvenation/replacement of senile plantations

Low productivity of perennials is due to preponderance of old and senile trees and poor management of inputs such as water, nutrients and pesticides. Under the SHM, it is proposed to take up productivity improvement programmes through removal of senile plantations, re-plantation with fresh stock supported with appropriate and integrated combination of inputs, pruning and grafting techniques. The programme will be implemented through individual farmers, farmers' cooperatives, self-help groups, NGOs, growers' associations and commodity organizations. The assistance for rejuvenating senile plantations will be @ 50% of the cost subject to a maximum ceiling of Rs.15, 000/- per ha limited to 2 ha per beneficiary.

Rejuvenation of pepper

In the current year action plan (2006-07) of State Horticulture Mission approved by National Horticulture Mission an amount of Rs.1500 lakhs is provided as assistance for rejuvenation of 10,000 ha. pepper garden. In the action plan for 2005-06, 5000 ha. has been kept for rejuvenation with an assistance of 750 lakhs.

Pepper is one of the most important dollar-earning crops in Kerala. The state enjoys virtual monopoly in its production accounting for about 81 per cent of the nations production and bagging 37 per cent of the total export earnings from pepper. The area under the crop in the state is 2,16,440 ha (2003-04) 2,37,669 ha. (2004-05), 2,16,759 (2005-06). The present average yield is only 319 kg/ha (2003-04), 316 kg per ha. (2004-05) against a potential of 1000 kg/ha under better management practices. The present low productivity is due to senile and disease affected vines and poor management practices. Hence this programme is concentrated in the major traditional pepper growing districts, *i.e.*, Idukki, Wayanad, Kannur, Kasaragod, Palakkad, Thrissur and Kozhikode.

The main objectives of the schemes are

- To rejuvenate pepper gardens by removing senile and diseased plants and by filling gaps and to put to new standards if lost
- To enhance production by adopting scientific management practices
- To augment average productivity to 1000 kg/ha by growing pepper in most suitable locations
- To increase employment opportunity
- To increase export
- To reduce the cost of cultivation and increase overall income from the land

The cost of cultivation for rejuvenation of one hectare of pepper garden comes about Rs. 30000 per hectare. The assistance for rejuvenating senile plantations will be @ 50 per cent of the cost subject to a maximum ceiling of Rs. 15,000 per hectare limited to 5 ha per beneficiary. The proposed subsidy is to meet the cost of pepper rooted cuttings and cost of soil ameliorants, manures, fertilizers, bio control agents and PP chemicals *etc.* as in the following order

- Cost of rooted cuttings (40 per cent of total recommended population)
- Application of the organic manure/FYM, chemical fertilizer and PP chemicals as per the package of practices of KAU
- Application of bio-control agents like *Trichoderma, Pseudomonas* and soil ameliorants *etc.* with other components of IPM and INM.
- Other expenses like cost of standards, cultural expenses, like shading, training, pruning, twining vines to standard *etc.*

The estimated cost of rejuvenation for 1 ha. pepper is Rs.30,000/- which is divided as follows:

Cost of rooted cuttings for replacing senile, diseased - Rs. 2,000 (40% of total recommended population); vermi compost/FYM/ organic manure - Rs.11, 000; chemical fertilizers - Rs. 5,000; bio-control agents, soil ameliorants *etc.* - Rs. 5,000; PP chemicals - Rs. 5,000; other expenses - Rs. 2,000.

While calculating eligible subsidy 50 per cent of total cost will be considered instead of 50 per cent of expenses incurred in each component.

It is estimated that around 40% of the pepper plantations in the state are old and senile. Majority of the traditional pepper plantations are poorly managed leading to low productivity of 275-300 kg/ha. However, there is potential for improving productivity to one ton/ha through better management. A systematic rehabilitation programme is also reported to be over due in the pepper growing districts. The proposed subsidy is to meet the cost of pepper cuttings and cost of soil ameliorants, manures, fertilizers, bio control agents and PP chemicals. An area of 10000 ha with an assistance of Rs.1500.00 lakhs will be rehabilitated under the programme.

Protected cultivation

Activities like green house construction, mulching, shade net and plastic tunnels would be promoted, the assistance for which is indicated below:

Green house (hi-tech)	Estimated cost	Pattern of assistance
Small and marginal farmers	Rs. 650/ m^2 for hi-tech GH Rs. 250/- m^2 for normal GH	50% of the cost subject to a maximum of Rs. 325/ m^2 for hi-tech and Rs.125/ m^2 for normal GH, limited to1000 m^2 / beneficiary
Other farmers	-do-	33.3% of cost subject to a maximum of Rs. 215/m^2 for hi-tech and Rs.67/m^2 for normal GH limited to 1000 m^2
Mulching	Rs. 14,000/ha	50% of the total cost subject to a maximum of Rs. 7000/ha limited to 2 ha per beneficiary
Shade net	Rs. 14 / m^2	50% of cost subject to a maximum of Rs. 3500/ 500 m^2 limited to 2 ha per beneficiary
Plastic tunnel	Rs. 10 / m^2	50% of cost subject to a maximum of Rs. 5000 /1000 m^2 limited to 5 ha per beneficiary

Promotion of integrated nutrient management/ integrated pest management

Assistance for INM/IPM will be @ 50% of cost subject to a maximum ceiling of Rs.1000/- per ha limited to 4 ha per beneficiary.

Assistance will also be available for developing facilities like disease forecasting units, bio control labs, plant health clinics and leaf/tissue analysis labs as per the pattern of assistance indicated below:

Promotion of INM/IPM	Estimated cost	Pattern of assistance
Sanitary and phytosanitary (public sector)	Project based	Project based
Promotion of IPM	Rs. 2000/ha	50 % of cost subject to a *maximum* of Rs 1000/ha limited to 4 ha / beneficiary
Disease forecasting units (PSUs)	Rs. 4 lakhs/unit	Upto Rs. 4 lakh/unit
Bio-control labs	Rs. 80 lakhs/unit	
a) Public sector		Upto Rs. 80 lakh/unit
b) Private sector		Upto Rs. 40 lakh/unit
Plant health clinics	Rs. 20 lakhs/unit	
a) Public sector		Upto Rs. 20 lakh/unit
b) Private sector		Upto Rs. 10 lakh/unit as credit linked back ended subsidy
Leaf/ tissue analysis labs.	Rs. 20 lakhs/unit	
a) Public sector		Upto Rs. 20 lakh/unit
b) Private sector		Upto Rs. 10 lakh/unit as credit linked back ended subsidy

Assistance for setting up sanitary and phyto sanitary certification facilities would be provided to the public sector on project basis. Assistance will also be extended for meeting the cost of sanitary and phyto sanitary certificates for importing / exporting horticultural produce and planting material on case to case basis.

Organic farming

Organic farming in horticulture is becoming increasingly important. Its environmental and economic benefits have captured attention in many countries. Consumers' demand for organically produced food products and society's demand for more sustainable development provide new opportunities for farming and business around the world.

The basic rules of organic production are that the natural inputs are to be applied and the synthetic inputs are prohibited. But there are exceptions in both cases, certain natural inputs determined by various certification programmes to be harmful to human health or the environment are prohibited (e.g., arsenic). Certain synthetic inputs determined to be essential and consistent with organic farming philosophy are allowed (*e.g.*, insect pheromones).

An organic production system would be designed to

- Enhance biological diversity within the system
- Increase soil biological activity;
- Maintain long-term soil fertility;
- Recycle plant and animal waste;
- Rely on renewable resources in locally organized system;
- Promote healthy use of soil, water and air and minimize all forms of pollution;
- Handle agricultural products with emphasis on careful processing methods in order to maintain organic integrity and vital qualities of the product at all stages.

In view of the growing demand for the organically produced food items worldwide the natural advantages in this regard needs to be fully exploited. In order to help the growers obtain the required certification for organically produced crops, awareness has to be generated through training and distribution of information material.

For adopting organic farming for perennial and non perennial crops including pepper and betel vine, additional assistance will be given over and above the area expansion programme @ Rs. *10,000* per hectare subject to a limit of 4 ha per beneficiary. For organic cultivation of vegetables, the maximum assistance will be limited to Rs. 10,000/- per ha.

The SHM will also provide financial assistance up to a maximum of Rs 5.00 lakhs for a group of farmers covering an area of 50 ha, duly recommended by State Govt., on a case to case basis for certification of organic process/produce. Vermicompost can be used as a major input in organic farming.

Item	Assistance	Maximum limit
Adoption of organic farming	Rs.10000/ ha (50%)	4 ha
Vermi compost units	Rs. 30000 / unit (50%)	-
Certification	Project based	Rs. 5 lakhs in cluster of 50 ha

All the above activities will be undertaken as per the following rules

- The programmes will be undertaken scientifically as per the package of practices recommendation of Kerala Agricultural University.
- The procedures followed in the schemes of Department of Agriculture should be adopted in the absence of specific working instructions under State Horticulture Missions.
- The farmers will be permitted to use only superior quality inputs.
- The inputs can be purchased by the farmers only from approved firms or through Service Cooperative Banks/Societies or govt. agencies of their area.
- The subsidy will be disbursed in the order of planting material, fertilizers, PP chemicals, bio control agents, organic manures *etc.*, only after ensuring the 100 per cent utilization of the inputs and should be visible in the field on inspection.
- No component wise ceiling is fixed under SHM programmes. But overall subsidy ceiling may be strictly observed and subsidy will be limited to 50% of the amount spent subject to the maximum of 50 per cent of the unit value fixed.
- The cash vouchers will be received and examined thoroughly by the Agricultural Officers in the Krishi bhavan before approval.
- The Deputy Director of Agriculture will effect payment based on the utilization certification of the agricultural officer and on recommendation by the Assistant Directors of Agriculture concerned.
- All the claims should be placed in the District Level Committee (DLC) and get it passed and the statement of the beneficiaries with address of all schemes to be kept in bound form in all Krishi bhavans and a copy of the same has to be placed in the NIC net system for assessment of SHM.
- All the programmes allotted to district should be implemented with approval from District Level Committee /District Horticulture Mission.
- The quality of the inputs like fertilizers, plant protection chemicals, bio control agents, organic manures may be tested by proper lab analysis. Quality testing by Department of Agriculture and University/ICAR laboratory is compulsory.
- The procedure for making available the subsidy will be transparent and decided by DLC. But it should be beneficial to the farmers and ensure that the assistance is given to the farmers without any difficulty.
- The valuation of shade net, green house, creation of water resources will be done by Assistant Directors of Agriculture.

- The material for shade net, green houses will be purchased from approved firms as per Bureau of Indian Standards and specification prescribed by Directorate of Agriculture.
- The planting material utilized for the programmes should be purchased from Kerala Agricultural University, Agricultural Department, research institutions of ICAR or nursery funded by NHM. If sufficient material is not available, it should be purchased from SHM nurseries or nurseries approved by Department of Agriculture.
- The subsidy from SHM will be released only after ensuring the utilization of inputs as per POP and the total cost for development as per the NHM guidelines and on seeing the effect of application in the field, as back ended subsidy
- The quality of planting material purchased from approved nurseries will be ensured by a committee consisting of experts from Kerala Agricultural University, ICAR and SHM and after inspection and quality certification.

WTO: SPS and IPR dimensions of Piperaceae and its implications

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Introduction

India, in recent years, has been a net exporter of agricultural goods. The export of agricultural products from India, which stood at US$6,734 million and US$7,533 million in 2002-03 and 2003-04, respectively, were more than two times the import of agricultural products in the corresponding years. During the first half of the current year 2004-05, the export of agricultural products were US$3,511 million. The Foreign Trade Policy 2004-09, emphasized the importance of agricultural exports and announced the policy measures to boost agri-export. The Government of India in 2003-04 had initiated major steps towards introduction of futures trading in commodities, which included removal of prohibition on futures trading in all the commodities by issue of a notification and setting up of the National Level Commodity Exchanges.

In light of the challenges currently being posed by industrialized country agricultural trade policies, the severity of rural poverty, and the central role of agriculture in developing countries' economic growth, there is an urgent need to refocus on this sector to take advantage of the food safety as comparative advantages.

The Agreement on Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT) define the international rights and obligations of member countries with respect to the development or application of measures that affect trade. Especially, SPS acknowledges a country's right to protect itself from risks to human, animal and plant life and health, and it confirms the need to constrain countries from using such measures as excuses to create unnecessary barriers to trade. In short, the purpose of the agreement is to enable the legitimate protection of life and health while not giving rise to illegitimate protectionism. The Codex Alimentarius Commission, a UN body, complies agreed measures into the Codex Alimentarius, the Codex Food Code (CFC).

Issues in agribusiness trade

India has lost sufficient trade because of failure to meet food safety standards. Different countries in the past had rejected Indian products. To quote some examples, European Community banned fish imports from Gujarat, chilli exported from India was detained by Spain due to aflatoxin contamination. Indian spices were detained by Italy and Germany for pesticide residues and microbial standard for shrimp cost India nearly 58 metric tons. More than trade, human health is under threat due to physical, chemical and biological contaminants. For example, Polycyclic Aromatic Hydrocarbons (PAH's) contamination with copra and fish in the process of smoking caused carcinogenic and mutagenic effects on human. Aflatoxin contamination in chilli and groundnut caused hepatic necrosis and hepatomes. *Salmonella* and *E. coli* 0157: H7 contamination in fruit juices caused deadful illness.

Therefore, TBT Agreement is intended to ensure that WTO Members do not use technical regulations and standards as disguised measures to protect domestic industries from foreign competition. In international trade law, health and environmental standards and regulations, labeling, symbols, packaging and markings can be considered as technical barriers to trade. In the agrifood sector, the TBT Agreement applies to all rules other than those specifically covered by the SPS Agreement. The TBT Agreement does not permit requirements for the labeling of some products whereby "like products" remain unlabeled (Article 2.1). For example, GM crop commodities that have been assessed and found to be "substantially equivalent" to their conventional counterparts would be considered "like products," and thus would not require specific labeling. Critics of the WTO stance argue that "substantially equivalent" is an unacceptable outcome of the risk assessment of GM products and assert that these products are not "like products" for purposes of labeling, and in fact, can be subjected to labeling would not be viewed as a legitimate objective within the context of the TBT Agreement.

In the present debate about health and safety, the "precautionary approach" is often opposed to a "sound-science approach." Varying perceptions about public health risks, different levels of acceptance of them, divergent priorities, and dissimilar economic interests have driven countries to take quite opposite positions in this field and have created acute tensions among them. International trade magnifies the problem.

Relevance of SPS in agribusiness trade

The main goal of the SPS Agreement is to prevent SPS measures from having unnecessary negative effects on international trade and from being misused for protectionist purposes. However, the agreement fully recognizes the legitimate interest of countries in setting up rules to protect food safety and animal and plant health, and in fact allows countries to give these objectives priority over trade, provided there is a demonstrable scientific basis for their food safety and health requirements. The need for specialist scientific or technical knowledge makes restrictions imposed for health and safety reasons much more difficult to challenge than some other barriers to trade. While the requirement the SPS measures be based on scientific evidence helps secure trade policy objectives, it is perceived by some environmental and consumer protection groups in some developed and developing countries as a dangerous limitation on the right of governments to take precautionary measures to protect their citizens and the environment against risks that can have irreversible effects. Differences between "sound science" and the "precautionary approach" to health and safety are causing acute tensions among countries.

IIPM under the sponsorship of the Division of Agriculture Extension of ICAR secured the ability to generate immediate strategies to process existing extension system to enter into the new platform of agri-business led extension service to meet SPS aspects of WTO at the grassroots level within agri-business, commodity and plantation sector.

The ultimate aim of this paper is to produce an accumulatory body, reliable knowledge, which enable us to understand the role of trade/export in global food safety management. For decades, the service of social and biological sciences had been providing insights to successful production based on the benefits of obsessive focus on technology-led production. The underpinning of this success all along has been to capitalize and improve production, productivity and profitability in the sector. The dominant motive of trade/export is currently sniffing the edges of valuing time as a dimension of success, for food scenario within global perspective to meet the demands of WTO-SPS-TBT agreements.

Research and development priorities

The importance of SPS for patents is increasing, partly because of changes in the funding of R&D for agribusiness. Until recently, agribusiness R&D was publicly funded. Research results were given to farmers through extension services. The financial returns for publicity financed R&D into improved farming productivity are high for both developing and developed countries. The U.S. economy, for example, benefited from its long-term investment of US$134 million worth of support to international wheat and rice research aimed at developing countries by up to US$14.7 billion, according to research by the IPGRI.

In theory, stronger SPS led IPRs should encourage more research and development (R&D) in countries where they exist, but there is "limited empirical evidence", even in industrial countries, that IPRs protection leads to increased investment in R&D. This is partly because of the difficulty of separating cause and effect – IPRs may stimulate more investment, but countries and firms that invest more in R&D may demand more protection in trade.

The Codex Alimentarius Commission, a U. N. body, complies agreed measures into the Codex Alimentarius, the Codex Food Code (CFC).

> Article 27, section 5 of TRIPS agreement on agriculture states that an invention in all fields of technology is patentable if it is new, innovative and capable of industrial application.

In India, a vicious circle of R&D and corporate sectors are exclusively working around patents of products and processes, protection of seeds and disputes. The key features of IPR implications for agricultural technology, especially in terms of "food safety" technology development, access and profitization are limited.

Features of SPS-IPR in agribusiness

The implementation of the new SPS Agreement has raised significant problems for developing countries. Some result the lack of capacity to develop the institutional arrangements that permit them to meet their SPS-related WTO commitments. Even if the capacity exists, these commitments are costly to implement: standards, along with testing and certification, represent between 2 and 10 per cent of overall product costs, which impose a burden on agriculture in the developing countries.

> Article 10.1 of the SPS Agreement says that "in the preparation and application of sanitary and phytosanitary measures, Members shall take account of the special needs of developing country Members and in particular of the least-developed country Members"

A recent paper found that a 1998 European Commission regulation that raised the standards for the minimum level for certain types of aflatoxin (a toxic substance found in foodstuffs and animal feed), to levels higher than those required by the Codex Alimentarius (the food standards code) is estimated to cost close to US$700 million in lost revenue to African groundnut exporters, many of them LDCs [1].

India has immense potential for trade / export agri-plantation and its products, the presence of plantation crop-based disease and insects contamination is of economic importance and shall be eradicated/ controlled with appropriate patentable technology. The Agency recommends creation of "Disease Free Controlled Zones" in selected areas of the country, to meet the WTO-SPS agreement that act as a non-tariff barrier.

- For example, high priority in crop husbandry is contamination of microorganisms (*e.g.*, ochratoxin, aflatoxin, *etc*), which is highly carcinogenic has truncated export.
- Generation and patterning of technology to prevent chemical residue in food sector is warranted. The SPS standard should be formulated on par or equivalence with codex by R&D system in India.
- In the past, materials and machines were produced to enhance productivity and quality rather than food safety dimension. It is recommended that technology to patent food-engineering design for Piperaceae must focus on food safety aspects.

It is difficult to argue against developed-country actions that aim to protect consumer health and safety. But when such actions result in significant costs to developing-country exports, it would seem fair that the developed countries to legally commit to take steps that will help the developing country to meet the problem that the developed-country regulation has created. Under the agreement, WTO members are encouraged to adopt international standards (where they exist), but may define even higher standards provided these are based on a sound scientific risk assessment and do not discriminate against imports.

Recognizing that a complete risk assessment may not possible in the short term because of scientific uncertainty or the lack of sufficient evidence,

> Article 5.7 of the SPS Agreement allows member countries to adopt temporary restrictive measures.

In such cases, members are expected to seek the additional information required to complete a full risk assessment within a reasonable period. Maintaining restrictive measures indeterminately in the absence of scientific evidence of risk solely for "precautionary" reasons is not allowed. The TBT Agreement is intended to ensure that WTO members do not use technical regulations and standards as disguised measures to protect domestic industries from foreign competition.

Operational dimensions of SPS-IPR in Piperaeae trade

The features of future trade in agri-business solemnly depend upon identification of critical control points (CCP) and patenting of critical limits (CL) related to HACCP (ISO:22000).

A Critical Control Point (CCP) is defined as "any point step or procedure at which control can be applied and a food safety hazard can be prevented, eliminated (or) reduced to an acceptable level of SPS". The identification of critical control points is based upon the assessment of severity and likely occurrence of hazards and upon what can be done to eliminate, prevent or reduce the hazards at a process step. The selection of CCPs are made on the basis of

- Identified hazards (knowledge) and likely occurrence in relation to that constitutes unacceptable contamination
- Operations (know-how) to which the product is subjected to during processing and preparation, and
- Intended use of the product.

It should be noted that a separate critical control point does not have to be designated for each hazard. However, actions must be taken to ensure elimination, prevention or reduction of all identified hazards. Examples of CCPs may include heating, chilling, formulation control and its limits. The steps to identify critical control points are:

- Use decision tree approach to identify CCP
- With the help of experts verification of the control of all the identified hazards
- Develop parameters attached to CCPs

There must be a column in hazard identification form where CCPs are identified. CCPs should be identified numerically with a category qualifier "B", "P" or "C" for biological, physical and chemical respectively. For example, if the first CCP identified will control a biological hazard, it will be recorded as CCP-1B. If the second CCP identified will control a chemical hazard, it will be recorded as CCP-2C. If a biological and a chemical hazards are controlled at the same processing step, and this is the fifth CCP, then the CCP number used will be CCP-5BC. This identification protocol was developed to sequentially identify CCPs independent from process step numbering and readily inform the user of the HACCP model which type(s) of hazard needs to be controlled at a particular process step.

Critical limits are defined as criteria that separate acceptability from unacceptability. A critical limit represents those boundaries (technology) that are used to judge whether an operation is producing safe products. Critical limits may be set for factors such as temperature, time (minimum time exposure), physical product dimensions, water activity, moisture level, *etc*. These parameters, if maintained within boundaries will confirm the safety of the product.

> Article 4 of SPS agreement encourages to give positive consideration to accepting as equivalent the SPS measures of other WTO members.

The recognition of the equivalence of SPS measures through appropriate CL to Indian products with appropriate patent would represent a key instrument to enhance WTO led market access to our products. The Critical Control Points and Critical Limit must be specified and validated by the panel of scientific body working in the area of Piperaceae with special reference to biological, chemical, physical and genetic aspects. The examples of CCP and CL with reference to SPS is given below:

Sl. No.	Area of Operation	CCP (Know-how)	CL (Technology for IPR)	Remarks
1.	Chemical Hazard			
	Optimizing MRL of quinalphos in pepper*	• Right time of harvesting • Adoption of good agricultural practices (GAP)	• Harvest pepper after 12 days of application of quinalphos 25FC	• An understanding on plant protection measures and agronomic practices to minimize residual level may be worked out to identify correct CCP/CL and related IPR
	Optimizing MRL of mancozeb in Betel vine	• Right time of harvesting • Adoption of good agricultural practices (GAP)	• Harvest of betel vine after 30 days of application of mancozeb 75WP	• An understanding on plant protection measures and agronomic practices to minimize residual level may be worked out to identify correct CCP/CL and related IPR(Agnihotri 1999)

2. Biological hazard			
Cleaning of Spices	Number of dead insects and excreta	Insects: • Pepper < 2 excreta mg/lb:	• Insects live symbiotically with micro organism for their digestion and their excreta contain micro organism which are toxic • It is important to exclude insect/ excreta before processing (American Spice Trade Association Specification 2001)
Drying of black pepper Control of mould formation and its multiplication during storage	• Moisture level • Drying period & periodic turning of layers • Optimum relative humidity • Optimizing store house environment	• Optimum moisture level <10% • Drying period 4-5 days with regular turnings • Mechanical drying, washing pepper by hot water air at 90-100°C • RH <80% • Critical limit for number of dunnage and ventilation units needs to be identified based on the capacity	• >10% of moisture level initiates development of *Aspergillus flavus* and *Aspergillus ochraceus* which leads to aflatoxin and ochrotoxi respectively (IISR) (Dwarakanth 1989) • High moisture content (14%) leads to sweat and damage products during shipment (Ishihara 2000) • Higher relative humidity (80%) leads to the development of *Aspergillus flavus and Aspergillus ochraceus*
3. Physical Hazard			
Spices grinding process (Iron filing in the spice powder)	• Removal of iron filing with metal detector	< 10ppm	• >10 ppm for iron filings is considered to be hazardous for human consumption (Kalyanaraman 2002) Use of metal detectors GENIUS GLS tunnel detectors for application in conveyor belt systems and GENIUS RZ tunnel detectors for monitoring sectional and pressure conveyor pipes (Makarand Mandke 2002)

Conclusion

The role of bio-social scientists inPiperaceae-business trade to manage global food safety scenario is relatively a new concept involving the integration of social science and biological science of all the value creation elements in agri-business development. This paper advocates a strategic approach in resolving food-safety management in joint alliance between social, biological scientists and trade experts. The study also proposes a model for the accountability of socio-biological scientists of Piperaceae in trade related to production, supply and service. The ultimate goal of presentation is to make social science discipline such as Extension, Sociology, Economics, Law & Trade, Commerce and Psychology disciplines at the forefront in resolving food safety management issues. An important element of SPS guidelines in the compliance with HACCP (ISO:22000), HAZAP, GLOBALGAP, SQF, *etc*, a world class quality management system for SPS will be discussed to encompass the entire food chain with a value on "trade" for the benefit of consumers. In this context, conceptualizing a management system for trade on food safety becomes essential. The conceptual framework to understand interrelationship between SPS-WTO agreements and its associated activities of socio-biological sciences is illustrated in Figure No.1. The model is proposed as a "sensitizing framework", that is, as a way of seeing and thinking which alerts the socio-biological scientists to alternative ways of understanding trade and hence managing institutional innovations to meet WTO agreements with reference to SPS.

The prospects of identifying SPS, IPR and TBT related R&D will be up-coming hinge on how Indian agri-business can take maximum advantage of the existing clauses of the WTO and to what extent it is successful in amending some of the clauses are the thrust areas. Using modern biotechnology, plant breeders are able to introduce specific genetic material taken from any species of plant, animal, or microorganism, or created synthetically within the laboratory, into many different species of plants or animals, to create transgenic-organisms. The "first generation" of genetically modified (GM) products has generally included crop plants with new input traits, such as pest resistance or herbicidal tolerance. These have included insect- resistant varieties of maize, potato and cotton, containing a toxin-encoding gene from strains of the bacterium *Bacillus thuringiensis*; plants with tolerance to broad-spectrum herbicides, such as glyphosate (Round-up tolerant canola, maize, and soybean), and glufosinate ammonium-tolerant canola, maize, rice and soybean; and plants, such as melon, papaya, potato, and squash, with resistance to disease caused by specific plant viruses. In addition, there are a very few products with modified quality traits, such as high-oleic acid canola and soybean, and delayed-softening melon and tomato.

In international trade law health, environment, standards, regulations, *etc.* can be considered as TBT. Therefore, SPS thus serve as a strict interpretation of the precautionary approach for generation of "wholesome technology" to protect human, animal & plant health and life. This paper calls for Piperaceae commodity and agri-business strategies for the promotion of India's Piperaceae export/trade and evokes policy discussions and implications on SPS-TBT, IPR with special reference to management of food safety in trade.

Implications

It is expected that over the coming years there will be newer of "patentable SPS food safety technology" for trade. These next-generation products will include plants enhanced resistance to diseases caused by fungal and viral pathogen; agricuticles; improved tolerance to abiotic stresses such as heavy metal contamination; improved nutritional quality or medicinal value; vehicles for delivery of oral vaccines and therapeutics; factories for the production of pharmaceutical proteins; safety technology for food chain from genomics to government and farms to super market to consumers. The SPS agreement sets out the basic research, education and outreach for food safety and animal and plant health standards. Although it allows individual countries to set their own standards, it demands that regulations be based on science, and that be applied only to the extent necessary to protect human, animal, or plant life and health.

WTO also instructs countries to enter into consultations with the aim of achieving bilateral and multilateral agreements on recognition of the equivalence of specified sanitary and phytosanitary measures between academic and industry partnership domain to enhance market access. It also instructs countries to develop and document "CL" with the aim to achieving agreements of SPS and TBT.

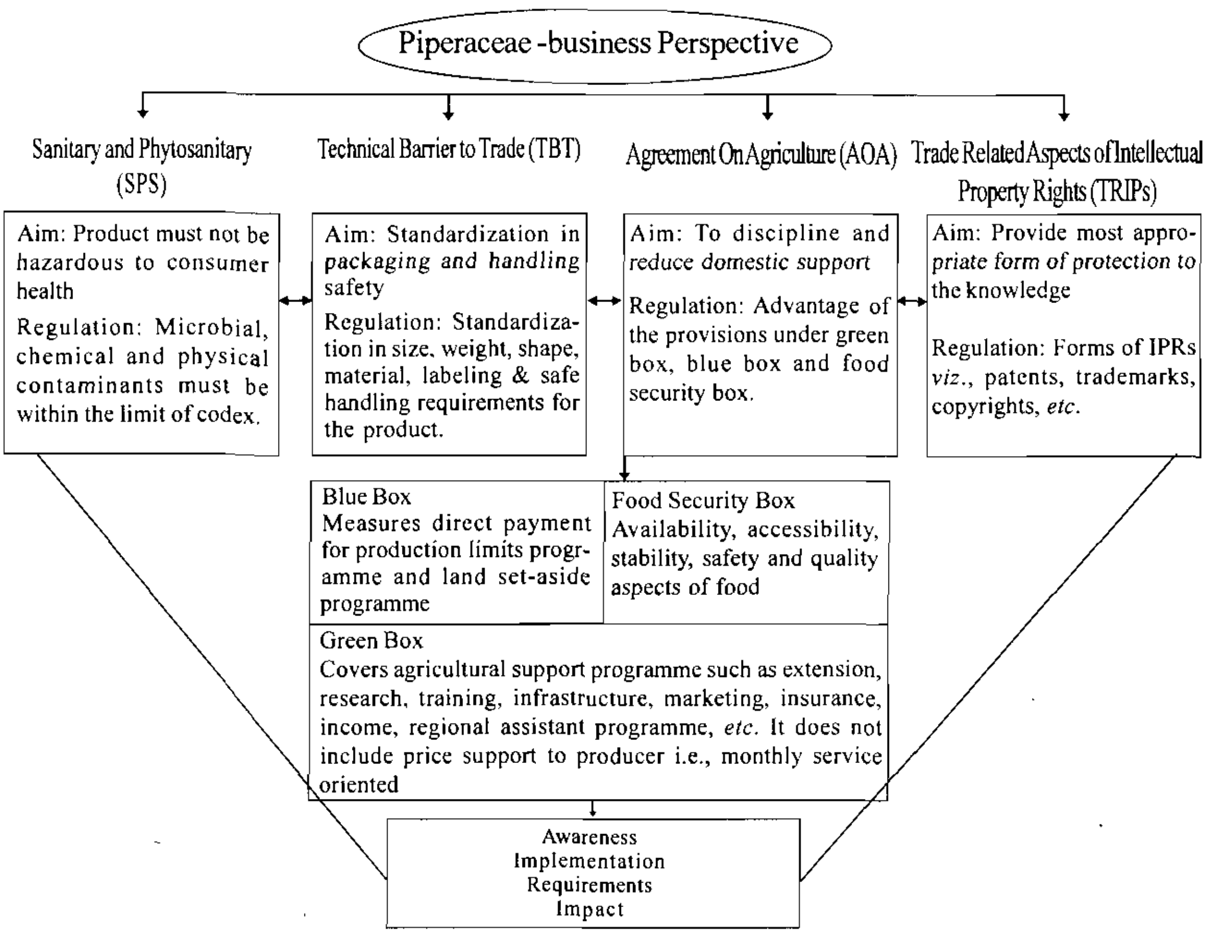

Fig 1. Conceptual framework to understand interrelationship of WTO-SPS-AOA-TBT-TRIPs agreements and its implications for Piperaceae -business

References

Otsuki T, Wilson J S & Sewadeh M 2000 What price precaution? European harmonization of Aflatoxin regulations and African food exports. World Bank, Washington D C.

American Spice Trade Association Specification 2001

Aditya Mattoo & Robert M Stern 2003 India and the WTO A Co-publication of the World Bank and Oxford University Press, Washington.

Agnihotri N P 1999 Pesticide safety evaluation and monitoring IARI New Delhi. p 135.

Kalyanaraman K 2002 Quality specifications for spices and spice products in Europem, Tata Spices Center, Cochin.

Makarand Mandke 2002 'No' to metal in food. Agro India. p 32.

Dhanakumar V G 2005 IPR for food safety technology and management, Lead Paper presented at the National Seminar on IPR at Gandhigram Rural Institute, Gandhigram.

Dhanakumar V G 2004 Safety management for fruits and vegetables. J. Agri-business and Food Industry 1(6): 19-23.

Dhanakumar V G 2003 Biological Risk Management (Biosecurity) in Coffee: An HACCP Perspective (Part I & II). Indian Coffee XVII: 14-17 and LXVII (7):18-21.

Dhanakumar V G 2002 Total Quality Management in tea through quality safety and risk management: An HACCP perspective. International J. Tea Science 1 (2 & 3): 12-27.

Dwarakanath C T 1989 Microbiological Quality Control of spices In: Proc. Seminar on Recent trends and developments in post harvest practices and processing technologies for spices, p.126

Ishihara K 2000 Present situation of pepper in Japan, International Pepper News Bulletin 21 (2/3): 86.

Merlinda D, Ingco & John D Nash 2004 What's at Stake? Developing Country Interests in the Doha Development Round. Agriculture and the WTO A Co-publication of the World Bank and Oxford University Press, p 3.

Pradeep U 2003 Agricultural exports – Status and strategies agribusiness, August 2003, pp. 34-35.

Satyanarayanan T V 2004 Agriculture processing pathway to progress. Agri-business & Food Industry, August 2004, pp. 35-37.

Simoneta Zarrilli & Irene Musselli 2004 The sanitary and phytosanitary agreement, Food safety policies and product attributes. Agriculture and the WTO. A Co-publication of the World Bank and Oxford University Press, pp. 215-234.

Taxmann 2005 The Economic Survey, 2004-05 Taxmann Publications (P) Ltd. New Delhi.

Tiwari S C 2003 Paradigm jump in Indian agriculture: Natural or Coercive? Current Science 85(5): 578-581.

WTO (World Trade Organization) 1994 The WTO Agreement on Technical Barriers to Trade (TBT Agreement). Office of the Secretary General, Geneva.

WTO (World Trade Organization) 2002 Information on the utilization of special and differential treatment provisions, February 7, WT/COMTD/W/77/Rev.1/Add.4. Office of the Secretary General, Geneva.

S 1 - Studies on genetic parameters of bush pepper plants of South Kerala

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Introduction

Bush pepper cultivation is a method of growing pepper vines in the form of bush plants either in pots or on the land using the plagiotropic fruiting branches. It is a welcome alternative to the pepper vines as it has greater potential for cultivation in homestead. The availability of berries throughout the year and less cost of cultivation are added advantages of bush pepper cultivation. It is gaining importance now adays as it is handy in management and its multipurpose utility in urban horticulture.

Materials & methods

A study was conducted at College of Horticulture, Vellanikkara to find the suitability of different cultivars of black pepper, cultivated in different parts of Kerala for growing as bush pepper in each location. The popular cultivars such as Kottanadan, Panniyur1, Karuvilanchi, Thulasikodi, Narayakodi, Ramapuram, Aimpiriyan, Vattamundi, Malamundi and some local cultivars from four districts namely, Thiruvananthapuram, Kollam, Kottayam and Idukki formed the materials for this study. Three to five nodal cuttings were made from one non woody lateral fruiting branches of healthy high yielding 8-10 year old pepper vines and one node was dipped in IBA for 45 seconds for easy rooting and planted in poly bags kept in mist chamber. After 45 days the rooted cuttings were transferred to pots and kept in shade houses. Observations were taken on vegetative characters. The yield and yield contributing characters and data were subjected to statistical analysis. Genetic parameters such as association analysis, genotypic and phenotypic coefficients of variation, heritability and genetic advance were worked out.

Results & conclusion

In Thiruvananthapuram, the cultivars Karuvilanchi, Panniyur1 and Kottanadan recorded the highest green berry yield, whereas in Kollam, Aimpiriyan and Karuvilanchi gave high yield. The popular cultivar Narayakodi and a local cultivar recorded the highest green berry yield in Kottayam. Vattamundi and Malamundi recorded as high yielders in the high range zone of Kerala, Idukki. The correlation analysis with various characters revealed that green berry yield had highly significant positive correlation with all the characters except drying percentage (0.6 and 0.8). Inter correlation among characters was found to be highly significant for number of laterals with number of spikes, spike length, developed berries and green and dry berry yield. The coefficient of variation both at genotypic (GCV) and phenotypic (PCV) level showed low to high for all characters studied. The drying percentage showed the lowest GCV and PCV, whereas rest of the characters exhibited high magnitude of variation at both levels. The maximum magnitude of GCV and PCV were indicated by number of spikes, number of developed berries and spike length (above 95%).The broad sense heritability values ranged from 65 to 99 percent. Maximum heritability was observed for the characters number of spikes, developed berries and leaf number and minimum for percentage of drying. The genetic advance expressed as percentage over mean ranged from 9.52- 38 % (drying) to 65-96.88 % (number of berries/spike). High heritability coupled with high GA indicates that the heritability is most likely due to additive gene action and selection may be effective for such characters.

S 2 - Evaluation of pepper varieties in arecanut based cropping system under Sub-Himalayan Terai Region

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Introduction

Black pepper (*Piper nigrum*), the king of spices is an important spice crop grown in India. In order to fulfill the increasing demand of this crop, area expansion is one of the best options which can increase the production of this crop. Rapid urbanization and industrialization forced us to increase the production of the pepper without obligation to additional land for its cultivation. Since pepper requires a standard/ Support for its growth, it has been proved that besides Kerala and other Southern states, where it grows profitably, it can be grown as well in Sub-Himalayan Terai Region of West Bengal and other North Eastern states using arecanut and coconut as standards.

Materials & methods

A study was undertaken at CPCRI Research Centre, Mohitnagar with 14 varieties of black pepper during 2004 to study the performance of the pepper under arecanut and to observe the disease incidence, if any. The experiment was carried out following a randomized block design with three replications. The data on different yield characters and incidence of *phytophthora* wilt and other diseases were recorded regularly.

Results & conclusion

The results indicate that maximum vine length (547.0 cm) was recorded in case of P-339 followed by Panchami (524.6 cm). Maximum branches were produced by the variety P-24 (60.0) followed by Pournami (40.5). Variety KS-14 produced maximum number of spikes (182.8) per vine followed by Panchami (134.5). So far no quick wilt disease incidence has been observed in any of the lines.

The number of berries per spike recorded was highest (55.40) in P-339 followed by Narayakodi (47.40). Estimated dry pepper yield per vine recorded was maximum in the variety Chumala (265.2 g) followed by KS-27 (196.2 g). However, it may be noted that the yield data mentioned here was that of the first year.

An overview of the data and earlier records it is inferred that black pepper can be grown as a suitable and profitable intercrop in arecanut garden in this part of the country.

S 3 - Testing the fidelity of micro-propagated black pepper (*Piper nigrum* L.) plants in the field using conventional and molecular markers

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Introduction

Variability available in black pepper (*Piper nigrum* L.) was utilized in the development of around 12 high yielding varieties. To overcome the paucity of planting materials, protocol for micro propagation has been standardized. The real applicability of micropropagated plants would ultimately depend upon their genomic integrity and the field performance compared to the clones produced through conventional methods. An investigation was carried out to compare the field performance of micro clones with conventional clones of black pepper at morphological, cytological and molecular level.

Materials & methods

Observations were recorded from a total of 58 vines developed from Panniyur1, Panniyur2, Panniyur4 and Subhakara. Morphological data were recorded for two consecutive years (52 vegetative traits, 30 qualitative and 22 quantitative). Range, mean, variance and coefficient of variation were worked out for the biometrical traits and the data were subjected to Bartlett's χ^2 test of homogeneity of variances. Total genomic DNA was extracted using modified CTAB method. For PCR, 60 random primers were screened for polymorphism out of which 11 were selected for varietal characterization and four for comparison of the clones.

Results & conclusion

All the clones were found conforming to the somatic chromosome number of the species, 2n=52.The study revealed that morphologically the tissue culture derived clones (TC group) are more vigorous (fast growth and early flowering) even when they confine to the genetic features of the variety at molecular level, compared to the conventional clones (CC group). Bartlets's χ^2 test of homogeneity showed that for 17 out of 22 traits, within group variance was homogenous in both TC group and CC group. Comparison between groups showed that, out of 17 traits mean values of TC group were significantly higher for 11 traits. Among the qualitative characters, leaf shape, leaf base, colour of tender growing regions, thickness of orthotrope and clinging ability of adventitious roots showed marked difference.

The RAPD profile revealed the true to type nature of microclones. A total of 89 DNA amplification products were generated with the number of bands per primer ranging from 5 to 9 and an average of 6.85. The RAPD products generated by each of the four decamer primer gave characteristic pattern for each variety with highest number of bands produced by Panniyur 4 followed by Panniyur 1. Genetic diversity analysis of the marker data of the varieties showed that Panniyur 1 and Panniyur 2 had maximum similarity (GD = 0.1) followed by Panniyur4 and Subhakara (GD = 0.21). Panniyur 2 and Subhakara were widely separated with maximum genetic distance (GD = 0.38). The genetic distance between Panniyur1 and Subhakara (0.36) was only slightly lesser than that between Panniyur 2 and Subhakara whereas Panniyur 1 and Panniyur 4 were closer (GD = 0.31). Micro propagation in combination with RAPD for checking the conformity was found to be a reliable and easy tool for large-scale multiplication of elite varieties in black pepper.

S 4 - Performance of black pepper (*Pipir nigrum* L.) varieties/hybrids as mixed crop in coconut garden

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Introduction

Black pepper (*Piper nigrum* L.) is raised exclusively as mixed crop in homestead gardens in Kerala and Karnataka and over 90 per cent is trained on coconut and arecanut trunks. In recent days, many new pepper varieties/hybrids have been developed in the country and hence field screening of these varieties as mixed crops in coconut garden is necessary to assess the performance in terms of yield and quality. In view of this, a field experiment was undertaken at CPCRI, Kasaragod to study the performance of different varieties as mixed crop in coconut garden under irrigated condition.

Materials & methods

The experiment was laid out in RBD with 16 black pepper varieties/hybrids *viz.* Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-4, Panniyur-5, Sreekara, Subhakara, Panchami, Kottanadan, HP-780, HP-105, HP-1411, HP-813, HP-34, OPKM and Collection 1041, as mixed crop in coconut garden aged about 30 years. There were three replications, with the plot size of 4 palms (4 pepper vines) per treatment. The rooted cuttings were planted 1 m away from the bole of coconut in North-East direction. The crops were managed with the application of recommended dose of fertilizers in two splits along with integrated disease management approaches involving application of fungicide and bioagents blended with neemcake. The garden was drip irrigated with 27 to 35 lit of water per palm (vine) per day. Growth and yield observations were recorded from all the vines, mean was worked out and subjected to statistical analysis.

Results & conclusion

In general wilt disease incidence was observed in Pannuyur-2, 3, Kottanadan, OPKM, HP 34 and HP 813 varieties/hybrids. The growth observations recorded during December 2007 indicated that, height of the vines differed significantly among the treatments, and collection 1041 recorded maximum height (5.2 m) followed by HP 105 (5.1 m). The lowest height was recorded in HP 34 (2.9 m). Number of laterals (in 1 m column height) differed significantly and collection 1041 recorded significantly higher number of laterals (56.6) and significantly lowest was recorded in HP 105 hybrid (15.06). The dry pepper yield obtained during 2006-07 was significantly higher in collection 1041 (1.1 kg/vine) followed by Panchami (0.82 kg/vine) and HP 813 (0.78 kg/vine). OPKM variety recorded significantly lowest yield (0.25 kg/vine). From the preliminary data on growth and yield of different varieties, it can be derived that, varieties like collection 1041, Panchami, Sreekara, HP 813, Panniyur 1 and 4 were found to perform well in the coconut garden. The trial has to be tested for some more years before we obtain final conclusion.

S 5 - Growth and yield of bush pepper varieties in coconut garden under partially shaded conditions

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Introduction

Bush pepper is a novel idea of growing black pepper, as bushy plant that requires no support. Harvesting is easy in bush pepper because of low vertical growth. Higher plant population per hectare and low harvesting costs compensate for low per plant yield. A study was initiated to find out the suitability of different released varieties to grow as bush pepper in the partially shaded condition of coconut garden.

Materials & methods

Bush pepper of ten released varieties of pepper *viz.* Panniyur 1, Panniyur 2, Panniyur 3, Panniyur 4, Panniyur 5, Panniyur 6, Sreekara, Subhakara, Panchami and Pournami were planted in partially shaded conditions of coconut garden in 2005 at a spacing of 2 m x 2 m.The experiment was designed in RBD with three replications having four plants/replication. Observations were made on establishment, growth, yield and yield contributing characters.

Results & conclusion

Casualties were very low in Panniyur 3 and Pournami (<10%), low in Panniyur 2, Panniyur 4 and Panniyur 5 (10-20 %), medium in Panniyur 6, Panchami and Panniyur 1 (20-35%) and high in Sreekara and Subhakara (> 50%).

Observations on height and spread were recorded three years after planting in 2008. Variety Panniyur 3 was the tallest with a mean height of 67 cm. Panniyur 2 and Panniyur 5 showed height above 50 cm. Other varieties had height below 40 cm. Spread was maximum for Panniyur 5 (139.2 cm). Other varieties with good spread of plants were Panniyur 2, Panniyur 1, Panniyur 3 and Pournami (> 100 cm). Karimunda selections, *viz.*, Sreekara and Subhakara were least spreading. Number of laterals was highest in Panniyur 5 followed by Panniyur 3.

All the varieties started yielding in the first year itself. However, the yield varied from 7-17 g (fresh). The yield increased through second to third year. Subhakara and Panchami were poorest yielders. High yield was recorded in Panniyur 5 (1 kg), Panniyur 2 (647g) and Pournami (520 g). Highest per plant yield was recorded in Panniyur 2 (2652 g fresh).

Spike length was maximum for Panniyur 5, followed by Panniyur 1 and Panniyur 3. Hundred berry weight and volume were maximum for Panniyur 2 and Panniyur 3. Driage of varieties ranged from 31.2- 36.9 per cent. Preliminary observations indicate that varieties Panniyur 5, Panniyur 2 and Pournami are best suited for growing as bush pepper in coconut garden.

S 6 - Varietal variability in the rooting of cuttings in *Piper nigrum* L.

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Introduction

Black pepper *(Piper nigrum)* the king of spices is commercially propagated though rooted cuttings. In large scale nursery programmes, proper rooting of cuttings is very important. A study was conducted to find out whether improved varieties differ in their ability to root and establish. The influence of IBA in the rooting of different varieties of pepper was also evaluated.

Materials & methods

Five released varieties of pepper, namely Panniyur 1, Panniyur 2, Panniyur 3, Panniyur 4, and Panniyur 5 were used in the study. Two nodded semi-hardwood cuttings were planted after treatment with 1000 ppm IBA for 45 seconds and without IBA treatment. Five hundred cuttings were planted in each variety under each treatment. Uniform potting mixture consisting of 1:1:1 river sand, farm yard manure and garden soil was used for planting cuttings. Ten cuttings each were selected at random per variety per treatment, after one, two and three months after planting. The cuttings were collected without damaging the roots and observations were made on number of primary roots, length of primary roots and number of secondary roots. The experiment was repeated for three years.

Results & conclusion

At one, two and three months after planting, Panniyur 1 showed least number of primary roots and was significantly lower than Panniyur 2 and Panniyur 5. IBA treatment did not influence the number of primary roots developed. Intervarietal variation was less for length of primary roots except for a few significant variations, which were not consistent over time. IBA treatment did not show influence on length of primary roots.

Variety Panniyur 1 had the lowest number of secondary roots compared to other varieties. At one month after planting, difference in the number of secondary roots was not significant among varieties. However, at two months after planting, Panniyur 1 had significantly less number of secondary roots compared to Panniyur 5. At three months after planting, Panniyur 3, Panniyur 4 and Panniyur 5 had significantly more number of secondary roots compared to Panniyur 1.

Thus it can be seen that in variety Panniyur 1, root production was significantly lower compared to other varieties. IBA treatment did not have any significant positive influence on rooting of pepper.

S 7 - Studies on the effect of different spacings on yield and quality of pepper cv. Panniyur 1

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Abstract

Black pepper (*Piper nigrum* L.) is one of the oldest and most important spices widely used for culinary and medicinal purposes. It accounts for over 35 per cent of export earnings among spices. It is cultivated in an area of 1,74,000 ha in India. Normally, pepper vines are trained on arecanut, coconut and forest trees and no proper spacing is followed. As a pure crop, it is trained on *Erythrina indica.* A spacing trial was conducted to standardize the optimum spacing for pepper cv. Panniyur 1. The experiment was conducted at Horticultural Research Station, Pechiparai during 1997 to 2004 with five spacing treatments, 2 x 2 m (control); 2.5 x 2.5 m; 3 x 3 m; 3.5 x 3.5 m and 4 x 4 m. The results of the study revealed that 3 x 3 m spacing recorded the highest yield of 2.56 kg of dry pepper per vine. Control registered dry pepper yield of 0.730 kg/vine.

S 8 - Evaluation of suitable standards for higher production of black pepper cv. Panniyur 1 under high rainfall zone of Kanyakumari District

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Abstract

Pepper is the most remunerative crop under rubber based cropping system in the high rainfall zone of Kanyakumari District. Besides the regular cropping season, it gives an off season crop during the month of April-May. Owing to thc fact, the area under black pepper is getting expanded. So far the pepper vines are trained normally in *Erythrina* standards. Of late, due to the severe out-break of gall wasp (*Quadrastichus erythrinae*) in this tract, the standards gets devastated in an alarming manner. As a result, the vines along the support gets toppled due to the death of the standards. Hence, pepper cultivation is facing a gradual decline.

In order to revive the declining trend in black pepper, an experiment was conducted at Horticultural Research Station, Pechiparai to find out a suitable and alternate standard for black pepper. The native standards such as *Thespesea populanea, Gliricidia maculata, Leucana leucocephala, Delonix regia, Delonix alata, Erythrina lithosperma* (dadaps), *Physonia alba, Moringa olefera* (perrcnial moringa), *Muntingia calabra* (Singapore cherry) were planted and the vines were trained. The results revealed that among the standards, thc vines trained on *Thespesia populnea*, exhibited vigorous growth, higher productive laterals, increased biomass and more yield/unit area.

S 9 - Influence of standards on the growth and yield of black pepper (*Piper nigrum* L.)

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Introduction

Black pepper (*Piper nigrum* L.), known as the king of spices, is the most important and most widely used spice in the world. One of the major reasons for low productivity of black pepper in India is the use of undesirable standard or support. The effect of different standards on pepper with respect to rhizosphere characteristics, nutrient uptake, growth, yield and quality of pepper will give an idea about the most ideal standards for trailing pepper which have the least root and shoot level competition with pepper. With this objective an investigation was undertaken to study the effect of different standards on growth and yield of black pepper.

Materials & methods

The experiment was conducted at the College of Horticulture, Vellanikkara, Thrissur, Kerala, (10°32'N, 76°13'E and 22.5 M above mean sea level). All the selected plants received uniform management practices as per the package of practice recommendations. Ten year old vines of black pepper var. Panniyur-1 trailed on different standards were evaluated in a completely randomized design with 3 replications. The standards used for the study were *Acacia mangium* Willd.; *Ailanthes triphysa* (Dennst.) Alston; *Areca catechu* L.; *Artocarpus heterophyllus* Lamk.; *Azadirachta indica* A. Juss.; *Bombax malabaricum* DC.; *Caesalpinia sappan* L.; *Cocos nucifera* L.; *Erythrina indica* (Lamk.); *Garuga pinnata* Roxb.; *Gliricidia sepium* (Jack.) Kunth; *Grevillea robusta* A.Cunn; *Leucaena leucocephala* (Lamk.) de Wit; *Moringa oleifera* Lamk; *Pajanelia longifolia* (Willd) k.Schum; *Thespesia populnea* Soland ex.Correa and teak pole. Major growth attributes of black pepper namely height of bearing column, canopy spread, spike and berry characters and yield were recorded.

Results & conclusions

There was significant variation in the height of bearing column of pepper, spread at chest height, number of laterals per 0.25 m^2, number of spikes per 0.25 m^2 and green berry yield among various treatments. Height of bearing column of pepper was maximum (7.83 m) when trailed on coconut followed by *Artocarpus* (6.67 m). It ranged from 5.81 to 6.62 m when *Acacia*, arecanut, *Azadirachta, Grevillea* and *Pajanelia* were used as the standards. Coconut followed by jack and *Ailanthes* were the superior standards with respect to yield of pepper and belonged to the high yield group with a green berry yield of 9.25, 7.14 and 6.83 kg per vine respectively. Medium yield group included pepper trailed on standards such as *Grevillea, Garuga, Acacia, Azadirachta, Pajanelia, Thespesia, Bombax, Gliricidia, Erythrina, Caesalpinia* and teak pole. The standards found inferior with respect to yield of pepper were arecanut, *Leucaena* and *Moringa*. Yield was low due to the lesser spread of vine around the palm and lesser number of laterals per 0.25 m^2.

S 10 -A study on latitudinal variation of essential oil from *Piper nigrum* leaves

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Introduction

Essential oils have been used for flavoring, incense and medicinal purposes for many centuries, but its systematic study has started only now. Among the many areas of systematic studies the usefulness is prominent in, studies of taxonomy, geographic variation and intra species diversity. It has been found that the total amount of oil produced by the plant may be influenced by various environmental factors, but the total constituents is much more stable, and is more suitable for systematic studies. In this study an attempt was made to study the latitudinal variation of essential oil from black pepper leaves.

Material & methods

Essential oil was extracted from fresh P. *nigrum* leaves collected from different location of Western Ghats by hydro distillation using Clevenger trap method. The oil was analyzed using a Shimadzu GC-2010 gas chromatograph equipped with QP2010 mass spectrometer using RTX -5 columns. The carrier gas used was helium with a flow rate of 1.0 ml/min. The injection port was maintained at 250^{0}C; the detector temperature was 220^{0}C; the oven was programmed as follows; 70^0 C for 5 minutes and then increased to 110^{0}C at the rate of 5^{0}C/ min, then up to 200^{0}C at the rate of 3^{0}C/ min again up to 220^{0}C at the rate of 5^{0}C/min, and was maintained for 5 minutes at 220^{0}C. The constituents of the oil were identified by matching the mass spectral data with those stored in NIST and Wiley libraries and wherever possible, by co-injection with authentic standards.

Results & conclusion

All the major constituents of essential oil were identified through GCMS analysis. A very clear latitudinal variation was noticed. Nerolidol and α- seline were present only in lower latitudes from 9° to 12 °. Nerolidol was absent in samples where myristicin was present. Caryophyllene, a common component of pepper was absent in some samples from Karwar. Pinene which is a common component of berry oil was present only in specific locations and in the higher latitudes. No latitudinal preference was noticed for α- elemene which was present in seven out of ten locations. Safrole was found only in Maharashtra and Goa collections which are located at higher latitudes. Sabinene also was noticed in two locations where myristicin was noticed but not nerolidol. In conclusion, the above study showed that the essential oil composition of black pepper has clear latitudinal intra species diversity.

S 11 - Sulphate of potash (SOP) as potassium source for increasing nutrient availability, yield, quality and profitability of black pepper

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Introduction

Low productivity black pepper in India is attributed to the poor soil nutrient status and inadequate nutrient supply and management. Sulphate of potash (SOP), a mined product of potassic fertilizer, is organic in origin and can be exploited as a component in crop nutrition.

Materials & methods

In this context, experiment on evaluating the efficacy of sulphate of potash as an effective source of K on black pepper was undertaken during 2004-2007 as field experiment at Kannur (Kerala) and Coorg (Karnataka) districts with nine treatment combinations of T_1-Control / Check (K_0), T_2- Recommended K as MOP (K_1), T_3 - Rec K as SOP (K_1), T_4 - 125 % of Rec. K as SOP (K_2), T_5 - T_3 + SOP 2 % Foliar Spray, T_6-50 % of Rec K as SOP (K_3) + SOP 2 % Foliar Spray, T_7: 50 % of Rec.K as SOP (K_3), T_8 - T_2 + Mg @ 25 kg / ha as Mg SO_4 and T_9- T_3 + Mg @ 25 kg / ha as Mg SO_4 laid out in a randomized block design with three replications.

Results & conclusion

At Kannur, the mean soil nutrient status of three years showed that 25% higher recommended K as SOP recorded significantly the highest concentration of soil organic carbon, K, Ca, S, Zn and Cu. There was a significant reduction in soil pH, OC, Ca, Mg, Mn, S and Zn contents in the subsequent years of experimentation which might be due to the crop uptake. At Coorg, the continuous application showed a significant increase of all the major, secondary and micronutrients in the third year as compared to the initial years. The soil K, Ca and Zn contents showed gradual increase over years with the highest buildup in the third year and that of S was maintained over years. When pooled over locations, exchangeable K and non exchangeable K showed signifieant buildup over years with a corresponding decrease in mineral K and total K in the third year. The mean yield at Kannur did not show significant variation due to treatments. At Coorg, significantly highest mean fresh yield of 2.74 kg/vine was obtained for the treatment recommended K as SOP + 2% foliar spray on par with 50% of the recommended K as SOP and recommended K as SOP + $MgSO_4$. The treatment with recommended K as SOP + foliar spray and 50% of recommended K as SOP recorded significantly highest piperine followed by recommended K as MOP + $MgSO_4$. In case of oleoresin content significantly highest content of 9.07% was recorded in recommended K as SOP + 2% foliar spray followed by 50% of the recommended K as SOP and recommended K as MOP + $MgSO_4$ which were on par with other treatments.

The net return and benefit cost was found high in MOP treatment (1.72) followed by 50% of recommended K as SOP (1.59). But when we consider a premium price (20% higher) for the SOP treatments, then recommended K or 50% of it as SOP with or without foliar spray recorded higher net returns and B: C ratio (1.73-2.10) as that of MOP treatment.

S 12 - Application of *Azospirillum* and nutrients on yield, quality and economics of black pepper (*Piper nigrum* L.)

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Introduction

The increasing cost of chemical fertilizers, the growing environment concern and energy crisis have created considerable interest for search of alternative sources of plant nutrients. Nitrogen fixing bacteria belonging to the genus *Azospirillum* is known to increase the yield of crops by 5 to 20 % with saving of nitrogen up to 40 % of recommended dose. In the present study an attempt was made to test the influence of *Azospirillum* on yield, quality and economics of black pepper.

Materials & methods

The experiment was conducted at Indian Institute of Spices Research, experimental farm, Peruvannamuzhi during 2001-2006 using the variety Subhakara. The experiment was conducted in split plot design, with four replications. Treatments with and without *Azospirillum* formed the main plot. There were six sub plot treatments *viz.,* 1. FYM 10kg alone, 2. *Azospirillum,* 3. Inorganic nitrogen (50%) + 10kg FYM, 4. Inorganic nitrogen (50%) + zinc, boron, molybdenum, 5. Inorganic nitrogen 50% + magnesium and 6. NPK alone. Six month old black pepper plants were planted in the basins of support tree *Ailanthes* sp. during 2001. Efficient strain of *Azospirillum* isolated from black pepper garden of experimental farm was multiplied in agar medium under laboratory conditions. The inoculum was mixed with FYM to get a final inoculum potential of 10^8 cfu/g and applied to the plants twice during May and October in a year. Chemical fertilizers were given in two splits, June and October as per the treatments. The plants were irrigated during summer months and plant protection measures were given as per the package of practice recommendations of Indian Institute of Spices Research (IISR), Calicut.

Results & conclusion

Yield was significantly higher in plots in which *Azospirillum* was applied. During 2004-2005, maximum yield (1590g/pl) was recorded by the treatment inorganic nitrogen 50%+ Mg followed by inorganic nitrogen 50%+ Zn+B+M. During 2005-2006, yield was slightly higher and the same treatment recorded maximum yield (1741g/pl) followed by application of NPK alone (1442g/pl). Interaction effect was significant during both the years. Effect of *Azospirillum* application had no effect on quality parameters (oleoresin and piperine) of black pepper. Economics worked out for the two sets of the treatments shown that inorganic nitrogen 50% + magnesium along with *Azospirillum* recorded maximum gross and net return in both the years. The treatment earned a maximum net return of Rs. 39,548/ha when *Azospirillum* was included as an added input. Benefit -cost (B: C) ratio (1.9) was also higher in this treatment which was followed by application of NPK alone (1.3). Thus the treatment of inorganic nitrogen 50%+ magnesium emerged as the best alternative technology to boost black pepper yield.

S 13 -Organic farming in black pepper

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Introduction

In Uttara Kannada which is situated in upper region of Western Ghats, black pepper is mainly cultivated in moist valleys as mixed multistoried crop in arecanut plantations wherein arecanut palms serve as live standards for training black pepper. There is vast demand in the international market for organic spices specially for black pepper. Several kinds of organic manures viz., farmyard manure, compost, organic cakes like neem cake releases organic ions during decomposition of organic matter and forms complexes with Fe and Al, thereby preventing P fixation and making more P available to the plants. There is less information on cultivation of black pepper with available natural resources to fit in organic farming. Hence an attempt was made to study organic cultivation of black pepper with use of burnt earth (smoked earth), vermicompost, *Azospirillum* and farm yard manure (FYM).

Materials & methods

A field experiment was carried using burnt earth, vermicompost, *Azospirillum*, and farm yard manure and their combinations. The trial was conducted in farmers field (having a history of organic farming) in Shigehalli, Uttara Kannada, Karnataka in arecanut garden from 2000-01 to 2004-05. Black pepper vines of uniform growth were selected for the experiment. There were five treatments *viz.*, FYM 10 kg/ vine, vermicompost 10 kg/vine, FYM 10 kg + burnt earth 10 kg/vine, FYM 10 kg + *Azospirillum* 50 g/vine and FYM 10 Kg + leaf manure 10 kg (local practice of farmers). P and K nutrients were supplemented in the form of rock phosphate (220 g) and wood ash (2 kg) which were common to all treatments. There were six vines/ treatment of variety Panniyur 1 replicated five times. The treatments were imposed during first week of June. The observation on fresh yield was considered for analyzing the data.

Results & conclusion

The data revealed that application of burnt earth along with FYM produced significantly highest fresh berry yield of 6.74 kg/vine during first year as compared to the other treatments. The remaining treatments were at par. Similar trend was recorded where burnt earth with FYM application to vines resulted in significantly higher yield (6.52, 5.94, 6.20 and 6.75 kg/vine) during all the five years. The pooled data of five years revealed that fresh berry yield obtained in treatment consisting of FYM 10 kg and burnt earth 10 kg /vine was significantly highest (6.43 kg/vine, fresh berry yield) over all the treatments. The C:B ratio revealed that benefits obtained was 1:4.17 which was higher than any of the other treatments. Hence, the practice of application of burnt earth could form a profitable method of manuring of black pepper to obtain higher and sustainable yields.

S 14 - Impact of pre monsoon showers on black pepper spike setting in coffee based cropping system in Kodagu District, Karnataka

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Introduction

In Karnataka black pepper (*Piper nigrum* L.) is grown as a mixed crop in Kodagu, Chikmagalur and Hassan districts. The performance of the varieties depend on local climatic conditions, management methods and pest and disease complex. In hilly regions crop failure due to spike shedding and anthracnose infection has been reported. Due to delayed monsoon the black pepper was not yielding in many plantations from last few years. The objective here was to study the influence of early rains and management practices on black pepper spike production and setting in coffee based cropping systems in Kodagu District, Karnataka.

Materials & methods

The survey was conducted to study the rainfall pattern and black pepper setting in coffee mix cropped with black pepper based cropping system in Kodagu District. The rainfall received in different zone was collected from planter's field and recorded the spike emergence and setting in different region in Kodagu in different cropping systems like Rubosta coffee and Arabica coffee with black pepper. Number of spike per $0.5m^2$, spike length, bisexual flower status and shade levels were recorded.

Results & conclusion

Total rainfall received in pre monsoon (March – May) ranged from 156.5-456.6 mm. The area received continuous rainfall in March-May, new leaves and spikes emerged early and crop setting is significantly better (Hebbettageri, Virajpet, Anandapur, Suntikoppa, Pollibetta) compared to the area that received rains only in March followed by less rains (Kutta, Somwarpet). Intensity of spiking varied between Arabica and Robusta coffee. In Robusta coffee due to better light availability the vine produced spike in June and uniform setting (35.7 per $0.5m^2$, 15.2cm spike length). In Arabica, 11.13 spike per $0.5m^2$ was recorded with spike length of 12.5cm, due to higher shade 50 % of spike emerged in June. Makandur zone (near to Madikeri) black pepper crop was failed from last 6-8 years due to delayed rainfall, mist, cloudy condition in May, anthracnose incidence, spike shedding and late production of spikes. This year due to March rains crop setting was significantly better in this zone. New leaves and spikes emerged early, setting was good and anthracnose incidence was also less and spike shedding was nil. In Kutta, even though early rains were received in March, it was followed by dry spell and hence black pepper did not produce spike in June, new leaves and spikes are emerged in August, spikes are not dropped but recorded partial setting of berries.

The data clearly indicated that March, April and May rains had positive impact on black pepper production in Kodagu District in Rubosta coffee and shade regulated Arabica coffee mix cropped with black pepper in Karnataka.

S 15 - Impact of basin irrigation on black pepper production in coffee based cropping system in Kodagu District, Karnataka

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Introduction

The mixed crop of coffee and black pepper is a common practice in many coffee growing regions. The performance of the varieties depends on local climatic conditions, management methods, pest and disease complex of that area. Due to delayed monsoon and moisture stress the popular released varieties like Panniyur-1 does not yield in misty, cloudy, high altitude coffee based cropping systems. The possibility of promoting early spiking and production in Panniyur-1 through basin irrigation in pre and early monsoon period was tested in two hot spots of spike shedding.

Materials & methods

The experiments were conducted in misty area in coffee based cropping system in Kodagu District during 2003-04 cropping season in two farmers plantations (Sandalkad estate in Boikeri and Fair field estate, Hosakeri) in Kodagu District, Karnataka. The pepper was trained on silver oak (*Grevillea robusta*) and palwan (*Erythrina* sp.). The area was divided into two blocks one irrigated and another rain fed. The basal irrigation with hose @ 50-60 litres was given after harvest from March 15th onwards once in 15 days up to May 15th. Shade was regulated in April in both blocks. The number of spikes per m^2, number of lateral per m^2 and number of leaves per m^2 were recorded at end of cropping season. The time of emergence of spike, spike shedding and anthracnose incidence were monitored May onwards. In both the blocks recommended package of practices for coffee + pepper cropping system was followed.

Results & conclusion

Significant difference in number of spikes per m^2 was observed between the treatments in both plantations. In Sandalkad estate 163.7 spikes/m^2, spike length of 15.33 cm and 108.5 berries per spike were recorded in irrigated treatment compared to 40.7 spikes/m^2, 11.5 cm spike length, 47 berries per spike in rain fed treatment. Where as number of laterals and number of spikes per m^2 were same in both treatments. In Hosakeri, 231.46 spikes/m^2, spike length of 18.75 cm and 126.33 berries per spike in irrigated treatment and in rain fed treatment, 52.85 spikes per m^2, 14.46 cm spike length and 28.84 berries per spike were observed.

This data clearly indicated that basal irrigation of pepper vine during March-May and shade regulation in April help in early initiation of spike and good setting. In a year of pre monsoon failure black pepper need to be irrigated in summer to harvest good crop in high altitude in coffee based cropping system where black pepper is a mixed crop.

S 16 -Integrated disease management of *Phytophthora* foot rot of black pepper

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Introduction

Foot rot of black pepper caused by *Phytophthora capsici* is a very important disease that affects the sustainable production of black pepper not only in Karnataka but in other parts of country as well. No single method is effective against this disease, hence a study was initiated to manage the *Phytophthora* with integration of all possible methods of control.

Materials & methods

A field experiment on management of foot rot of black pepper was carried out by using chemicals, biological agents and plant product like neem cake in a farmer's garden at Hosabale village, Sirsi taluk of Uttara Kannada District of Karnataka during 2006-07. The treatments included fungicides, bioagents alone and their combinations. In each treatment, 20 pepper vines were selected. The treatments were taken as pre monsoon and peak monsoon applications, in May-June and in the month of August-September respectively.

Results & conclusion

The results revealed that metalaxyl MZ 72 WP (Ridomil MZ 72 WP) (0.125 %) as spray and drench in combination with *Trichoderma harzianum* and *Pseudomonas fluorescens* along with neem cake application was most effective followed by potassium phosphonate (0.3 %) application along with *T. harzianum*, *P. fluorescens* and neem cake application. Copper hydroxide (0.2 %) was found least effective when applied as spray and drench followed by soil application of *T. harzianum*, *P. fluorescens* and foliar spray of *P. fluorescens*.

S 17 -Endogenous movement of *Pseudomonas aeruginosa* IISRBP35 in *Piper nigrum* L. *vis-à-vis* its density and duration dependent protection against *Phytophthora capsici* infection

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Introduction

Plant associated endophytic bacteria have been reported to control plant diseases. Black pepper (*Piper nigrum* L.) associated endophytic bacterium, *Pseudomonas aeruginosa* IISRBP35 (*P. aeruginosa* EF568931, MTCC5410) inhibited the mycelial growth of *Phytophthora capsici in vitro* and prevented rot on nodal stem cuttings of black pepper. The dynamics of rot prevention by *P. aeruginosa* IISRBP35 and relationship among the population size of bacterial antagonists in bacterial suspension, duration of bacterial treatment and the *Phytophthora* suppression were investigated.

Materials & methods

Optimization of minimum density of bacterial cells and the minimum duration of bacterial treatment (bacterization) required for suppression of *P. capsici* rot was performed as described by Dinu *et al.* (2007). Briefly the stem cuttings after bacterization were partitioned and assayed. The qualitative and quantitative assay of the endophytic population of the bacterium in the bacterized stem cutting was determined by serial dilution plating and was confirmed using PCR based method using *P. aeruginosa* specific oligoprimers. Endophytic movement of the bacterium was tracked by plate and PCR assay of extract from tissues excised from three nodal stem cuttings or rooted cuttings periodically.

Results & conclusion

Effect of varying density of *Pseudomonas aeruginosa* IISRBP35 and varying duration of bacterial treatment on nodal stem cuttings and rooted cuttings of black pepper were determined. Significant rot suppression was observed when the shoots were dipped in cell suspension of *P. aeruginosa* for 15-20 minutes at cell densities ranged from 10^{12}-10^{13}cells ml^{-1}. At these cell densities the endogenous population size of *P. aeruginosa* was of the order 10^5-10^6 cells g^{-1} of tissue which was positively correlated with lesion prevention on stem cutting. Spatiotemporal movement of *P. aeruginosa* IISRBP35 in *P. nigrum* was further deciphered. The bacterium moved upto 16 cm away in the stem cutting the from lower cut end within 30 min indicating its passive migration enroute the apoplastic path. The results confirms the earlier report on endophytic colonization of plant such as spruce, grapevine, grass, rice by plant growth promoting rhizobacteria. The study provided evidence for the ascending movement of endophytic bacterium *P. aeruginosa* in the stem cutting and rooted cutting of black pepper.

Duration of bacterization (20 min) and bacterial density (10^{12}-10^{13}cells ml^{-1}) strongly influenced the endogenous population size (10^5-10^6 cells g^{-1}) with concomitant lesion (rot) suppression (100%) on stem and rooted cuttings of black pepper. Root applied bacterium *P. aeruginosa* could be tracked in the aerial plant parts of black pepper within 14 days indicating its endophytic movement.

S 18 -Translocation and distribution of ^{32}p labelled potassium phosphonate in black pepper *(Piper nigrum* L.)

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Introduction

Potassium phosphonate, a systemically tanslocated chemical is used to protect plants against oomycete pathogen, induces rapid, localized defence responses in normally susceptible plants that are similar to those observed in incompatible reactions. An investigation was carried out to study the translocation and distribution of potassium phosphonate in black pepper system using radioactive ^{32}P through autoradiography.

Materials & methods

Potassium phosphonate labelled with radio phosphorus containing 10 mCi (370 MBq) of the tracer with a specific activity of 2 mCi ml^{-1} was procured from Board of Radiation and Isotope Technology (BRIT), Mumbai. Pot. phosphonate solution having a concentration of 1200 mg HPO_3^{2-} l^{-1} and contained 4µCi ^{32}P ml^{-1} was applied to black pepper vines of variety Panniyur-1 and black pepper laterals of variety var. Karimunda both by foliar and soil application and the treated plants were subjected to autoradiography. Simultaneously, the quantity of the tracer in different parts of the pepper plant and soil was analyzed using liquid scintillation counter following Cerenkov counting and the percentage radioactive phosphonate (% P) at a particular site was found by the equation,

$$\% P = \frac{\text{(Specific activity of } ^{32}\text{P at that site)} \times 100}{\text{Total of the specific activity from each site, apart from the applied leaf}}$$

Results & conclusion

Results through autoradiograph showed that pot. phosphonate migrated to different parts of the plant from the site of application. By soil application the chemical was detected in whole plant within two days whereas by foliar application the compound reached the leaves in 3 days and took 5 days to reach the root. However the compound was not detected in the soil. Foliar spray of pot. phosphonate to pepper can be an effective method since the loss of the chemical is less. Moreover foliar application is economical than soil drenching as the chemical is not concentrated in a particular region and also ensures direct entry into the plant. The initial concentration of the chemical in the berries is of less importance, since the chemical's mammalian toxicity is less and the concentration is expected to decrease considerably at the time of harvest. The finding is significant as the loss of chemical by method of soil drenching can be considerably minimised. But further investigations are warranted to understand the role of accumulated chemical with in the plant.

S 19 -Biochemical changes associated with host-pathogen-fungicide interactions in black pepper - A study using potassium phosphonate

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Introduction

Potassium phosphonate is a potential fungicide being used successfully to control foot rot disease of black pepper caused by *P. capsici*. More than having a fungistatic effect, it is believed to disrupt pathogen metabolism leading to a stimulation of the natural defense mechanism of the host. Preliminary investigations carried out at Indian Institute of Spices Research, Calicut have shown that an aqueous solution of potassium phosphonate is effective against *Phytophthora* foot rot in black pepper. The fungicide can be applied both as foliar spray and soil drench. The objective here was to study the biochemical changes following host- pathogen-fungicide interaction in black pepper with reference to PAL activity and changes in total phenols and proteins.

Materials & methods

Healthy black pepper vines were raised in green house was used for the studies. The were four main treatments *viz.*, T_1 - 0.3 % potassium phosphonate spray + inoculation with *P. capsici*, T_2 - 0.3 % potassium phosphonate spray alone, T_3 - Inoculation with *P. capsici* alone and T_4 - Control. Three healthy leaves per vine were inoculated with *P. capsici* on the lower side of the leaf. Leaf samples were collected at 1, 3, 6, 12, 24, 48, 72 and 96 h interval after imposition of the treatments and stored at 4°C for further analyses. PAL activity was determined spectrophotometrically following the formation of trans-cinnamic acid. Total phenols and total proteins were estimated using standard protocols. Data were analyzed by windowstat programme.

Results & conclusion

Results clearly indicated that application of potassium phosphonate enhanced the PAL activity. However, up to 24h, the activity remains high indicating that PAL and the related enzymes in the phenyl propanoid pathway are active, leading to the formation of lignin. This provides additional protection to avoid necrotic lesions. The decrease in the phenolic content is a clear evidence of the susceptibility of the plants to the effects of fungal inoculum. In combined treatment the protein content initially showed slight increase (3.22%) but declined up to 9.6% in 6h and again increased up to 10.75% in 48h. Whereas in pathogen alone inoculated plants (T_3) there is a gradual increase in total protein content from 5.34% to 21.51%. Drenching fungicides to root will lead to leaching of the chemical or runoff of the chemical in the soil thereby polluting the environment. The present study leads to the conclusion that pot. phosphonate spray alone will be sufficient as a foliar application due to its ambimobile nature. Moreover, the application of chemical enhances the defense mechanism by increasing the PAL activity, the major defence enzyme present in the plant and also increases the total proteins, which include PR proteins that are antimicrobial.

S 20 - ITS-RFLP for discerning pathogenic variability of *Phytophthora capsici* from black pepper (*Piper nigrum* L.)

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Introduction

The genus *Phytophthora* is known for the variability brought about by sexual and parasexual recombinations for several characters including pathogenecity. Race differentiation among *P. capsici* isolates infecting black pepper is difficult as there are no differential host genotypes. An attempt has been made to evaluate ITS-RFLP for discerning pathogenic variability of *Phytophthora capsici* from black pepper (*Piper nigrum* L.)

Materials & methods

The National Repository of *Phytophthora* has about 250 black pepper isolates of *P. capsici*. In order to test their pathogenecity on black pepper 50 isolates were tested on a known susceptible black pepper cultivar IISR- Subhakara following stem inoculation. Black pepper cuttings of 4-5 leaf stage were used for the inoculations. The plants were inoculated on the third inter-node with 5mm mycelial discs from 48h old culture of *P. capsici* grown in carrot agar medium. Inoculated plants were incubated in the green house condition with 90% relative humidity at a temperature of 25-27°C for 72 hours. The observations were recorded on lesion length in millimeter and depth of penetration as index in a scale of 0-4. Some of the isolates showed variability for lesion length and depth of penetration. Ten such selected isolates were tested for the pathogenic variability. In another study, *P. capsici* isolates were subjected to ITS-RFLP. The ITS region of the isolates were amplified using the primers ITS 6 and ITS-4.The amplicons were digested with three restriction enzymes, *Alu*-1, *Taq*-1 and *Msp*-1. Digested products were separated in 3% agarose gels using 100bp ladder (Genei, Bangalore, India) as size marker. The bands were scored and data analysis was done by unweighted pair group method using arithmetic averages and similarity coefficient drawn using NTSYSpc 2.0 software.

Results & conclusion

The lesion size varied from 5-55mm and penetration index from 1-4 after 72 h of incubation. Based on the lesion length and penetration index obtained isolates were characterized as less virulent (<5mm), moderately virulent (5.1 -25.0 mm) and highly virulent (>25.0 mm). Among the ten isolates, one was less virulent, 2 were moderately virulent and 7 were highly virulent. Isolates 99-148 and 99-144 formed a separate cluster that included the less virulent groups, 99-166, 97-54 as moderately virulent groups and 96-2, 05-14, 03-10 formed a separate banding pattern and a distinct cluster that included the clade of most virulent isolates. *P. capsici* isolates from black pepper exhibited intra-specific pathogenic variation when tested on a susceptible genotype IISR Subhakara. Though the ITS region is highly conserved, the amplicon size from these isolates varied from 800 to1200bp. The RFLP analysis revealed the existence of four subgroups within the populations that confirmed several earlier reports of high divergence of *P. capsici* species. The clustering pattern matched with the pathogenic variation observed among the isolates.

S 21 - Massetolide A: A zoosporicidal biosurfactant produced by black pepper associated endophytic bacterium *Pseudomonas aeruginosa* IISRBP35

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Introduction

Biological controls of foot rot by deploying bacterial antagonists such as *Pseudomonas* and *Bacillus* are reported. Black pepper associated endophytic bacterium *Pseudomonas aeruginosa* IISRBP35 (*Pseudomonas* EF568931, MTCC5410) is found to inhibit mycelial growth of *P. capsici* and successfully prevented rot on the cut shoots as well as rooted cuttings of black pepper upon pre-treatment. With this background we have investigated the modes of action of the endophytic bacterium by analyzing the strain for production of zoosporicidal biosurfactants.

Materials & methods

Extraction of biosurfactant from *Pseudomonas aeruginosa* IISR BP 35 and its effect on *Phytophthora*: The biosurfactant from *P. aeruginosa* IISR BP 35 was extracted and evaluated *in vitro* against zoospores and mycelial growth. Prophylactic and curative action of the surfactant on *Phytophthora* rot (lesion) was assayed on stem cuttings. Lesion length and progress of the lesion size was measured and analysed.

Characterization of biosurfactant by RP–HPLC (Reverse Phase - High Pressure Liquid Chromatography): RP–HPLC analysis was performed to identify the biosurfactant extracted from *Pseudomonas aeruginosa* IISR BP 35. Reference compound massetolide A was used for comparison.

Results & conclusion

The cyclic lipopeptides are bioactive compounds, composed of a fatty acid tail linked to a short cyclic oligopeptide, produced by a wide range of *Pseudomonas* species and strains. *Pseudomonas aeruginosa* IISRBP 35 was found to produce 88-90μg of biosurfactant per ml that was found to exhibit inhibitory action on zoospores and mycelium. The biosurfactant caused cessation of zoospore motility within 30s and cell content of zoospore changed to a granule appearance and collapsed within 60s. Microscopic analysis of mycelium obtained from agar plate revealed that biosurfactant at a concentration of 50 $\mu g\ ml^{-1}$ and higher, caused increased branching of hyphae with less intensity of mycelial growth. It was found that the prophylactic treatment of biosurfactant for 30 min showed protection against *Phytophthora* infection. Biosurfactant further exhibited curative action on cut shoots. The RP-HPLC profile of both reference and the biosurfactant from *Pseudomonas aeruginosa* BP 35 revealed that the biosurfactant isolated from *Pseudomonas aeruginosa* IISR BP 35 is massetolide A, a rhamnolipid. Biocidal effect of biosurfactant on zoospore can potentially be exploited for foot rot management in nurseries as well as in field.

S 22 - Constraints in production and marketing of pepper in Kerala

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Introduction

Pepper known as the king of spices, occupy an important position in the spices sector of Kerala. The world today consumes as much black pepper as all other spices combined and it is freely traded in world commodity markets.

Materials & methods

The constraints in production and marketing of pepper was analysed based on primary data collected from 30 pepper farmers of Kattappana panchayat in Idukki District of Kerala through personal interview method using a structured and pretested interview schedule. The collected data was tabulated and analyzed using averages and percentages.

Results & conclusions

The results revealed that the important constraints related to pepper production were high labour wage, unavailability of labour and prevalence of pest and diseases while price fluctuation was the major constraint in pepper marketing. Prices will change according to world market prices and if there is a boom in production in any other country naturally the prices will fall. Even though pepper can be stored for a long time, because of the immediate need for money, farmers usually disposed their produce to village traders soon after harvest even if the price is low and the quantity handled by co-operative society was only 10 per cent of the production in Kerala. In general, the marketing system of pepper was found to be efficient providing increased share of consumer price to farmers with comparatively low market cost.

S 23 - PiperBase – an information bank on *Piper* species in India

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Introduction

The genus *Piper*, one of the largest in the family Piperaceae, has around 6700 binomials that occur throughout the world, ranging from sea level to the high ranges of Andes and the Sub Himalayas. Out of these, about 119 species are reported from India from two independent centers of distribution *viz.* the Trans Gangetic region and the South Indian Deccan. Most of the plants of this pantropical genus are climbing shrubs that are used in traditional and folk medicine. There are several reports on the biodiversity of *Piper* spp. in South India. The South Indian *Piper* species are found extensively in the humid evergreen forests and the semi evergreen forests of Western Ghats. Indian Institute of Spices Research, Calicut, Kerala has a mandate to collect, conserve, catalogue and evaluate all the genetic resources of *Piper*. At present the Institute's gene bank holds a sizable number of germplasm accessions of *Piper* comprising of all South Indian species, few exotic species such as *P. colubrinum, P. arboreum, P. ornatum, P. magnificum, P. chaba* endangered species, land races, hybrids *etc.* The objective of this work was to develop an electronic tool that may be helpful to the researchers and students dealing with *Piper* taxonomy of the country.

Results & conclusion

The program 'Piperbase' is a database of *Piper* species occurring in India. This database contains information on botany, taxonomy and other related matters on 48 most common species of this important genus. The database is designed using Visual Basic in the front end and MS Access in the back end. It provides a useful interface for the biosystematics of *Piper* spp. in India. The interactive, hierarchical key enables the user to understand the tentative identity of the pepper plants based on the key character. It also provides detailed description of the entire *Piper* species reported from India. The module on biochemistry lists the major chemical compounds present in black pepper, their biochemical pathways and associated enzymes. The bibliography on major species is also provided for the benefit of students and researchers with a search facility. Similarly major patents on these plants are also documented in this database with a good retrieval facility. The database is available on CDs on request to The Manager, ATIC, Indian Institute of Spices Research, Calicut, Kerala – 673 012.

S 24 - Ploidy distinction in male and female plants of betel vine – A study by flow cytometry

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Introduction

Piper betle Linn. is a dioceous species with a basic chromosome number x=13. Ploidy determination in betelvine is complicated by very small size chromosomes and somatic variations in chromosome number. Because the nuclear DNA content of nuclei in certain phase of the cell cycle is related to the ploidy level, flow cytometry has a potential to replace alternative methods for ploidy screening. Hence the study was undertaken to determine ploidy level of available male and female germplasm and hybrids based on flow cytometry to understand compatible ploidy levels.

Materials & Methods

Seventy one accessions of *Piper betle* which included three hybrids maintained at AICRP centers were used for the study. Leaf samples for flow cytometry were prepared according to Dolezel *et al.* with modifications. Relative fluorescence intensity of stained nuclei was analyzed using a PA II flow cytometer (Partec GmbH, Münster, Germany). The control samples used for the analysis were Kapoori lines (male) and Bangla lines (female) which were first tested for chromosome number by cytological study.

Results & conclusion

Conventional chromosome counts showed that Bangla types which are females were tetraploids (2n= 4x= 52) and Kapoori types were triploids (2n= 3x= 39). Ploidy comparison by flow cytometry confirmed that all the accessions could be grouped into two classes *i.e.*, all the males were triploids and females were tetraploids. The hybrids studied were having ploidy level higher than the females and were aneuploids (4n+). Hence the present study showed that the hybrid depression showed by certain hybrids is due to the formation of aneuploids (*viz.* 2n+1) produced from the triploid male parents. The study also showed that in the species distinct ploidy differences are there between the sexes, hence, it indicates the necessity of further study of sex evolution in the species.

S 25 -Performance of a new Bangla type betel vine in Tamil Nadu

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Introduction

In India betel vine is grown in an area of 55,000 ha, of which Tamil Nadu occupies 6000ha. The annual revenue earned to our country is around Rs. 700 crores. India is the largest producer of betel leaves in the world and the leaf area expansion is high in India. In India more than 100 types of betelvine are reported to be in cultivation and most of them are synonyms and confusing one. To assess the varietal wealth of betelvine, different ecotypes were collected from different states in different places of India and were evaluated for their yield and quality.

Materials & methods

Field trial was conducted for three years from 2003-2006 to test the suitability of Calcutta pan type betelvine germplasm under Tamil Nadu conditions. The experiment was conducted in randomized block design and replicated three times with twelve germplasm accessions of betel vine.

Results & conclusion

The pooled data of two years revealed that among the different bangla genotypes under study, the Bangla Sagar recorded the maximum yield (29.92 lakh leaves per hectare per year) followed by the Karapaku (29.30 lakh leaves per hectare per year) and Black leaf (28.76 lakh leaves per hectare per year). Black leaf also registered the maximum vine elongation (22.4 cm per month) and number of laterals (7/vine). Karapaku and Maghai recorded the maximum shelf life of about 12 days. The per cent disease incidence was very less in Bangla Sagar followed by Maghai. The leaf area was also maximum in Bagla sagar (148.57 cm) followed by Karapaku (127.42 cm^2). Among twelve Bangla types, Bangla Sagar was found to be the superior clone under wetland system of cultivation in Tamil Nadu.

S 26 - Stomatal size and density in *Piper betle* L.

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Introduction

Betel vine (*Piper betle* L.) is a perennial dioecious climber. Both male and female vines are under cultivation in different parts of the country. Male and female vines are reported to differ in their leaf size and essential oil content. Variability in terms of chlorophyll content, total phenol and thiocyanate content is also observed between the female and male clones. Stomatal structure varies greatly with species habitat and leaf architecture. Stomatal openings control the loss of water and the exchange of gases in the environment of a plant thus controlling its water relations and metabolism. It is stated that there are large heritable differences between species in stomatal dimensions, distribution and morphology. In this study an attempt has been made to study the differences in stomatal size and density between the female and male clones of *Piper betle*.

Materials & methods

Sixty-two clones of *Piper betle* collected from different parts of the country consisting of 22 male and 40 female clones were utilized in this study. Stomatal density and size were measured on the fifth well-expanded leaf on the laterals of the vine growing in the field under arecanut support. Stomata of the leaf were recorded by applying thin film of quick fix on the dorsal surface of leaf. The dried film bearing the impression of the cuticle was removed and placed on a glass slide. The prepared slides were examined using a 15 X ocular and a 40 X objective. The length and width of stomata was measured using micrometer. Data were statistically analysed using SPAR statistical program.

Results & conclusion

The stomatal frequency of sixty two betelvine genotypes varied significantly. The mean stomatal density varied significantly between male and female clones. It was found that average stomatal size differed according to male and female clones. Variation for stomatal density and size with in female and male group was also observed and the range for the traits being higher in female clones. The mean stomatal density was 143.90/mm^2 in female clones, the cultivars Mysore local and Desi Bangla recorded the maximum stomatal density (210.38/mm^2). Smaller stomata were observed in clones Maghai and Simrali Sanchi (25/12.5 μ). The mean stomatal density is 174.25/mm^2 in male clones where maximum density was recorded in Kapoori (TN) (245.44/mm^2) with smaller stomata (17.50/12.50 μ). The male clone CARI 6 showed bigger size stomata (35/25 μ). In general the stomatal density is less in female clones but they possess bigger size stomata where as the male clones had higher stomatal density with smaller sized stomata. Variation among female and male vines for stomatal traits was also reported. Since stomatal counts are also used in determining the ploidy levels, the detailed investigations to study the relationship with the ploidy status may be useful in betelvine.

S 27 - Rapid propagation of *Piper betle* L. hybrids through split bamboo technique

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Introduction

Betel vine (*Piper betle* L.) is a perennial dioecious climber belonging to Piperaceae family and is native to Malaysia and Sumatra. It is an important commercial crop of India grown for its fresh leaves which are masticatory. Efforts are on way for the genetic improvement of betelvine through hybridisation at Indian Institute of Horticultural Research (IIHR), Bangalore under All India Network Research Project of Betel vine. The multiplication of large number of rooted cuttings in short time from selected single is essential for evaluation. This study aims at generating more rooted cuttings in short time through split bamboo technique in betelvine hybrids.

Materials & methods

The split bamboo technique, which is used in black pepper for rapid propagation, was attempted to multiply the hybrids of the betelvine. Bamboo splits of 8-10 cm diameter and 2 mts length were arranged at an angle of 45^0 to the ground. The bamboo splits were filled with sterile digested cocopeat as rooting medium, which was kept moist by regular watering. Ten vigorous polybag grown hybrid seedlings of 50-60 cm length were trained and allowed to grow on the medium for a period of 90 days. The growing point was pinched off and the vines were crushed at the base leaving 3 nodes intact in the vine. The rooted vines were taken out from media, cut into single nodes with roots and leaf intact. The single node cuttings were transferred to polybags and kept in poly house for establishment and growth was observed for 75 days.

Results & conclusion

There was variation in growth and production of number of nodes produced among the hybrids. The vines grew to a length of 97 to 175 cm and produced 11-24 nodes in a period of three months and put forth roots at each node. Establishment of the rooted cuttings ranged from 70.83 to 95.24 per cent. Better growth of vines in bamboo splits was due to continuous supply of water and nutrients from media (cocopeat) to the growing vines through the newly emerging roots.

The growth of vines in polybags 75 days after planting was found to vary. The vine length varied from 33 to 98 cm and number of leaves from 6.6 to 14.8. Maximum vine length was recorded in Hy 07-1 (98 cm) followed by Hy 07-6 (53.8 cm) whereas number of leaves were maximum in Hy 07-6 (14.8) followed by Hy 07-10 (11.0). Well established root system with single mother leaf when transplanted to polybags has further enhanced the growth of vines. The variation in rooting, establishment and growth in polybags may be due differential response of the hybrids.

The present investigation has indicated that a single vine can produce 60 rooted cuttings in a year. The method can be used for large-scale multiplication of hybrids and commercial varieties in shortest period.

S 28 - Impact of bio-fertilizers and organic manures in relation to crop health and performance of betel vine (*Piper betle* L.)

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Introduction

Betelvine (*Piper betle* L.), which is grown for its leaves, covers an area of 55000 ha in India. The yield and quality of betel leaves is markedly influenced by quantity and source of nutrient supply. The non judicious and unbalanced use of inorganic source of nutrient is often attributed to adversely affect the sustainability of crop production, deteriorate the produce quality and also make the crop vulnerable pathogens. On the other hand, the use of bio-fertilizers and organic manures have shown to improve soil health, sustain crop production, improve the quality of the produce and induce defense mechanism of plant against pathogen ingress. In the present study an attempt has been made to assess the effect of organic manures and bio-fertilizer on performance of crop and severity of *Phytophthora* rot on betel vine.

Materials & methods

The experiment was conducted in the year 2006-07 and 2007-08 at RAU, Pusa in RBD using seven treatments *viz.*, azotobacter @ 5kg + 100 kg N/ha as FYM, azotobacter @10kg + 100 kg N/ha as FYM, phosphobacter @ 5kg + 100 kg N/ha as FYM, azotobacter @ 5kg + phosphobacter @ 5kg/ha + 100 kg N/ha as FYM, vermicompost @ 12 ton/ha, mustard cake:urea (200:100:100 kg N, P_2O_5, K_2O/ha) and control (nil application of nutrient) in three replicates. Observation was recorded on marketable yield, fresh weight of 100 leaves, shelf life and severity of Phytophthora rot.

Results & conclusion

The pooled data of result of the experiments conducted for two consecutive years showed that application of vermi-compost registered the highest production of crop in terms of total number of leaves (31.23 lakh/ha), fresh weight of hundred leaves (303gm), leaf area (103cm^2), shelf life (15 days) and relatively less severity of *Phytophthora* rot (9.7%). All other treatments comprising of bio-fertilizer and FYM were almost at par in relation to their effect on crop performance and disease severity, but combination of mustard cake and urea produced poor quality leaf with maximum disease severity (16.21%). It was also found that plot receiving no treatment gave poor yield, but the keeping quality was improved and the disease was quite low.

The application of nutrients either in the form of vermi-compost or combination of azotobacter, phosphobacter and FYM increased the marketable yield, improved leaf quality, prolonged the shelf life of leaf and also checked the development of *Phytophthora* rot, hence may be incorporated in integrated crop management strategy for quality leaf production of betel vine.

S 29 - Effect of different organic manures on vine growth, yield and storage life of betel leaves *(Piper betle* L.*)* cv. Simurali Jhal

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Introductio.ı

Betelvine requires 200 kg N, 100 kg K_2O and 100 kg P_2O_5 /ha /year for optimum growth and leaf yield. Organic manures are beneficial for improving the quality of soil and betel leaves. Experiment was conducted to study the superiority of the commonly available organic manures for more leaf production, better quality and longer storage life.

Materials & methods

The experiment was conducted during 2005-07 at Horticultural Research Station, BCKV Mohanpur, West Bengal, India situated in Gangetic alluvial plains with a soil pH of 6.8 . The experiment was designed in RBD with 3 replications. Five organic manures *viz.*, mustard oil cake, cow dung, vermicompost, poultry manure and neem cake were applied individually with urea in equal four splits in an year to provide total N recommended for betelvine at 50: 50 ratio. The plants were spaced at 50 x 15 cm from row to row and from plant to plant respectively. The cultural practices were followed as per recommendation. Data were recorded on growth and yield parameters. To study the storage life of betelvine, fresh, green and matured leaves from 4th to 8th node of the vine were kept in bamboo basket in depetiolated condition, covered with green banana leaves and stored at room temperature. The data were recorded at regular intervals during 3 seasons of the year *viz.*, April - May (pre - rainy season), July - August (rainy season) and December - January (winter season).

Results & conclusion

The observations on vine increment /month (cm), leaf petiole length (cm), leaf area (sq. cm), leaf yield /vine and fresh weight of 100 leaves (g) clearly revealed that all the growth and parameters were maximum with mustard oil cake closely followed by vermicompost, whereas the longest storage life of leaves was observed with neem cake.

S 30 - Standardization of nutrient management schedule for increased yield in betel vine (*Piper betle* L.)

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Introduction

Since betel vine is cultivated for it's green leaf, nitrogen plays a direct role on growth, yield and keeping quality. The crop is usually manured with heavy doses of bulky organic manures and the farmers are reluctant to use commercial fertilizers as they fear that the quality of the leaves may be affected by the use of fertilizers. A study conducted at college of Agriculture, Vellayani, showed that the bulky organic manures can be partly substituted by chemical fertilizers without affecting the chewing quality of leaves. Earlier, it was recommended to manure the betel vine crop with 60 kg N ha^{-1} and 25 kg P_2O_5 ha^{-1} over a basal dose of 30 t ha^{-1} of FYM. Hence a study was undertaken with the objective to evolve an integrated nutrient management practice for increased productivity and quality of betel vine.

Materials & methods

The field study on integrated nutrient management was conducted during the main planting season starting from June-August in 2001-2002 and 2002-2003 at College of Agriculture, Vellayani, Thiruvananthapuram. The soil of the experimental site was red loam, acidic in reaction, low in available n and K and medium in available P status. The experiment was laid out in RBD with 13 treatments and three replications. The treatment involved combination of two nitrogen levels (60 and 90 kg N ha^{-1}), three organic sources (poultry manure, FYM and neemcake) and two substitutions (1:1 and 2:1). P_2O_5 was given at the rate of 30 and 45 kg ha^{-1} and K_2O at the rate of 60 and 90 kg ha^{-1} for maintaining an uniform ratio of 2:1:2.

Results & conclusion

Although there was a varying trend in the response to substitution and type of organic manures, in general and increasing trend in growth and yield characters of betel vine was observed as the nitrogen application was increased from 60 to 90 kg ha^{-1} during both the years of crop growth. During both the years highest yield was recorded by NC + urea in 2:1 and 1:1 ratio at 90 kg N ha^{-1}. In first year PM + urea in 2:1 ratio and in second year FYM+ urea in 2:1 ratio were found to be equally effective. NC + urea in 2:1 ratio at 90 kg N ha^{-1} recorded 59 per cent higher yield that farmer's practice, the control treatment. The study also showed that NC + urea in 2:1 ratio is the best INM treatment (30.72 leaves ha^{-1}) and was on par with NC+ urea in 1:1 ratio (27.30 leaves ha^{-1}) and FYM + urea in 2:1 ratio (24.68 leaves ha^{-1}), all at 90 kg N ha^{-1}.

The results of the study revealed that the integration of inorganic and organic manures produced the highest yield and this supports the concept of integrated plant nutrient management system. From the study it can be inferred that nitrogen at the rate of 90 kg ha^{-1} through NC and urea at 2:1 or 1:1 ratio is the best nitrogen management schedule for achieving high yield in betel vine.

S 31 -Response of betel vine cv. Ambadi to various nutritional sources

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Introduction

Betel vine (*Piper betle* L.) is perennial, diocious creeper belonging to the family piperaceae. It is cultivated in India for its leaves used mainly for mastication. In betel vine cultivation, nutrition plays an important role. Among the various essential nutrients, nitrogen plays a pivotal role in improving the productivity and quality of leaves. It is usually cultivated in small holdings and once the crop is established it becomes continuous source of income to the growers. Since the green leaves constitute the economic part of the plant, the nitrogen requirement of the crop is quite high.

Materials & methods

Field experiment was conducted to study the effect of different sources of organic manures on growth, yield and quality of betel vine cv. Ambadi at Arabhavi, Gokak taluk, Belgaum Dist., Karnataka during the year 2005-06 on sandy loam soil having a pH of 8.2-8.4. The experiment was laid out as RBD. The trial consisting of thirteen treatments was replicated thrice. Recommended dose of fertilizers (200: 100: 100 kg NPK ha^{-1}) was applied in the form of ammonium sulphate (N), single super phosphate (P_2O_5) and sulphate of potash (K_2O). Different organic manures *viz.*, FYM, neem cake, vermicompost, sheep manure and press mud were supplied at the time of lowering as per the treatment. Foliar spray of vermiwash (25 %) was done at monthly intervals. Farmers practice consisted of FYM (15 t ha^{-1}) + groundnut cake (0.5 t ha^{-1}). Growth observations on vine length, girth and number of laterals were recorded at 210 days after lowering (DAL) along with leaf yield. Leaf size was worked out considering leaf area constant 0.64 for cv. Ambadi.

Results & conclusion

Growth attributes at 210 DAL indicated that the application of FYM (25 t ha^{-1}) + RDF produced significantly higher plant height (4.33 m), basal vine girth (6.72 mm) and number of laterals per m^2 (55.43). However, petiole length was maximum (4.49 cm) in foliar spray of vermiwash. Lowest growth parameters were recorded in farmers practice. The higher leaf size and LAI observed in foliar sprays of vermiwash may be due to the presence of coelomic body fluid in vermiwash. It is a source of phosphates, sulphates and chlorides of potassium, sodium, magnesium are in soluble form. It must have increased the absorption efficiency of the leaves and also sprays at monthly intervals increased the availability of nutrients directly leading to production of more number of leaves, leaf size and LAI

The highest leaf yield of 588.55 leaves per vine was recorded by the treatment receiving FYM (25 t/ha) + RDF (200 : 100 : 100 kg NPK/ha) followed by farmers practice (FYM 15 t/ha + ground nut cake @ 0.5 t/ha) along with monthly foliar spray of vermiwash @ 25% dilution (540.17 leaves/vine) and FYM @ 25 t/ha + neem cake @ 5 t/ha (512.07 leaves/vine) compared to the lowest in farmers practice (279.03 leaves/vine).

S 32 - Effect of weather parameters on the incidence of foot rot, leaf rot and bacterial blight of betel vine (*Piper betle* L.)

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Introduction

Weather parameters such as rainfall, minimum and maximum temperatures, relative humidity play an important role in the development of fungal and bacterial diseases of belel vine. The objective of the present study was to study the influence of these weather parameters in the development of foot rot, leaf rot and bacterial blight of betel vine.

Materials & methods

An experiment was conducted to observe the effect of various weather parameters- (maximum temperature, minimum temperature, relative humidity, rainfall, number of rainy days) on the initiation and further development of two most important diseases of betel vine *viz*. foot and leaf rot and bacterial blight, in betelvine conservatory at JNKVV, Jabalpur during 2006-07 and 2007-08.

Results & conclusion

Observation recorded during 2006-07 revealed that the foot and leaf rot of betelvine, incited by *Phytophthora nicotianae* var. *parasitica* appears during second week of June (0.05%) and increased gradually, finally reaches to its maximum (30.66%) in the second week of September, when the difference between maximum and minimum temperature was very less and humidity was ranging from 88.00 to 92.00 per cent. During the month of October, stem rot infection was ranging from 12.33% to 30.66 per cent. Disease development was found to be positively correlated with relative humidity, rainfall, number of rainy days and number of cloudy days. Similarly, during 2007-08 disease appeared during 2nd week of June (1.60 per cent) and increased gradually, reached to its maximum in 2nd, 3rd, 4th week of September (20.33, 21.86 and 22.00 per cent). During the month of September, the difference between maximum and minimum temperature was ranging from 7.0 to 14.8^{0}C which was very less. Similar trend was noticed in case of relative humidity.

Studies on the appearance and further spread of bacterial blight on betelvine caused by *Xanthomonas campestris* pv. *betlicola* during 2006-07 and 2007-08 revealed that it appeared during second week of June and progressive development was recorded till 4th week of October when rainfall was at maximum. Bacterial stem infection was at maximum during the month of October. Weather parameters such as minimum temperature, relative humidity, rainfall and number of rainy days showed positive correlation with bacterial blight disease development.

S 33 - Effect of integrated management practices on growth parameters and disease incidence of betel vine (*Piper betle* L.)

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Abstract

An experiment was conducted to study the integrated management practices through IPM & INM during two consecutive years 2006-08 at betelvine experimental area of JN KVV, Jabalpur. Results were compared with the various combinations of treatments and farmers practice. The data revealed that the treatment comprising, 1.75 lakhs plant population/ha + 200 kg/ha nitrogen in four split doses in organic form + 100 kg/ha P_2O_5 +100 kg/ha K_2O + irrigation at 100 per cent replenishment of CPE + four application of *Trichoderma viride* + sanitation + recommended insecticide if required, recorded significantly maximum average length of vine per month (16.18 cm), length of internodes (7.77 cm), leaf yielded (35.88 lakhs/ha), hundred leaf weight (628.03 g) and best keeping quality (15.47 days to 50% rotting) with lowest disease incidence (6.93%). In the second treatment which consisted of 1.75 lakh plant population/ha + 200 kg/ha nitrogen in four split doses in organic form 100 kg P_2O_5/ha + 100 kg K_2O/ha + irrigation at 100 per cent replenishment of CPE + Bordeaux mixture application (4D + 8S) + recommended insecticides application if required, recorded leaf yield of 35.0 lakhs/ha, vine elongation (15.79 cm), internodes length (7.26 cm), hundred leaf weight (593.05 g) and keeping quality (14.11 days up to 50% rotting) with relatively less incidence of diseases (11.37%) which was significantly inferior to the first treatment but superior to farmers practice. Farmers practice was not superior to the above two treatments with all the growth parameters and C: B ratios. The maximum disease incidence (16.50%) was recorded with farmers practice as compared to both the treatments.

S 34 -Screening of betel vine cultivars for resistance to betel vine whitefly, *Singhiella pallida* (Singh) (Aleyrodidae: Hemiptera) and new host plant records for *Singhiella pallida* (Singh)

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Introduction

Betelvine (*Piper betle* L.) is commercially cultivated in India over 50,000 ha as cash crop. Five major cultivar groups, *viz.*, Bangla, Meetha, Sanchi, Kapoori and Desawari have been identified in India based on morphology and chemical characteristics. Betelvine whitefly, *Singhiella pallida* (Singh) (Aleyrodidae: Hemiptera) is most important and common pest of betelvine causing severe damage to the foliage. Screening of germplasm for resistance to betelvine whitefly is very relevant for genetic improvement programs. Only *P. betle* is its well known host. Host range study has its significance in the epidemiology of the pest.

Materials & methods

Screening was carried out in a closed conservatory (boraj) located at Research Farm of BCVK, Nadia, West Bengal during 2005 and 2006. A total of twenty-three cultivars were evaluated. Mean adult betelvine whitefly population and mean successful adult emergence percentage in field condition were taken as the parameters for assessment of degree of resistance/susceptibility in the cultivars. To test the host range, pipul (*Piper longum*), choi (*Piper chaba*) and awani pan (*Piper hamiltonii*) were planted in betelvine borej along with the common cultivars of betelvine. Adult whitefly population, number of eggs laid, percentage of egg hatching and successful adult emergence on different *Piper* spp. were recorded and compared with those on common betelvine cultivars.

Results & conclusion

Population levels of adult whitefly and percentage of adult emergence varied significantly on different cultivars in both the years. None of the entries under observation was completely free from whitefly infestation. Based on the adult population harboured, cultivars were grouped into three categories, *i.e.*, moderately resistant, moderately susceptible and highly susceptible. Simurali Sanchi and Kalipatti (Sanchi type) were consistently classified as moderately resistant in both the years. Bangla type cultivars, namely Harishpur Bangla, Kadwa, Bagerhat Bangla, and Desawari type cultivar, Bilhari showed moderately susceptible reactions. Halisahar Sanchi (Sanchi type), Simurali Bhabna (Bangla type) also showed medium performance as evident from one year data. Rest of the cultivars tested were almost highly susceptible. Comparatively low level of emergence of whitefly was found on two Sanchi cultivars *viz.*, Simurali Sanchi and Kalipatti indicating higher level of antibiosis against betelvine whitefly. It may be suspected that stear-aldehyde compound present in Sanchi cultivars may have exerted antibiosis effect on betelvine whitefly. Here, three species of genus Piper (*P. longum, P. chaba* and *P. hamiltonii*) are recorded as new hosts of *S. pallida* as it successfully completed its life cycle on these plant species.

S 35 - New acaricides for the management of red spider mite on betel vine

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Introduction

The betel vine red spider mite *Tetranychus cinnabarinus* Boisduval is a serious pest of betel vine causing significant yield loss. The feeding mites on the leaves cause speckling on upper surface and bronzing symptoms on the lower side resulting in drying and defoliation. Residual toxicity of recent acaricides was evaluated to find out the best acaricides for effective control of betel vine mite.

Materials & methods

A pot culture experiment was conducted in April-May 2006. Three acaricidal chemicals, namely, abamectin 1.8 EC (0.0365%), diafenthurion 50 EC (0.05%) and wettable sulphur 80 WP (0.3%) were sprayed and water spray served as control. Ten numbers of mites were released per plant at every 24 hours interval and observations were recorded on mortality of mites until it reached less than 20%. Corrected mortality was calculated by using Abotts formula.

Results & conclusion

The results indicated that among three acaricides tested for their residual toxicity effect, abamectin at 0.0365 proved significantly superior and maintained its superiority up to 17 days after spraying. Cent per cent mortality of mite was observed up to 10 days. The next best acaricide was found to be diafenthurion 0.05 % and sulphur was found to be moderately effective.

The new acaricides, abamectin 0.036 % and diafenthurion 0.05 % were found effective for control of betelvine red spider mite and reported that a waiting period of 5 days after spraying of diafenthurion is considered safe for consumption of green French bean pods as per dissipation studies.

S 36 - Betel vine linear scale - An economics of management

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Introduction

In India betel vine is grown in 550,000 hectares and yields revenue worth Rs. 9000 million annually. The crop is damaged by pests and diseases at one time or other and cause economic loss to the tune of several crores. An estimate shows that the loss due to insect pests in betelvine is 20-30 %. The insect linear scale, *Lepidosaphus cornutus* is a serious pest in betelvine cause economic loss (Sadakathulla *et al.* 2002). The correct estimate of the population levels and its economic damage and its management are absolutely necessary.

Materials & methods

The stock culture of *L. cornutus* was maintained in potted plants of betelvine variety SGM1. The experiment was laid out in CRD with three replications. The treatments were *L. cornutus* released @ 1, 3,7,10 linear scales/vine. The first instar crawler was released 12 weeks after uniform lowering of vines. Betel vine sprayed with chlorpyriphos (0.04%) at fortnightly interval served as control. The leaf yield was recorded after three months after release of the linear scale and when the leaves were at maturity, settlement of crawlers and development of symptoms were observed and number of scales/vine was recorded at monthly intervals after the release of the scales.

Results & conclusion

The study indicated the population of scales, *L. cornutus* in betelvine 1, 3, and 5 vine^{-1} seem to tolerate infestation and in the leaf it could be at 0.25, 0.15 and 0.25/ leaf^{-1}. It has not affected the leaf yield also till the 5 scales/vine by recording 60.0 leaves/vine compared to the 3 scales/vine and 1 scale/vine which recorded 60.60 and 61.33 leaves/vine respectively. There were significant differences in number of scales vine^{-1} with respect to various treatments. Maximum population vine^{-1} occurred on vines infested with 10 linear scale vine^{-1} followed 7, 5, 3 and 1 linear scales vine^{-1}. Control plots, where betelvine was protected by spraying chlorpyriphos 0.04% recorded only 2% damage and the leaf yield was highest (62.67 leaves vine^{-1}) in plants released with initial load of 1, 3 & 5 scales respectively. The leaf yield recorded from vine released with 5 linear scales was drastically lower and on par with 1&3 released scales. The leaf yield recorded from vines released with 7 & 10 scales was significantly lower than 5 scales vine^{-1}. The leaf yield was on par with the sprayed crop. The loss of leaf and monetary loss followed from the second week onwards and lasted till seven weeks. Hence the control measures should be started before the threshold level of 1 scale/vine for effective suppression of linear scale insect. The results of the present study indicate that *Lepidosaphus cornutus* is an important pest of betelvine which cause significant yield loss when the population of scales is above 5 scale vine^{-1} (0.25 scale leaf^{-1}). The linear scales when left to damage the crop for more than week could cause economic loss.

S 37 - Quantitative analysis of scientific research output on Piperaceae - A bibliometric study

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Introduction

Bibliometrics is the quantitative evaluation of literature. It is used in science and technology arena to determine the knowledge output of national systems of innovation. It helps to monitor growth of literature and patterns of research enabling monitoring. The study attempts to evaluate the research publications with respect to content and coverage, growth rate areas of research concentration, research performance of various institutions, identification of core journals *etc.* The crops selected for the present study are black pepper (*Piper nigrum*), betel vine (*P. betle)*, long pepper (*P. longum)* and *P. chaba,* the commercially important species of Piperaceae family. All these species are also medicinally important.

Materials & methods

For the study, Horticultural Science database (CABI) for the period 1973 to 2007 has been used for data collection. CABI is the leading abstracts database for agriculture providing comprehensive access to the most international agricultural and applied life sciences journals in the world. Keywords and appropriate descriptors were used for data collection. The collected data were analysed using MS Excel. Bibliometric indicators like Relative Growth Rates (RGR), Participatory Index (PI), Doubling Time (DT) *etc.* were calculated. The validity of Bradford's Law of journals was also checked and core journals were identified.

Results &conclusion

The RGR and growth curve for black pepper indicate that the growth of literature was maximum (22%) during 1998 to 2002, stagnant during 1973 to 1982 and 1992 to 1997. Output on betel vine shov ed greater fluctuations during 1977 to 1982. The maximum output (21%) was reported during 1998 to 2002. The growth of research output for *P. longum* was maximum during 1998 to 2002 and that for *P. chaba* 2003-2007. Analysis of country wise distribution highlighted the predominance of India for all the four crops. Out of the total research articles published, 56% of black pepper, 82.82% of betel vine, 67.8 % of long pepper and 50% of *P. chaba* were published from India. Brazil ranked second with 7.6% and 9.5% in black pepper and long pepper respectively. Core journals were identified for each crop. Regarding black pepper, the Indian Journal of Arecanut, Spices and Medicinal Plants (8.3%) published maximum articles and tops first in the list followed by Journal of Spices and Aromatic Crops (6.8%). With regard to betel vine, Indian Phytopathology (8.1%) ranked first followed by Journal of Plantation Crops (4.7%). For *P. longum*, Journal of Ethnopharmacology (5.6%) and Current Science (3.8%) were the toppers in the list. Journal of Essential Oil Research and Planta Medica (12.5% each) published maximum for *P. chaba.* Subject wise analysis of publications on black pepper revealed that maximum research papers were published in crop protection aspect (36%) and the next priority is given to crop production (32%) aspect. For betel vine maximum research papers were published on crop protection (55.4%) aspects of the crop followed by crop production (21.62%). In *P. longum* most of the papers were published on crop production (36.1%) aspects followed by medicinal properties (27.8%). Institution wise analysis of the research out put revealed that in black pepper, long pepper and *P. chaba* Indian institute of Spices Research, Calicut, India has maximum number of research papers. In the case of betelvine, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India tops the list.