Impact of Vegetable Research in India

Editors
Sant Kumar, P.K. Joshi and Suresh Pal

This volume provides an overview of vegetable research and development in India. Dissemination and adoption of improved technologies and their impacts on food and nutritional security, sustainability, equity, trade, etc. are discussed at length. It is hoped that this volume will be useful to the researchers, development specialists and students alike.

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Acronyms and Abbreviations

AEZs	Agri-Export Zones
AGMARK	Agricultural Produce (Grading and Marketing) Act
AICRP	All India Coordinated Research Project
AICVIP	All India Coordinated Vegetable Improvement Project
APEDA	Agricultural Processed Food Export Development Authority
BCR	Benefit Cost Ratio
Bt	*Bacillus thurengenisis*
CA	Commission Agent
CII	Confederation of Indian Industries
CIP	International Potato Centre
CMS	Cytoplasmic-nuclear Male Sterile
CPRI	Central Potato Research Institute
TCV	Tomato Curl Virus
CV	Coefficient of Variation
DANIDA	Danish International Development Assistance
DBM	Diamondback Moth
DNA	Deoxyribose Nucleic Acid
EEC	European Economic Commission
FAO	Food and Agriculture Organization
FCDS	Food Characteristics Demand Systems
FYM	Farm Yard Manure
GA	Gibberellic Acid
GDP	Gross Domestic Product
GoI	Government of India
ha	Hectare
HACCP	Hazard Analysis and Critical Control Point
HaNPV	Nuclear Polyhedrosis Virus of *Helicoverpa armigera*
HOPCOMS	The Horticultural Producers Cooperative Marketing and Processing Society
HP	Himachal Pradesh
IARI	Indian Agricultural Research Institute
IBPGR	International Bureau of Plant Genetic Resources
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IIHR	Indian Institute of Horticultural Research
IIVR	Indian Institute of Vegetable Research
IPM	Integrated Pest Management
IVDP	Intensive Vegetable Development Programme
IVLP	Institute Village Linkage Programme

kg	Kilogram
KHDP	Kerala Horticulture Development Programme
MFPI	Ministry of Food Processing Industries
MH	Maleic Hydrazide
MPKV	Mahatma Phule Krishi Vidyapeeth
Mt	Million tonnes
NAA	Naphthalene Acetic Acid
NAFED	National Agricultural Cooperative Marketing Federation
NARP	National Agricultural Research Project
NCAP	National Centre for Agricultural Economics and Policy Research
NEH	North-Eastern Hill
NHB	National Horticulture Board
NHRDF	National Horticultural Research and Development Foundation
NKPE	Neem Kernel Powder Extract
NPK	Nitrogen Phosphorus and Potash
NPV	Nuclear Polyhedrosis Virus
NSC	National Seeds Corporation
NSKP	Neem Seed Kernel Powder
NSPE	Neem Seed Powder Extract
NSKE	Neem Seed Kernel Extract
NSS	National Sample Survey
NSSO	National Sample Survey Organization
OFT	On-Farm Trial
OPV	Open Pollinated Varieties
PFA	Prevention of Food Adulteration
PGR	Plant Growth Regulators
PLW	Physiological Loss in Weight
PRA	Participatory Rural Appraisal
R&D	Research and Development
RNA	Ribonucleic acid
SAUs	State Agricultural Universities
TAR	Technology Assessment and Refinement
TDC	Terai Development Corporation
TLCV	Tomato Leaf Curl Virus
TPS	True Potato Seed
TRIPS	Trade Related Intellectual Property Rights
TSWV	Tomato Spotted Wilt Virus
UP	Uttar Pradesh
USA	United States of America
WBMV	Watermelon Bud Necrosis Virus
WTO	World Trade Organization
WYTEMP	Women Youth Training and Extension Programme

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Foreword

Vegetables are rich source of vitamins, minerals and plant fibres which provide food and nutritional security. These also generate high income and employment, particularly for small farmers. There has been a revolution in the production of vegetables in the country in the last three and a half decades. The vegetable production of our country was very low, less than 20 million tones during 1947 at the time of independence. The production of vegetable till 1961-65 was about 23.45 million tones, which increased to 28.36 million tones in 1967-71 and to 39.99 million tones in 1986. During 1991-1992, the total production was 58.54 million tones from 5.593 million ha of land with a productivity of 10.5 t/ha. During the year 2000-2001, the country has produced 93.92 million tones of vegetables from 6.25 million ha of land raising productivity level to 15.0 t/ha. Thus, in last decade country's vegetable production has increased more than 35 million tones and the gross vegetable productivity has increased by one and half times. Presently India's share is 13.6 per cent of total world production of vegetables and occupies second position next to China with a production of over 94.5 million tones. It is estimated that the total vegetable production of the country will touch the figure of 100 million tones by the year 2005-06.

Impact assessment of agricultural research has been in vogue since the green revolution era. Most of the impact assessment studies have, however, focused on food grain and commercial crops, and the developments in fruits, vegetables, and livestock largely remained unnoticed, perhaps due to lack of socio-economic data. Only recently, analysis of the, contributions of these rapidly growing sectors, in terms of both food and nutritional security; and poverty alleviation, in a systematic manner has received attention of researchers. This publication is the outcome of a National Seminar on 'Impact of Vegetable Research in India' held at the Indian Institute of Vegetable Research, Varanasi, in March 2002. This volume contains the contributed papers and deliberations held in the seminar. It provides an excellent overview of vegetable research in India, development and adoption of improved technologies and their impact on society. I hope this publication will be helpful to those who are associated with vegetable research and production in the country.

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Preface

Today, India is the second largest producer of vegetables in the world with a production level of more than 97 million tonnes. It can become the highest producer of vegetables in the world by improving the national productivity at least to the world average and avoiding post-harvest losses. That would require proper production and post-production management, without putting extra pressure on cultivated land which is limited and shrinking day-by-day.

The advent of hybrid technology and increasing awareness about nutritional security among the masses has provided impetus to vegetable production. The credit for the vertical expansion goes to the improved production and management technologies. The country's vegetable requirements would be 123 to 129 million tonnes by the year 2011. It can produce the required quantity of vegetables as it is endowed with diverse agro-climatic conditions and abundant labourforce. The only need is to provide a strong support of infrastructure and encouraging policy environment. As per the recent National Family Health Survey there are over 53 per cent malnourished and under-weight children in below 4 year of age group. Globalization has opened up a lot of opportunities (and challenges too) for enhancing India's global trade in vegetables. In view of stagnation in the productivity of rice and wheat, particularly in the Indo-Gangetic Plains, diversification towards vegetable production has been emphasized for enhancing income and employment opportunities in the countr, particularly for the smallholders.

This proceedings is the outcome of a national seminar on 'Impact of Vegetable Research in India' held at the Indian Institute of Vegetable Research, Varanasi, in March 2002. Various issues concerning the vegetable sector were discussed in this seminar. The proceedings have been presented in five parts. Part I provides an overview and Part II describes vegetable research in India. The adoption and impact of vegetable research has been included in Part III and marketing, demand and nutrition security have been discussed in Part IV. The response to presentation at the seminar has been tremendous but due to space limitations, it has not been possible to include all the papers; however for the bnefit of researchers abstract of selected papers have been provided in Part V. I hope this volume will be of immense use to the vegetable scientists, economists, planners and policy makers.

September, 2004 — **Mruthyunjaya**
New Delhi — Director

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This proceeding is the outcome of the National Seminar on 'Impact of Vegetable Research in India' organized jointly by the National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, and the Indian Institute of Vegetable Research (IIVR), Varanasi, in March 2002.

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We express our sincere thanks to Dr Kirti Singh, President, Indian Society of Vegetable Science, and the former Chairman, Agricultural Scientists Recruitment Board, New Delhi, for delivering the inaugural address. We are thankful to Dr Dayanatha Jha, ICAR National Professor, for providing valuable guidance and insights for organizing this seminar.

We are thankful to all the Chairpersons and Rapporteurs for efficiently conducting the different sessions of the seminar. The role of participants in providing valuable inputs is highly appreciated. All the paper contributors deserve special thanks and appreciation for contributing the paper and also responding to several editorial requests for the preparation of this volume.

We acknowledge the financial support from National Agricultural Technology Project for organizing the seminar and NCAP for bringing out this volume. We hope that this publication will help in assessing the vegetable sector critically and provide directions for future development. Dr B. S. Aggarwal deserves special thanks for his skill in editing this volume.

Editors

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Part I : An Overview

1. Vegetable Research in India: Some Issues*

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The most urgent need today is to increase the production of nutritious food in a sustainable manner and improve farm income to ensure household food and nutritional security, while conserving the natural resource base. Vegetables are the vital sources of minerals, vitamins and dietary fibres and play an important role in supplying nutrition to human health. Vegetables require comparatively lesser quantities of agro-inputs to grow.

The accumulation of rice and wheat stocks in India along with a distinct shift in the consumption patterns away from cereals has necessitated the shifting of focus towards the non-cereal crops, particularly vegetables. The emphasis on minimum support price has benefited rice and wheat at the expense of infrastructures like irrigation, electricity, etc. This needs a review of policies, which have led to the diversion of scarce resources in the form of subsidies for fertilizers, rural electricity, irrigation, credit and other agricultural inputs, away from the creation of productive assets. Diversification in agriculture requires development of rural infrastructure including transportation, roads, reliable power supply, micro-irrigation systems, agri-food processing facilities, quality testing laboratories, new market facilities, etc. and other institutional support.

Diversity in Vegetable Production

The vegetable production in our country has touched a new height in recent years, occupying an area of 6.07 million hectares and production of 91.3 million tonnes. Due to advent of hybrid varieties and increasing awareness about nutritional security, vegetable production is getting continuous momentum in our country. During the 1990s, area under vegetable crops increased by 29 per cent and their production by 42 per cent. The credit for vertical expansion in vegetable production goes to

* Based on the Address delivered at the national workshop on 'Impact of Vegetable Research in India', organized jointly by National Centre for Agricultural Economics and Policy Research, New Delhi, and Indian Institute of Vegetable Research, Varanasi on 1-2 March 2002.

the development of improved vegetable varieties and new management technologies. However, as the country's population is increasing at the rate of 1.8 per cent per year, our vegetable requirements by 2010 would be around 135 million tonnes. Further, problems of malnutrition and birth of underweight children are very acute. According to a recent National Family Health Survey, over 53 per cent children under four years of age are malnourished and underweight. India is currently the home for about 40 per cent of the malnourished children in the world, although its share in the world population is less than 20 per cent.

Although more than 70 types of vegetables are grown in our country, higher emphasis is given to more popular vegetables like tomato, brinjal, chilli, cauliflower, cabbage, peas, potatoes, onions and few common cucurbits and leafy vegetables. Besides, a large number of minor vegetables are also grown in different parts of the country. These minor vegetables possess high export potential and could fetch very high price in many overseas markets. In Himachal Pradesh, cultivation of asparagus, broccoli, and some other minor vegetables like broad bean, runner bean, winged bean, lima bean, velvet bean, chives, yellowish onion has come up in recent years. Besides, Brussels sprouts, Chinese cabbage, *Momordica cochinchinensis, Momordica dioica, Coccinia indica, Melorthrium heterophylla*, curry leaf, drumstick, Indian spinach, parsnip, celery, lettuce, artichoke, sweetcorn, babycorn, etc. are also being grown for domestic and foreign markets. Looking at the economic importance of these crops, it is high time to chalk out long-term strategies so that commercial cultivation of these minor vegetables could be popularized and also research be initiated on them.

Hybrid Vegetables

Hybrid varieties play a vital role in increasing vegetable production due to their high yield potential, early maturing, superior quality and pest-resistance attributes. Hybrid varieties are of recent origin in India whereas in many developed countries they are being grown for many years. Tomato, eggplant, pepper, cucumber, muskmelon, watermelon, cabbage, cauliflower, carrot, etc. are important crops for which hybrids are not only available but are being adopted also by Indian farmers to a considerable extent. Presently, Karnataka, Maharashtra, Gujarat, Andhra Pradesh, Uttar Pradesh and Madhya Pradesh are the leading producing states of hybrid tomatoes. The entire cabbage production in southern parts of Maharashtra and West Bengal is under F_1 hybrids. However, it is estimated that presently only about 10 per cent of vegetable area is under hybrids, of which tomatoes cover 36 per cent, cabbage 30 per cent, brinjal 18 per cent, okra 7 per cent, melons and gourds 5 per cent each, cauliflower 2 per cent and chilli 1 per cent. It is expected that area coverage under hybrid vegetables would be more than 25 per cent after 5 years and more than 50 per cent after 10 years, leading to a substantial enhancement in vegetable production in the country. Therefore, a greater emphasis is needed on hybrid technology to make the optimum use of land.

Role of Family Labour Force

Women and children could play a major role in production, processing and hybrid seed production of vegetables. Intensive production of vegetables is often associated with the availability of female labour. Women should be educated about the importance of producing vegetables for improving their health and economic status. In Karnataka, the Department of Agriculture employs female Agriculture Officers in each Taluka under the Danish International Development Assistance (DANIDA) and Women Youth Training and Extension Programme (WYTEMP) to train rural women of small and marginal farms in cultivating crops with advanced technology. Similar schemes are in operation in Tamil Nadu and Orissa.

Market Intervention and Role of New Technologies

In the wake of globalization of agriculture, nutritional quality of any vegetable or its product has a very crucial role in its sustainable production. Therefore, there should be a network project on the development of transgenics using genes of nutritional quality of international standard. This technology, especially the use of anti-sense RNA for development of slow ripening varieties for post-harvest management is of great value. Since Bt transgenic should be evaluated in multi-location trials, a clear-cut policy should be formulated regarding the bio-safety measures and checking of possibility of gene piracy. Development in molecular gene tagging, DNA fingerprinting, gene cloning, production of transgenics, etc. would certainly help in enhancing the breeding programme of vegetable crops effectively.

During the past four decades, per unit cost of agro-inputs (viz. fertilizers, pesticides, labour wages and electricity charges, etc.) have increased manifold, making farm production less remunerative for farmers. For most of these items, except the wage component, costs have multiplied by at least 2.5 times. The price level of the agricultural produce has not gone up in proportion to the input costs. This fact has left the farmers at large to rethink and redefine their priorities. Such a scenario will have a negative effect on the national food–security.

Farmers generally follow mono-cropping on their fields, keeping the market demand in view. But, many a times crop fails or provides low returns. Even if the yield is good, the market could exploit the situation by creating an artificial glut. In this context, vegetable farming has great potential in terms of available options (number of crops and season-wise availability) and demand for processing and export.

There is a dire need for developing farmers' markets on the lines of Tamil Nadu, Andhra Pradesh and Punjab throughout the country so that the farmers can get remunerative price for their produce and consumers can have benefit of fresh vegetables at reasonable price.

Vegetables characterized with the specific attributes of high-yielding ability in per unit area require less plant nutrients as compared to cereals, sugarcane, cotton, etc. The long-term field experimental findings have indicated that soil health (N level, organic matter, pH) did not deteriorate where fertilizers in combination with organic manures and green manures were systematically applied.

Production of Organic Vegetables

Unlike other food crops, most of the vegetables are succulent and attract several insect pests. Some pesticides used to control them remain chemically active for a long period and produce hazardous effects on the environment. Also, some of them do not degrade and enter the human body along with vegetables consumption. Therefore, in the developed countries like the USA and Europe, a conscious consumer has started demanding organically produced foods. The production of organic vegetables has now become a commercial venture outside India where organically produced vegetables are available in the market at a premium price. However, In India it is done only on small scale for domestic and export purposes. The primary benefit of using organic manures for vegetable production is to improve the soil structure and availability of micro-nutrients.

The research for organic farming in vegetable crops in India must be done on a systematic basis. The aim of this research should be to develop technologies that would not only increase vegetable production but also create more jobs, incomes and foreign exchange. The research must focus on developing technologies that would meet the requirements of small landholders and resource-poor farmers. It should also consider the conditions and resources at growers field so that the developed technology becomes practical and economical. Strategy should be adopted to create interest of small farmers in adopting organic farming technologies for growing vegetable crops.

2. Vegetable Sector in India: An Overview

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Introduction

Vegetables being a rich and cheap source of vitamins and minerals, occupy an important place in the food basket of Indian consumers, a majority of whom are vegetarian by either choice or lack of access. This persistent vegetarianism coupled with rising per capita income is fuelling a rapid growth in consumption of vegetables.

Growing demand for vegetables is considered to have a favourable economic effect on smallholders who dominate the Indian agriculture scenario. Smallholdings comprising 78 per cent of the total holdings with an area share of 33 per cent, contribute more than half of the production of fruits and vegetables (Singh *et al.,* 2002). Smallholders have a distinct advantage in vegetable production; vegetable cultivation is labour-intensive and smallholders have abundant labour. Moreover, most of the vegetables have a short crop-cycle and therefore provide returns round the year.

Notwithstanding these advantages, smallholders confront a number of constraints in vegetable production. The production risks are high, primarily because of considerable production losses caused by pests. These are estimated to be about 30 per cent of the total vegetable output (Alam, 2001). The post-harvest losses are also quite high due to their perishable nature. There is a lack of marketing and processing infrastructure. Local markets are thin, and trading in distant markets is non-remunerative due to high transportation costs. Also, prices are volatile and often fall drastically with harvesting of normal production of vegetables.

This paper presents a holistic view of the vegetable sector in India in terms of consumption, production, marketing and value-addition. Section 2 describes demand and supply of vegetables in India. Section 3 presents the major constraints in the growth of vegetable sector, which is followed by discussions relating to vegetable export and processing of vegetables. And, finally the main conclusions and policy implications are outlined in Section 5.

Demand and Supply of Vegetables

Demand for Vegetables

The growing population and their improving economic status are causing a rapid growth in demand for vegetables in India. The annual per capita consumption of vegetables increased from 47 kg in 1983 to 76 kg in 1999 and in this, a considerable increase was due to the consumption of leafy vegetables (Table 2.1). The consumption of bulbs and tubers too witnessed a significant growth. On the other hand, the consumption of cereals remained stable during this period. The growth in per capita vegetable consumption was higher than that of milk, meat and fish.

The increase in consumption of vegetables during the period 1987-88 to 1999-00 was higher in the rural than urban areas, because of relatively higher consumption of livestock and fish products, and fruits in the urban areas. The overall increase in vegetable consumption was about 53 per cent during this period.

Table 2.1. Per capita monthly consumption of food items in rural and urban India

(quantity in kg)

Commodity groups	Rural		Urban	
	1999-00	**1987-88**	**1999-00**	**1987-88**
Foodgrains				
Cereals and millets	11.24	11.29	9.55	9.63
Pulses	0.67	0.72	0.85	0.87
Non-cereals and plant foods				
Leafy vegetables	0.46	0.08	0.40	0.17
Other vegetables	1.25	0.98	1.90	1.39
Total vegetables	1.71	1.06	2.30	1.56
Bulbs and tubers (onion & potato)	2.19	1.56	2.04	1.61
Fruits				
Banana (number)	2.48	0.21	5.0	5.10
Mango and apple	0.10	-	0.24	0.07
Fat and oils	0.44	0.29	0.63	0.45
Livestock products				
Meat products	0.15	0.11	0.36	0.26
Milk (litre)	3.79	3.20	5.10	4.26
Sugar and jaggery	1.08	0.82	1.32	0.97
Total food items	21.38	19.21	22.61	19.85

Source: NSSO Consumer Survey Reports, Various Rounds

Table 2.2. Vegetable demand elasticities in India – A chronological study

Reference	Place/group	Vegetable	Price elasticity	Income elasticity
Ramamurthy (1974)	Orissa	Tomato	–0.3968	0.6977
		Eggplant	–0.6083	0.2364
Srinivasan (1987)	All India, Rural	All vegetables	–0.2138	0.3836
	All India, Urban	All vegetables	–0.4030	0.9654
Mani and Vardarajan (1989)	Tamil Nadu (Coimbatore district)	Eggplant	–0.2961	0.3116
		Lady's-finger	–0.0589	0.4965
		Tomato	–0.7231	0.2322
		Carrot	–0.9814	1.3671
		Cauliflower	–0.9876	1.1823
		Beans	–0.1085	1.0746
	Low income (< Rs 9000)	Amaranths	–0.2135	0.9835
	High income (> Rs 15000)	Amaranths	–0.6713	–0.4713
Banumathy (1991)	Karnataka	Lady's-finger	–0.1387	0.4713
Nagarajan (1994)	Tamil Nadu	All vegetables	–0.5658	0.9907
Kumar *et al.* (2002)	All India, Rural	All vegetables	–0.28	
	All India, Urban	All vegetables	–0.30	

The income and price elasticities of demand are used to assess the effects of policy-induced changes on the consumption of vegetables. The demand elasticities estimated by various researchers are presented in Table 2.2.

The price elasticity varied in the range – 0.21 to – 0.57 for all vegetables, and individually from – 0.05 for lady's-finger to – 0.99 for cauliflower. The price elasticities were found higher for high income group and urban consumers. The demand for most of the vegetables was inelastic (i.e. income elasticity was less than one) with respect to change in income, except for carrot, cauliflower and beans.

Supply of Vegetables

India is the second largest producer of vegetables in the world, next only to China. Presently, India occupies 12 per cent of the total area and produces 10 per cent of the vegetable production in the world. In absolute terms, the country is producing about 92 million tonnes (Mt) of vegetables from an area of around 6 million hectares (Mha). The average productivity of important vegetables is, however, low if compared to the world average

Table 2.3. India's position in the world vegetable production during TE 2001

Vegetables	India's share (%)		Yield (tonnes/ ha)	
	Area	Production	World	India
Eggplant	39.34	35.69	16.23	14.70
Cauliflower	34.38	31.57	18.56	17.00
Peas (green)	32.40	34.28	8.27	9.23
Onion	17.73	15.16	16.90	10.27
Cabbage	11.29	10.16	23.90	21.30
Potato	6.77	7.17	16.27	17.20
Total vegetables	12.26	9.92	16.70	13.52

Source: www.fao.org

(Table 2.3). The average yield of most of the vegetables is 70-80 per cent of the world average. The yields in peas and potatoes are slightly better.

(i) Trends in Vegetable Production

In the year 2000, the vegetable production in India was 92.8 million tonnes, grown over an area of 6 million hectares, which is about 3 per cent of the gross cropped area of the country. Between 1993 and 2000, the total vegetable output increased by 28.9 Mt, of which about one-fifth was on account of increase in potato production (Table 2.4). Potato is the most important vegetable crop in India; it occupied 20 per cent of vegetable

Table 2.4. Trends in the production of vegetables in India during 1993-2000

Vegetables	Production (Mt)		Change in production		Share in total production (%)	
	1993	2000	Quantity (Mt)	Per cent	1993	2000
Brinjal	5.92	7.96	2.04	7.1	9.3	8.6
Cauliflower	3.24	5.07	1.83	6.3	5.1	5.5
Cabbage	3.28	6.62	3.34	11.6	5.1	7.1
Tomato	4.63	8.02	3.39	11.7	7.2	8.6
Okra	2.77	4.43	1.66	5.7	4.3	4.8
Peas (green)	1.50	2.75	1.25	4.3	2.3	3.0
Potato	19.29	24.80	5.51	19.1	30.2	26.7
Onion (dry)	4.92	4.78	-0.14	-0.5	7.7	5.2
Others	18.36	28.38	10.02	34.7	28.7	30.6
Total	63.91	92.81	28.90	100.0	100.0	100.0

area and contributed 27 per cent to the total vegetable production in 2000. Nevertheless, vegetable production has been diversifying gradually. The share of potato in total vegetable production has been declining, while that of other vegetables has been rising steadily. Cabbage and tomato each registered a change of over 11 per cent during this period.

(ii) Growth Performance of Major Vegetables

A study of decade-wise growth trends has indicated that during the 1980s, vegetable production increased at an annual rate of about 4 per cent (Table 2.5), which rose to about 5 per cent during the 1990s. Both area expansion and yield increase contributed to this growth, although the contribution of yield slowed down during the 1990s. The growth in the yield of total vegetables decelerated from about 2 per cent in 1980s to 1.50 per cent during the 1990s. On the other hand, fruits registered an impressive increase in their yields, as well as areas during the 1990s.

The growth in the area under tomato, peas and cauliflower during 1980s was more than 3 per cent (Table 2.5). The area under cabbage, potato,

Table 2.5. Annual compound growth rates of major vegetables and other food items in India

(per cent)

Vegetables	1980s		1990s	
	Area	Yield	Area	Yield
Cauliflower	3.58	2.16	7.83	0.73
Cabbage	2.92	0.07	2.08	0.79
Cucumber	1.90	0.40	1.06	0.14
Eggplant	1.72	1.95	8.73	0.26
Tomato	6.17	4.91	6.33	1.87
Onion (dry)	2.73	-0.29	4.40	-0.95
Potato	2.90	2.21	3.84	1.54
Okra	2.30	0.95	-1.61	6.94
Peas (green)	3.25	2.31	4.11	-4.25
Sweet potato	-4.24	0.66	-1.68	1.17
Others	0.47	2.07	2.89	1.54
Total vegetables	1.82	1.99	3.61	1.50
Cereals	-0.12	3.31	0.05	1.97
Pulses	0.09	1.41	-0.37	0.51
Oilseeds	3.02	2.70	-0.76	1.31
Fruits	0.75	1.99	2.31	3.37
Fibre crops	-1.16	3.23	1.71	0.75

okra and onion increased in the range of 2 to 3 per cent a year. The rate of decrease in area under sweet potato slowed down during the 1990s, while the growth rates in area, except in the case of cucumber and okra, improved during this period. There was a considerable growth in vegetable crops during 1980s and 1990s. Yield was the major source of output growth for tomatoes, cauliflower, brinjal and potatoes during 1980s; however, this decelerated significantly during 1990s, and became stronger in case of cabbage and okra.

(iii) Regional Production Patterns in Vegetables

The state-wise vegetable area as percentage of gross cropped area (Table 2.6) revealed that it was highest in Orissa (9%), followed by Bihar (5.75%), and West Bengal (5.7%). At all India level, vegetables occupied less than 3 per cent of the total cropped area.

The regional distribution of area and production showed their concentration in the eastern states, viz. West Bengal, Orissa and Bihar. These together accounted for 44 per cent of the area and 45 per cent of the output in the country. The eight states mentioned in Table 2.6 together contributed about three-fourths of the area and production of vegetables in the country.

Table 2.6. State-wise vegetable area and production in India

States/ Union Territories	Vegetable area as per cent of gross cropped area	Percent share in all India	
		Vegetable area	Vegetable production
West Bengal	5.68	18.65	19.44
Orissa	9.07	14.63	11.49
Uttar Pradesh	3.35	11.27	14.00
Bihar	5.75	10.56	10.85
Maharashtra	1.01	5.74	5.03
Karnataka	2.45	5.53	6.65
Madhya Pradesh	0.76	4.00	3.85
Tamil Nadu	2.79	3.40	6.15
Other states and Union Territories	3.34	26.32	22.54
All India	2.85	100.00	100.00

Source: Indian Agriculture in Brief, 2000 (Table 17.1), and Indian Agriculture, 1999 (Vikas Singhal for Economic Data Research Centre, New Delhi)

Note: The figures for Uttar Pradesh, Bihar and Madhya Pradesh are for undivided states.

Substantial changes took place in the regional shares during 1990s (Table 2.7). The share of Bihar which was 20 per cent in 1993, declined to 11 per cent in 2000. Similar was the case with Orissa and Kerala. On the other hand, West Bengal, Andhra Pradesh, Haryana and Tamil Nadu strengthened their positions in vegetable production during this period. The shares of other states remained almost unchanged.

Table 2.7. Trends in production of vegetables by states in India

States	Production (Mt)		Change in production during 1993-2000		Share in total production (%)	
	1993	2000	Quantity (Mt)	Per cent of total	1993	2000
Bihar	12.82	9.73	-3.09	-10.7	20.1	10.5
Uttar Pradesh	10.31	16.15	5.84	20.2	16.1	17.4
Orissa	7.67	9.09	1.42	4.9	12.0	9.8
West Bengal	6.54	17.19	10.65	36.8	10.2	18.5
Karnataka	4.23	5.83	1.60	5.6	6.6	6.3
Maharashtra	3.49	4.82	1.33	4.6	5.5	5.2
Tamil Nadu	3.05	5.79	2.74	9.5	4.8	6.2
Kerala	2.97	2.75	-0.22	-0.8	4.7	3.0
Other states	2.64	4.33	1.69	5.9	4.1	4.7
Madhya Pradesh	2.27	3.47	1.20	4.1	3.6	3.7
Assam	1.93	2.87	0.94	3.2	3.0	3.1
Gujarat	1.70	2.99	1.29	4.4	2.7	3.2
Punjab	1.54	2.17	0.63	2.1	2.4	2.3
Andhra Pradesh	1.41	3.18	1.77	6.1	2.2	5.0
Haryana	1.02	2.05	1.03	3.5	1.6	2.2
Rajasthan	0.32	0.42	0.10	0.33	0.5	0.5
Total	63.91	92.80	28.89	100.0	100.0	100.0

(iv) Availability of Vegetables

Although the consumption of high-energy commodities like eggs, poultry, fish and meat products has increased considerably in the recent past, a majority of Indians are still dependent on vegetables for their primary source of vitamins and minerals, besides milk and milk products. The net availability of vegetables in India is shown in Table 2.8. The production of vegetables, excluding melons, and their net availability increased at the rate of 4.9 per cent per annum between 1980 and 2000. The exports also increased at the rate of 5.3 per cent annually, but the actual quantity of export was too small to make any difference in the net availability of

Table 2.8. Per capita availability of vegetables in India, 1980-2000

Year	Total production (Mt)	Exports (Mt)	Net availability (Mt)	Population in millions	Per capita availability (kg/year)
1980	40.08	0.20	39.88	675.2	59.07
1981	40.40	0.17	40.22	688.5	58.42
1982	41.30	0.19	41.11	703.8	58.41
1983	47.10	0.19	46.92	718.9	65.26
1984	48.17	0.28	47.89	734.5	65.21
1985	42.99	0.21	42.78	750.4	57.01
1986	48.48	0.27	48.22	766.5	62.91
1987	53.28	0.14	53.14	782.7	67.89
1988	56.02	0.29	55.74	799.2	69.74
1989	56.53	0.36	56.17	815.8	68.86
1990	64.63	0.30	64.33	832.6	77.26
1991	69.04	0.39	68.65	851.7	80.60
1992	70.38	0.29	70.09	867.8	80.77
1993	74.67	0.38	74.30	883.9	84.06
1994	72.38	0.45	71.94	899.9	79.94
1995	81.89	0.42	81.47	922.0	88.36
1996	87.37	0.49	86.88	941.6	92.27
1997	89.01	0.43	88.59	959.8	92.30
1998	97.89	0.49	97.40	978.1	99.58
1999	92.20	0.36	91.84	996.4	92.17
2000	90.35	0.42	89.92	1014.8	88.61
Growth rate (%)	4.92	5.29	4.92	2.07	2.79

vegetables in the country. The population growth in India has been about 2 per cent per annum, and annual per capita availability of vegetables has grown at the rate of 2.8 per cent and most of this increase occurred during the 1990s. There also have been ups and downs in the per capita availability of vegetables during the 1990s; it reached about 100 kg per year (or 271 grams per day) in 1998 from 59 kg in 1980, but came down to about 90 kg in 2000.

Constraints in Vegetable Sector

In this section constraints in the vegetable sector and marketing channels of vegetables have been discussed. The commodity and region-specific constraints for the vegetable sector are summarized in Tables 2.9, 2.10 and 2.11.

Table 2.9. Major constraints in production and marketing of vegetables in India

S.No.	Production constraints	S. No.	Marketing constraints
A	**Infrastructure**	**A**	**Infrastructure**
1	Non-availability of good quality seeds	1	Lack of rural roads
2	Inadequate irrigation	2	Lack of cold storage facilities
3	Lack of soil testing facilities	3	Lack of refrigerated transport vans
4	Lack of extension staff and technical guidance	4	Inadequate space
		5	Inadequate processing capacity
		6	Poor market intelligence
B	**Technological**	**B**	**Technological**
5	Loss due to insect pest incidence	7	Lack of mechanical grading and packaging
6	High yield variability	8	Lack of post-harvest management and processing technologies
7	Lack of suitable varieties	C	**Economic**
8	Non-availability of location-specific recommendations	9	Costly transportation
9	Non-availability of effective fungicides to control rot diseases	10	High cost of packaging material
10	Inadequate and unbalanced manuring	11	High price risks (post-harvest losses)
C	**Economic**	**D**	**Administrative**
11	Shortage of skilled labour	12	Faulty weighing mechanism and price discounting
12	Lack of bank facilities	13	Delayed sale and payments
13	High cost of production	14	Lack of market information and regulation
14	Shortage of capital to purchase farm inputs	15	Lack of forward trading
D	**Education**		
15	Lack of information on weather and technical know-how		

Table 2.10. Major constraints in production of vegetables

Vegetables studied	Region	Study year	Production constraints*															Reported by
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Sweet potato	Punjab	1970							*	*								Pandey and Jauhari (1970)
Potato	Jammu & Kashmir	1972							*					*		*		Chohan (1972)
Onion	Haryana	1983		*					*		*							Madan and Sandhu (1983)
Eggplant	Tamil Nadu	1991	*						*		*				*		*	Banumathy (1991)
All vegetables	India	1992	*						*	*		*				*		Singh and Seshadri (1992)
Off-season vegetables	Himachal Pradesh	1992	*	*	*	*	*	*										Thakur *et al.* (1994)
Tomato	Haryana	1996							*	*							*	Dixit *et al.* (2002)
Major vegetables#	Himachal Pradesh	1998	*	*					*		*	*					*	Singh and Vashist (1999)

= Includes tomato, cauliflower, potato, radish, turnip, colocasia.
* The names of specific constraints are given in Table 2.9.

Table 2.11. Major constraints in marketing of vegetables

Vegetables studied	Region	Study year	Marketing constraints*															Reported by
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Sweet potato	Punjab	1970							*	*								Pandey and Jauhari (1970)
Off-season vegetables	Himachal Pradesh	1992	*				*	*	*					*		*		Thakur *et al.* (1994)
All vegetables	Gujarat	1995						*							*			Shiyani et al. (1998)
Potato	Madhya Pradesh	1996								*		*	*					Verma (1996)
Tomato	Haryana	1996					*	*					*		*	*	*	Dixit *et al.* (2002)
Major vegetables#	Uttar Pradesh (Hills)	1997			*			*	*	*		*	*			*		Kumar and Arora (1999)
Potato	Madhya Pradesh	1998									*		*					Verma *et al.* (2002)
Major vegetables ##	Himachal Pradesh	1998			*			*						*	*	*		Singh and Vashist (1999)

\# include potato, cauliflower, green pea, radish, carrot and capsicum
\## include tomato, cauliflower, potato, radish, turnip and colocasia
* The names of specific constraints are given in Table 2.9.

(i) Production Constraints

The most important problems in the production of vegetables were losses due to insect pest incidence, non-availability of quality seeds, inadequate irrigation facilities, high variations in yield, lack of suitable location-specific varieties, etc. Some studies also reported lack of soil-testing facilities, shortage of skilled labour, and non-availability of capital to purchase farm inputs (Table 2.10).

(ii) Marketing Constraints

In India, 90-98 per cent of vegetables were found to be sold and used afresh, except roots and tubers of which a considerable proportion was saved for seed (Subramanian *et al.,* 2000). The high volume and perishability of vegetables posed several problems in their marketing. Other problems included lack of market intelligence, price risks, delayed sale and payment, lack of processing and high cost of packaging materials, etc. (Table 2.11).

(iii) Marketing Channels

As many as 14 marketing channels have been identified by the different research studies for disposal of vegetables from producers to consumers (Figure 2.1). Channel (1) involving the shipper was important for distant markets. Channels (1) to (3), (10) and (11) involved commission agents who usually bought on behalf of the wholesalers. Channels (12), (13) and (14) were found more prevalent where production was consumed locally and were least important because they served only the limited local markets. The information on the relative shares of different channels in the total marketed surplus was scarce and scattered. A study (IIHR, 1989) conducted in Karnataka, Andhra Pradesh and Tamil Nadu showed the dominance of commission agents in vegetable marketing system. About 92 per cent farmers in Karnataka and 62 per cent each in Andhra Pradesh and Tamil Nadu sold vegetables through commission agents. In Andhra Pradesh, 22.6 per cent farmers sold their output to the wholesalers in markets and 15.4 per cent sold to the retailers at the farm gate. In Tamil Nadu, 21 per cent farmers sold through pre-harvest contracts (all farmers growing cabbage and carrot), and one-tenth sold to retailers (all farmers growing cauliflower). Only three per cent of the farmers made pre-harvest contracts, mostly for cabbage and cauliflower, and 5 per cent (mostly for lady's-finger) sold their output to retailers in Karnataka.

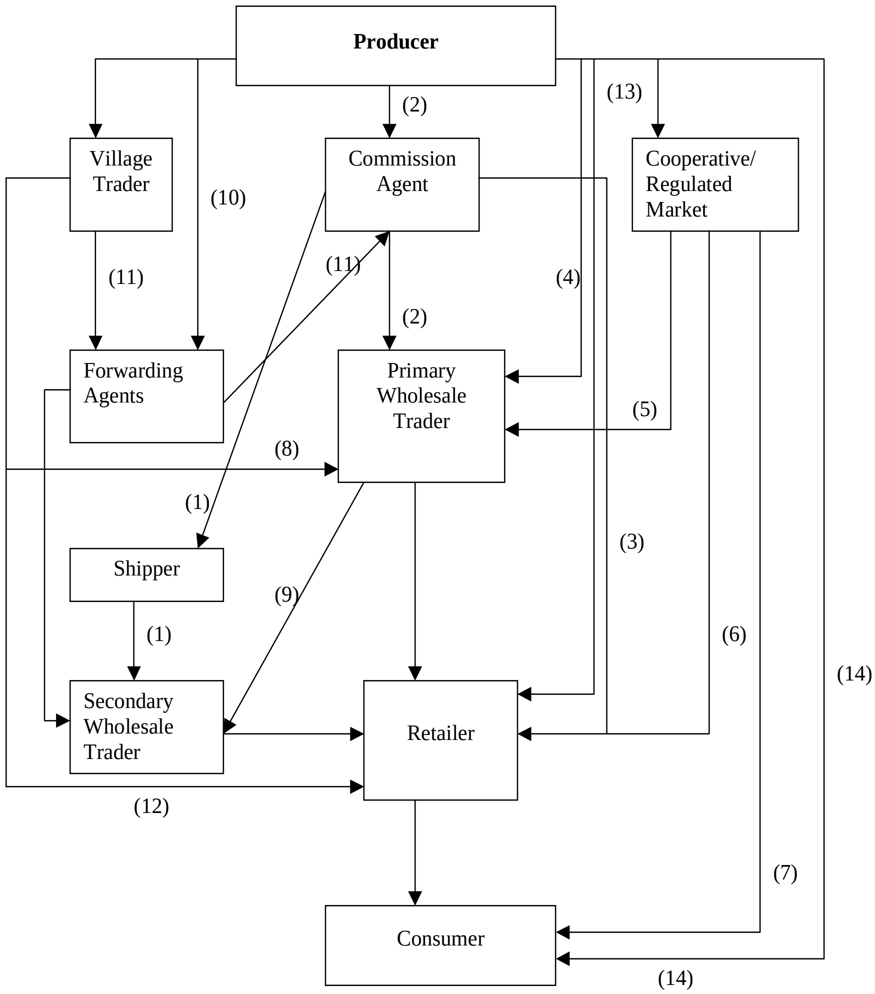

Figure 2.1. Marketing channels for vegetables in India

Price Spread in Vegetables

The producers' share in the retail price was an important measure to assess the market efficiency. It was influenced by the factors like value-addition in output, efficiency of marketing operations, profit margin, etc. Also, the transportation costs and losses in various marketing operations were quite high in vegetables. An idea about the marketing efficiency can be obtained from the producers' share in retail price given in Table 2.12.

Table 2.12. The producers' share in consumer prices in marketing of vegetables in India

Reported by	Area covered	Crops	Producers' share (%)	Remarks
Kasar *et al.* (1994)	Maharashtra	Bitter gourd	41	Bombay market
Thakur *et al.*(1994)	Himachal Pradesh	Tomato, Cauliflower/ Cabbage Capsicum Peas	46 46 52 48	Off – season vegetables in Delhi market
Mishra *et al.* (1995)	Kalahandi in Orissa	Onion	87 40 38	Channel K1* Channel K2 Channel K3
Singh and Kharwal (1995)	Himachal Pradesh	Chillies Cauliflower Tomato Peas	81(44)** 62 (47) 57 (44) 80 (80)	1970 (1994) 1970 (1994) 1970 (1994) 1970 (1994)
Dahiya (1995)	Allahabad, Unnao and Varanasi	Potato	77 (48)	1968 (1983)
Vasisht *et al.* (1995)	All India	Potato	35 69	Harvesting season Off-season
Yadav and Pant (1995)	Alwar (Rajasthan)	Onion	31 30	Place connected by road Place not connected by road
Prashad and Krishna (1995)	Bihar	All vegetables	61	-
Jairath *et al.* (1995)	Rajasthan	Cabbage Cauliflower	81 62	-
Maurya *et al.* (1995)	Varanasi (Uttar Pradesh)	Lady's-finger	59	Varanasi (Uttar Pradesh)
Marothia *et al.* (1996)	Madhya Pradesh	Tomato Brinjal	53 (58) 56 (67)	Shastri market (Subash market) Chhattisgarh region (1991-92)
Shiyani *et al.* (1998)	Gujarat	Brinjal Bottle gourd Cabbage Tomato Chilies	59 60 62 57 61	Kharif season of 1995
Shelke and Kalyankar (2000)	Maharashtra	Brinjal Cauliflower Potato Tomato Green chilies	45 42 41 58 47	June 1997 to May 1998
Verma *et al.* (2002)	Madhya Pradesh	Potato	65	1997-98

* The three channels in Kalahandi are:
K1- Producer-Consumer; K2- Producer-Village trader-Consumer; K3- Producer-Village trader-Wholesaler-Retailer-Consumer

** Figures within the parentheses in this column correspond to the year; market is indicated within the parentheses in the last column.

The following points emerged from the study:

(i) Farmers selling the produce directly to consumers received higher prices.

(ii) Farmers' share was higher in off-season than main season (Vashist *et al.,* 1995).

(iii) Connecting markets by road had only marginal effect on producers' share in retail price (Yadav and Pant 1995).

(iv) Vegetables like onion, cabbage, and peas had high producers' share in retail price.

(v) As the number of involved agents increased, the producers' share in retail prices fell drastically (Mishra *et al.,* 1995).

Suggestions to Improve Producers' Share in Retail Prices

To improve the producers' share in consumer prices, following suggestions have been offered by different researchers (Thakur *et al.* 1994; Kasar *et al.* 1994; Shiyani *et al.* 1998; Bhupal *et al.* 2000; and Verma *et al.* 2002):

- Develop strong vegetable network at priority.
- Provide a platform to sell vegetables through cooperative marketing
- Curb malpractices.
- Create healthy competition.
- Establish processing units.
- Vegetables like potatoes, with long storage-life may be supplied under cold chain facilities, so that farmers may sell their produce when the price is high.

Export of Vegetables

The quantity and value of the vegetables exported from India are reported in Table 2.13. It is clear from this Table that only a small fraction of the total vegetable production was being exported. It was, however, found that export of vegetables was growing at an annual rate of 2.6 per cent in quantity and 6.6 per cent in value terms. But there was a considerable instability. The coefficient of variation was estimated to be 15.4 per cent

Table 2.13. Export of vegetables from India, 1991-2000

Year	Export		Total vegetable production	
	Quantity (Mt)	Value, US $ (million)	Quantity (Mt)	Export share in production (%)
1991	0.39	66.70	61.66	0.64
1992	0.29	45.94	63.47	0.46
1993	0.38	62.50	66.61	0.57
1994	0.45	75.28	69.16	0.64
1995	0.42	85.81	73.38	0.57
1996	0.49	92.73	79.67	0.61
1997	0.43	82.93	81.65	0.52
1998	0.50	106.18	86.73	0.57
1999	0.36	76.73	88.99	0.41
2000	0.44	93.23	92.01	0.48
Annual compound growth rate (%)	2.6	6.6	4.9	-
Coefficient of variation (%)	15.4	22.9	14.4	-

in quantity and 22.9 per cent in value. The share of vegetable imports in total vegetable production was about 0.50 per cent during 1990s, it was still less during the 1980s.

There is a large demand for some high-value vegetables in the international markets. India can harness this opportunity by reaching foreign markets with good quality products; she has a comparative advantage in terms of labour costs and diverse agro-climatic conditions. The following vegetables may be accorded special attention for export:

- French bean and lima bean: Fresh for domestic and gulf markets, and processed and frozen, for the European markets
- Sweet corn: Fresh for domestic and gulf markets
- Bell pepper: Fresh for the domestic and gulf markets
- Brussels sprouts: Fresh for the European markets
- Broccoli: Fresh for European markets

Following other measures would help promote the vegetable trade in domestic and foreign markets:

(i) Development of high-yielding varieties, and cost-effective post-harvest technologies, promotion of such products as are more suitable for export (for example, low pungency chilli and ginger with low fibre content), identification of potential markets, compulsory quality control, and proper policies to stabilize production and export.

(ii) Protection of breeders' and farmers' rights through legislation on vegetable breeding and seed production.

(iii) Solving the problem of malnutrition through effective food and nutritional policies to achieve nutritional security at the household levels.

(iv) Achieving of more efficient processing and generating additional vegetable demand. It would require

- Maintenance of growth in the number of processing units
- Utilization of full capacity of the processing industry
- Maintaining strict quality control to keep hold on overseas markets
- Cost reduction to make processed products available at reasonable prices to domestic consumers
- Nutrition education to increase awareness among consumers regarding the importance of balanced diets, with special emphasis on child nutrition.

Vegetable Processing

Most of the vegetables produced in India are sold afresh (GoI 1989). The processing infrastructure is inadequate and value-addition is low. The installed capacity of the fruit and vegetable processing industries was of 1.4 million tonnes in 1995 and 2.2 million tonnes in 2000. This utilization capacity is still lower. It has been estimated that only about 1 per cent of the vegetable output was being processed commercially (Verma *et al.* 2002). This quantity is much less than the product processed in many developed and developing countries. For example, in Brazil, about 70 per cent of the vegetable produce is processed and in the USA, it is 65 per cent. Preference for the processed vegetables is also picking up in India due to rise in income, changes in the consumer tastes, food habits and life-style, convenience, more consciousness about nutritional value and purchasing power, etc. It is expected that this demand would be about

15-20 per cent in the long-run. The sectoral consumption for processed fruits and vegetables would be as follows: domestic 30 per cent, institutions (including defence) 40 per cent and exports 30 per cent. And to cope up with this demand, medium to large-scale units would replace the small-scale processing units.

It has been projected that there is a good potential in domestic and export trades of processed vegetables, if appropriate policy action is undertaken. The major thrust in the processing of vegetables should be on value-addition, employment generation, diversification of rural economy and acceleration of rural industrialization. The significance of food processing industry is increasing due to rapid urbanization, breaking down of joint family system, increasing cost of household labour, increasing number of working women and rising per capita income. These have all contributed to change in the food demand patterns. To achieve the needed success in vegetable processing, the components of total quality management such as quality control, quality system and quality assurance deserve special attention.

Future Thrusts

Use of Agro-chemicals

There is a growing concern about environmental safety on one hand, and use of modern technology for raising agricultural production on the other. Perhaps the maximum concern has been shown regarding the use of agrochemicals, i.e. chemical pesticides and fertilizers. To achieve the required increase in yield, use of integrated nutrient and pest management along with good quality seed/ planting material is necessary. There are reports about high use of fertilizers in vegetable production (Singh 1991); it not only affects the quality but also the taste. In addition, it promotes pest infestation. The quantity of needed fertilizers varies according to regions and vegetable crops. The recommendations for fertilizer-use need to be made location-specific and based on the requirement. The vegetable productivity is also affected by the infestation of pests and diseases. Chemical protection method in isolation has been found to be less effective against shoot and fruit borers in eggplant, lady's-finger and tomato and fruit flies in cucurbits. This emphasizes the application of IPM in vegetable cultivation.

Seed Quality

The seed agencies in the public and the private sectors are contributing significantly to the overall improvement in vegetable productivity by providing good quality seeds. A large number of varieties of different vegetables have been released for cultivation in different regions of India. Although the National Seeds Corporation (NSC) is responsible for providing quality seeds for centrally released varieties at the national level, the handling of multiplication and distribution of quality seeds of a large number of vegetables is a difficult task. The quantity of different types of vegetable seeds handled by NSC is shown in Table 2.14. NSC also provides technical support to the seed growers for quality seed production and educates them through training, field demonstrations, etc. It is believed that the yield of vegetable crops could be improved significantly, up to 30 per cent according to Chaudhary (1975), if quality seeds of improved varieties could be made available.

Table 2.14. Handling of vegetable seeds by the National Seeds Corporation

(quintals)

Year	Breeder seeds		Foundation seeds		Certified seeds	
1993-94	692	1159	5520	5489	8139	6655
1994-95	1036	928	5275	4167	13785	8691
1995-96	763	1035	5278	5307	16133	13975
1996-997	801	773	8292	6639	18320	14879
1997-98	827	787	2654	4518	7406	10079
1998-99	1250	747	6732	4072	7213	8858
1999-00	681	1256	4664	4347	7869	7984
2000-01	597	687	2186	3456	5118	7555

Source: Annual Reports, National Seeds Corporation, New Delhi

Research Thrust

On the basis of literature reviewing and analysis done in this study, the following research areas need priority attention:

(i) Identification of cultivar resistant to pests and diseases as well as stress-tolerant with regard to production and processing.

(ii) Standardization of location-specific package of production practices for major vegetables.

(iii) Breeding for resistance to major pests and diseases.

(iv) Use of biotechnology for transfer of genes for resistance, root modulation and other specific traits.

(v) Determination of maturity standards of harvesting for processing and fresh markets.

(vi) Development of low-cost technologies for processing and storage.

(vii) Standardization of seed production technology for improved and hybrid seed production.

(viii) Effect of fertilizers on crop quality and post-harvest shelf-life under normal conditions.

(ix) Assessment of demand and supply of vegetables for domestic and export purposes across vegetables.

(x) Research on cultivation of vegetables in protected environments.

(xi) Research on off-season and under-exploited vegetables.

(xii) Research on export-oriented vegetables like onion, chillies, okra, peas, tomato, brinjal, cucumber, cauliflower, etc.

Conclusions and Policy Implications

There has been a substantial increase in the annual per capita consumption of vegetables in India; the growth being much higher than that in milk, meat and fish. The price elasticity of demand of vegetables has been found higher for urban consumers than rural consumers and demand for most of the vegetables is inelastic with respect to income. Although India is the second largest producer of vegetables in the world, the average productivity of important vegetables is much lower than the world average. Further, the yield growth has been the major source of production growth during the 1980s, but its slowing down during the 1990s is a cause to worry.

Vegetable production has been affected by several production and marketing constraints. Among these most important production constraints are losses from pests, lack of quality seeds and irrigation facilities and high variations in yields. Among the marketing problems, lack of information, price risks, delayed sale and payment and lack of processing facilities and packaging are important. Since about half of the vegetable production is contributed by the eastern states of West Bengal, Bihar and Orissa, which have inadequate rural infrastructure and erratic weather, the marketing constraints are a big hindrance. Addressing these constraints and improving marketing efficiency through a better infrastructure and institutional reforms would go a long way in increasing vegetable production in the country. Augmenting the processing capacity and developing varieties of vegetables for processing would further improve the status of the vegetable sector, and enhance employment opportunities in the rural areas.

Several policy implications have emerged from this study. Since the vegetable consumption would be increasing due to growth in urbanization, and shift in dietary patterns, the rise in production of vegetables has to be stepped up to 123-129 Mt by 2011 and 139-149 Mt by 2016 to meet the domestic and export demands. As there is a limited scope to increase area under vegetables in the traditional vegetable growing regions, the future growth in the production is possible only by bringing additional area under vegetables in the non-traditional pockets like IGP and reducing post-harvest losses. Efficient post-harvest management of the produce and value-addition are essential for growth of the vegetable sector. Finally, increase in the productivity would be required to sustain the growth in the long-run, and augmenting the research efforts would play an important role in achieving this growth objective.

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3. Growing Vegetables: Role of Research*

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Background

Vegetables can contribute largely towards food and nutritional security of the people, particularly the poor. With a focused attention on the vegetable sector, there has been a spectacular change in terms of production and availability of vegetables. India, today, is the second largest producer of vegetables in the world, after China, contributing about 10 per cent to the world vegetable production. Vegetable production in the country increased from mere 19 million tonnes in TE 1962-63 to 92 million tonnes in TE 2000-01. Simultaneously, the per capita annual vegetable production has reached 91 kg in TE 2000-01 from just 43 kg in TE 1962-63 (Figure 3.1). The vegetable consumption has also increased by 2.9 per

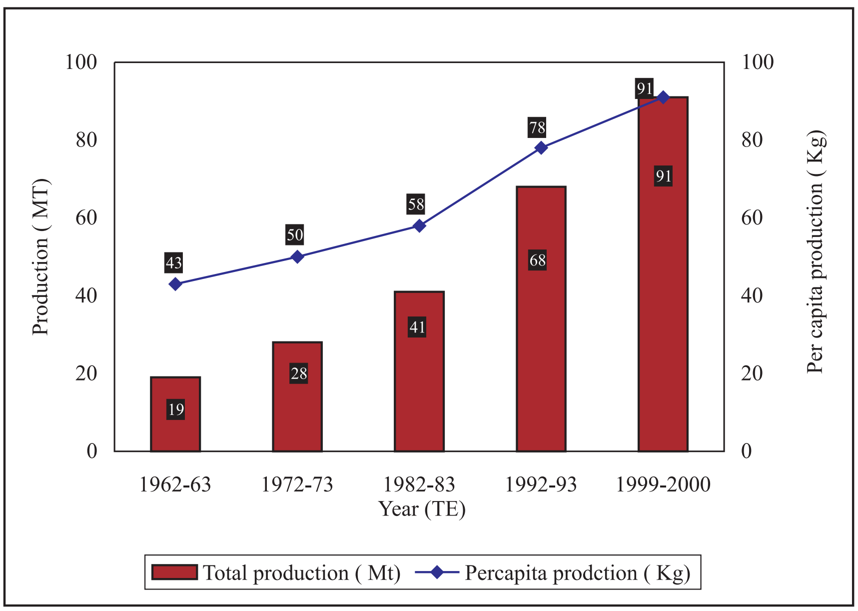

Figure 3.1. Vegetable production in India, 1962-63 to 1999-2000

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cent annually during 1984-2000 and interestingly, this consumption has increased comparatively at a higher rate among the poor consumers. The demand for vegetables is growing due to urbanization, increasing globalization and income levels. To meet the growing demand, we need to produce 123-129 million tonnes of vegetables by the year 2011, and 139-149 million tonnes by 2016 (Kumar *et al.,* 2002). With the diverse agro-climatic conditions that we have in the country, these targets are not very difficult to achieve, provided appropriate policy framework and infrastructure support is created. Further, in view of the changing food basket, diversification in production for sustained increase in income and employment, as well as promotion of value-addition and export, the role of vegetables has become more important than it was in the past. High labour-intensity in vegetable production offers a good scope for generating more employment opportunities for small and marginal farm holders in India.

Emerging Needs

Offing of the world trade reforms has thrown several new challenges on both the demand and the supply of vegetables, particularly in a developing country like India. Rapid urbanization, increasing per capita income and diversifying food basket on the demand front, and declining landholding size, and productivity of scarce natural resources like soil and water on the supply side induce the farmers to include vegetables in their existing farming systems. Being a labour-intensive activity, it is expected that vegetable production would augment income and employment opportunities on small farms, whose strength is the 'abundant labour'.

To document the impact of vegetable research in the country, a workshop on '*Impact of Vegetable Research in India*' was organized at the Indian Institute of Vegetable Research, Varanasi, during March 2002. The following were the objectives (i) to develop an inventory of successful, potential and pipe-line technologies of different vegetables in various target domains, (ii) to document evidences of impact of improved vegetable technologies, and (iii) list key economic and marketing constraints in vegetable research. Sixty-four papers were contributed in multiple areas like varietal and technological development, prospective technologies, energy requirements in vegetables, constraints in vegetable production and marketing, prospects of growing off-seasons vegetables, emerging institutional arrangements in vegetables, future requirements of vegetable production, etc. More than 70 vegetable scientists and economists, research managers, policy administrators and others attended the workshop from different parts of the country. This report is a synthesis of the workshop proceedings.

Research Efforts in Vegetable Crops

Efforts have been made to establish a sound infrastructure for agricultural research in the country since independence. These involved creation of a research system in the form of central institutes, state agricultural universities, coordinated research projects and *ad-hoc* research schemes. The research on vegetable crops in India was initiated in 1947-48 by the Indian Council of Agricultural Research (ICAR) with the sanctioning of a nucleus "Plant Introduction Scheme" at Indian Agricultural Research Institute (IARI), New Delhi. Simultaneously, the ICAR also started *ad-hoc* research schemes in different states like Himachal Pradesh, Jammu and Kashmir, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal. A more systematic research on vegetables was, however, organized with the creation of the Division of Horticulture at the Indian Agricultural Research Institute, New Delhi in 1956-57. It received a boost with the establishment of the 'Indian Institute of Horticultural Research' with a full-fledged Division of Vegetable Crops at Bangalore in 1968. The establishment of a several agricultural universities and AICRP on vegetables gave further fillip to vegetable research in the country.

Evidences of Vegetable Research in India

The establishment of vegetable research infrastructure in the country has led to the development of a number of improved production, protection, value-addition and post-harvest management technologies by the public sector institutions. The contribution of private sector research has been meager, confined only to a few inputs like seeds. However, these research contributions are scattered and not well documented. There is a need to document the empirical evidences on the adoption pattern, economic feasibility, impact and constraints in the vegetable sector and suggest suitable policies to augment production, processing, marketing and trade.

Impact on Technological Development

There has been an impressive record of the release of varieties by the ICAR institutions and SAUs in India. Under the All India Coordinated

Vegetable Improvement Project (AICVIP), more than 250 varieties in 22 vegetable crops have been identified for cultivation in different agro-climatic zones of the country. Besides, 105 production technologies, 62 disease management and 28 insect management technologies have been evolved (Table 3.1). Indian Institute of Horticultural Research, Bangalore, has released a total of 76 varieties in 25 vegetable crops, 34 of which are being cultivated at the national level. In addition, a number of production and protection technologies have been developed to improve the productivity of vegetable crops. Mahatama Phule Krishi Vidyapeeth at Rahuri has also released 36 varieties/hybrids in different vegetables. Information is available that in Maharashtra, about 45-50 per cent area is under improved varieties of vegetables.

Varietal improvement has been one of the important priority areas for vegetable research in India. With the varietal improvement, hybrids for higher yields, pest and disease resistant, better processing and higher storage-life have been generated. For instance, hybrids of brinjal have shown better yield performance over the standard parents (*Pant Samrat*). Besides, yield enhancements, shelf-life improvement through packaging

Table 3.1. Vegetables technologies developed through AICRP, 1975-2001

Vegetable crops	Number of varieties	Technologies developed (number)		
		Production	Protection	
			Diseases	Insects
Tomato	49	26	11	2
Brinjal	57	6	6	7
Chillies	13	9	12	1
Capsicum	2	2	2	-
Pea	26	8	3	-
Cowpea	5	1	-	-
Frenchbean	6	2	1	-
Okra	11	7	8	9
Onion	15	16	11	5
Garlic	5	4	1	-
Cabbage	7	8	-	3
Cauliflower	14	7	2	-
Muskmelon	8	2	2	-
Watermelon	5	1	2	-
Other cucurbits	6	5	1	1
Carrot	-	1	-	1
Total	229	105	62	28

Source: Singh *et al.* (2002)

and low-cost improved storage environment and related aspects have also received attention in different vegetable crops. For instance, packaging of vegetables, viz. palak, methi and coriander in polythene bags and storing in a cool chamber, could improve the shelf-life by about 3 days over that at the room temperature.

New Niches for Vegetable Production

New niches are emerging for vegetable production with the availability of improved technologies, having traits of short duration, disease resistance, adaptability in varying temperature regimes, etc. For instance, temperate region of Jammu and Kashmir has favourable agro-climatic conditions and adequate irrigation facilities for vegetable cultivation. With intensive research and development efforts in the state, vegetable area has increased by 72 per cent, from 10.27 thousand hectares in 1980-81 to 17.70 thousand hectares in 1999-2000. The production during the same period has gone up from 1.98 lakh tonnes to 4.42 lakh tonnes. And if the region could be suitably supported by strong institutional arrangements, it would be one of the most potential areas for producing and exporting quality vegetable seeds in the country. A similar optimistic scenario has been projected for vegetables in Kerala. Some apprehensions have been raised that there was a limited scope for registering quantum jump in vegetable production in the traditional areas. Future thrust to increase vegetable production lies in the arid region where several improved and indigenous horticultural crops can be grown commercially. For instance, cole crops confined to temperate and subtropical areas have been extended to arid region through the development of heat-tolerant cultivars. Besides, with supplemental irrigation and adjustment in season, most of the vegetables like tomato, chilli, watermelon, muskmelon, and beans can be grown in many localized areas under arid situations. Kharif onion, watermelon, chilli and tomato in monsoon season have excellent potential for high quality in this region.

Impact on Pest Management Research

A significant proportion of potential production is lost due to insect pests, diseases and weeds. Owing to continued increasing incidence of these biotic stresses, the use of chemical pesticides has increased many folds. To reduce adverse effects of pesticides, pest management research has received significant attention since the early 1980s. Pests are damaging the production of crops heavily. To address the use of pesticides, research towards application of bio-pesticides and such other alternatives has been undertaken. As a result of the use of bio-pesticides, farmers could obtain 23 per cent higher yield and incurred 15 per cent less cost in cultivation of cabbage and realized 43 per cent higher net returns. In another technology on integrated pest management (IPM) in cabbage, use of chemical pesticides on IPM farms was lowered as compared to that on non-IPM farms. Unit cost of production was reduced by 5 per cent, mainly due to higher yield and cost-saving potential of IPM technologies. The positive impact of bio-pesticide was reflected in the form of lower incidence level of biotic stresses, higher crop productivity and high benefit-cost ratios. However, lack of adequate and timely supply of bio-pesticides and lack of timely expert advice were identified as the main constraints in switching over to using of bio-pesticides. Lack of quality and slow effects of bio-pesticides were also indicated as the major technological impediments.

Constraints in Vegetable Sector

The realization of yield potential depends primarily on the cumulative effect of factors responsible for the production process and has been reflected in the field level yield gap studies. A number of factors hindering the production and marketing of vegetables were reported in several studies. High incidence of pests and diseases, lack of credit, non-availability of quality inputs and their high price and lack of proper storage facilities were reported as the main production constraints. Lack of marketing facilities, wide price fluctuations, high commission charges, malpractices in the market, high costs of packaging material and high transport costs emerged as the major constraints in the way of marketing of vegetables.

Emerging Institutions in Vegetables

Contract farming, especially in the case of high-value enterprises/crops has been gaining popularity because contract includes certain provisions in the form of assured supply of price and inputs and other facilities. The study conducted in Punjab during 1998-99 indicated that tomato crop had an edge over other crops, mainly due to assured price through contract farming. The gross returns from the tomato crop were Rs 69,160 per ha in comparison to Rs 23,465 from wheat, Rs 26,560 from paddy and Rs 20,007 from potato. The advantages of contract farming, namely, guaranteed price and low capital investment, not only come to the rescue of the contracting farmer, but also help the small farm holder to improve his marketing efficiency. Many seed producing companies in Karnataka were reported to have extended their activities to promote contract farming, mainly in gherkin, baby corn, dry chilli, spices, fruits, vegetables and flowers. Low capital investment, higher employment generation and access to new technologies were the benefits of contract farming. Besides, successfully working institutional arrangements as milk co-operatives, for both production and marketing of vegetables were discussed.

Conclusions

A perusal of the contributed papers suggests that the on-going research programmes on vegetables are addressing the issues of emerging challenges of production, quality, marketing, nutritional security, etc. However, some of the areas where more research attention is needed include assessment of the role of private sector, size and scope of economics in vegetable processing, value-addition and quality control. Attention is also required for food safety, particularly with the trend of growing vegetables using treated sewage water in peri-urban areas. Meeting the future demand of fresh (table purpose) and processed (preserved) vegetables, securing nutritional security, promotion of growing non-traditional vegetables, vegetable extension including market intelligence and analysis also need priority attention. However, these issues may be debated at length to devise a road map for the sustainable growth in vegetable production.

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Part II.

Vegetable Research in India

4. Vegetable Research in India—An IIHR Perspective

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Abstract

The major achievements in vegetable research carried out at IIHR are described. It is reported that a total number of 76 varieties and hybrids in 25 vegetable crops resistant to biotic and abiotic stresses have been released. Of these, 34 are being widely grown all over the country and remaining 42 have received regional acceptance and are being commercially grown. In addition, a number of technologies have been developed which have helped in improving the yield of vegetable crops. For example, fertigation in tomato, watermelon and capscium has been found to result in higher yields during summer months. Application of tomatotone harmone in tomato has helped in fruit set which has been found to vary from 20 to 78 per cent in sprayed plant as compared to non-sprayed plant. Drip irrigation, replenishment of 50 per cent evaporation losses as compared to 75-100 per cent with furrow irrigation is another technology. Besides, development of transgenic tomatoes resistant to TLCV plus TSWV, and transgenic watermelon resistant to WBNV is also reported.

Background

India is the second largest producer of vegetables, next only to China, covering an estimated area of 5.9 million hectares with a production of 90.8 million tonnes. In the world, India occupies first position in the production of cauliflower, brinjal and peas, second in onion and third in cabbage (Pandey 2004). In this paper, the status of vegetable research at the Indian Institute of Horticultural Research (IIHR), Bangalore, has been documented under heads like crop improvement, crop production, crop protection, crop utilization, etc.

Crop Improvement

The IIHR has contributed significantly towards vegetable improvement by developing a number of varieties and hybrids resistant to biotic and abiotic stresses. It is involved in conservation of large genetic stock for future use and facilitates the supply of germplasm to breeders working for vegetable improvement programme. It has developed not only high-yielding and high-quality vegetable cultivars but also cultivars suitable for processing and export. The Institute has released 76 varieties of 25 vegetable crops. Of these, 34 varieties have already been released by the Central Varietal Release Committee at the national level. The remaining varieties have received regional acceptance and are being commercially cultivated in various regions. Many of the varieties released by the Institute have become very popular with the farmers. The popular tomato cultivars/hybrids include *Arka Abhijit* and *Arka Shreshta,* both F_1 hybrids resistant to bacterial wilt; *Arka Vardan* (F_1 hybrid), resistant to root-knot nematodes; *Arka Ashish* and *Arka Ahuti,* suitable for processing; and *Arka Meghali,* suitable for rainfed cultivation. Important brinjal cultivars/hybrids include *Arka Navneet* (F_1 hybrid) with high yield; and *Arka Nidhi*, *Arka Keshav* and *Arka Neelkanth,* resistant to bacterial wilt (Yadav and Sadashiva 1998).

In addition to the above improved varieties, two varieties in chilli, *Arka Lohit* which become deep red on maturity, have fruits of high pungency (Capscicin, 0.70 per cent) and are suitable for both irrigated and rainfed cultivation, and *Arka Abhir,* which has low pungency (0.05%), is suitable for oleoresin extraction (16554 colour value) and has export potential, were also released. A number of highly adopted, high-yielding and disease-resistant varieties have also been developed, these include: *Arka Manik*— the multiple disease-resistant watermelon, *Arka Anamika*— the yellow vein mosaic-resistant okra, *Arka Niketan*— the onion with long shelf-life, *Arka Bindu*— the export quality onion variety with long shelf-life, *Swarna Rekha* and *Swarna Alaukik*—the first ever-released varieties of parwal (Yadav and Sadashiva 1998).

Crop Production

To improve the production and productivity of vegetable crops, several technologies have been developed. These include:

Intercropping

The intercropping combinations and their productivity levels are listed in Table 4.1. Some of these are:

- *Inter-cropping of cowpea with okra*: It gave 31-53 per cent higher okra equivalent yield and significantly higher net returns compared to those of okra sole cropping.

- *Tomato based inter-cropping system*: The planting of 4 rows of onion, 15 cm apart, between 2 rows of tomato (30 X 100 cm) gave 36 per cent higher tomato equivalent yield and higher net returns without affecting the quality of tomato.
- *Intercropping of cabbage with coriander or fenugreek*: It enhanced the productivity of soil significantly. The net returns were higher from cabbage-fenugreek followed by cabbage-coriander intercrops.

Table 4.1. Intercrop combinations and their productivity levels, 1995-96

Intercrop combinations	Yield (t/ha)	Net returns (Rs/ha)
Okra + Cowpea	24.98	36,824
Okra	16.31	26,389
Cowpea	20.54	27,917
Tomato + Onion	50.24	44,046
Tomato	36.99	30,667
Cabbage + Fenugreek	49.91	71,778
Cabbage	43.04	61,333
Fenugreek	14.46	15,469
Cabbage + Coriander	49.93	71,580
Cabbage	43.04	61,333
Coriander	20.02	21,383
Okra + French bean (kharif)	-	9,155
Capsicum + Onion (rabi)	-	12,644
Watermelon + Radish (summer)	-	22,988
Ragi + Dolichos bean (rainfed)	-	5,000

Micro-irrigation

The water management studies have revealed that drip irrigation, with one emitter per two plants, produced higher fruit yield and had higher water-use efficiency as compared to the furrow irrigation system. With drip irrigation, replenishment of 50 per cent evaporation loss was observed as compared to 75 to 100 per cent evaporation loss with furrow irrigation (Table 4.2).

Table 4.2. Impact of irrigation method on yield in different vegetables, 1996

(quintal per ha)

Vegetables	Methods of irrigation	
	Drip	Furrow
Watermelon	310.7	270.1
Tomato	783.5	704.2
Capsicum	182.8	128.1

Fertigation

The salient research findings of fertigation are as follows:

- Nutrients supplied through fertigation (100 per cent water-soluble fertilizers) increased marketable yield of tomato hybrid, *Avinash - 2* (45.7 t/ha).
- Tomato yields were increased up to 114 t/ha with nitrogen and potassium fertigation coupled with black polythene mulch compared to 50 t/ha in the conventional method.
- Sub-surface drip irrigation with nitrogen and potassium fertigation proved to be superior (90.9 t/ha) over surface drip irrigation in hybrid tomato production. Similar results were obtained in watermelon too.
- Under the protected cultivation, fertigation with nitrogen and potassium fertilizers in conjunction with polythene mulch, tomato hybrid, *Arka Abhijit,* produced higher yield (113.1 t/ha) as compared to soil application of fertilizers (95.2 tonnes per ha).

Fertigation studies on tomato, watermelon and capsicum revealed the possibilities of higher yields in summer months. Effective adoption of these recommendations by the farmers of southern region in India paved the way for higher production of tomato, watermelon and capsicum.

Hormonal Application

With the spray of tomatotone on the tomato cultivar *Arka Saurabh*, a high temperature-sensitive cultivar, the percentage of fruit set varied from 20 to 78 per cent in the sprayed plants compared to no fruit set in the unsprayed plants. Tomatotone permitted farmers to grow heat-sensitive varieties even in the summer months and produced bigger fruits that could receive high prices in the market. This recommendation has been widely adopted by the farmers in Kolar, Bellary and Raichur districts of Karnataka.

Bio-fertilizers

A new bacterium, *Azospirillum bangalorense* (ATCC 43315) has been found which can fix 40 kg nitrogen per year in the cortical cells of tomato roots (cultivar *Pusa Ruby*). Further, this group of bacteria was able to colonise all the cultivars of tomato tested. This research finding has helped in increasing the yield by applying neem biofertilizer as a substitute for inorganic fertilizers. Studies have indicated that *Bacillus polymyxa,* found in endorhizosphere and phyllosphere of brinjal cultivars *Arka Shirish*, *Arka Navneeth* and *Arka Kusumakar,* improved seed germination, plant growth, nitrogen and phosphorus content in the plant parts and increased the yield by 15-20 per cent. Studies have further revealed that this bacterium produced growth hormone cytokinin and gibberillin phosphate solubilization, promoting growth and nutrient uptake in brinjal. Similarly, nitrogen-fixing bacteria were isolated from capsicum, chillies and okra. The bacterium was multiplied and tested for substituting nitrogenous fertilizers. These useful bacteria have been tested in the farmers' field under NARP trials for their efficacy (Anonymous 2001).

A package of practices utilizing VAM in vegetables like tomato, brinjal, capsicum and chilli was developed. Seedling inoculation helped in better colonization and plant growth, nutrient uptake and increased yield in tomato. In addition to the saving of super phosphate by 50% when the treatment was supplemented with nitrogen fixing bacteria, it also helped a saving of 25% in nitrogen application. VAM treatment supplemented with neem cake, controlled nematode infection in tomato by 50-60%. Two tonnes of inoculum were prepared and sold to farmers and the technology was demonstrated in the farmers' field (Anonymous 2001).

Biotechnological Approaches

In the conventional breeding approach, the gene flow into the breeding lines is limited to sexually compatible genotypes and therefore a vast proportion of available germplasm, known to be the source of number of economically important genes, remains untapped. Recent developments in the area of plant biotechnology, including plant tissue culture and recombinant DNA technology, have made it possible to mobilize genes from across the species. At IIHR, pioneering work has been initiated in developing transgenics in several vegetable crops. Major emphasis is being laid on developing transgenics for virus resistance, where conventional methods of either plant breeding or plant protection have not yielded results. The research efforts included:

- Development of transgenic tomatoes resistant to TLCV plus TSWV and transgenic watermelons resistant to WBNV.
- Generation of transgenic tomatoes with delayed ripening, orange fruit colour, increased carotene level and nematode-resistance.
- Initiation of research on transgenic tomatoes and chillies with increased fungal resistance and transgenic brinjal resistant to fruit and shoot borer.
- Development of diagnostic probes based on nucleic acid for the following viruses:
  Tomato leaf curl virus (TLCV)
  Tomato spotted wilt virus (TSWV)
  Watermelon bud necrosis virus (WBNV)
- Generation of single chain antibodies for CTV and TOSPO
- *Development of seedless watermelons*: Embryo rescue and micro-propagation technologies have been developed. Through *in vitro* culturing of apparently abortive seeds from a cross between 4 X and 2 X of *Arka Manik* watermelon, a triploid (3 X) watermelon was derived. Using the rescued culture as the starting material, a micro-propagation protocol was developed for seedless watermelons. This protocol, making use of shoot tip and nodal micro-cuttings in a lan cytokinin-supplemented medium, was found to have a multiplication potential of 1-10 million plants per year. This could serve as a viable alternative to seed propagation of triploid water-melon, which could be maintained *in vitro* for many years with good proliferation rate and without any apparent signs of somaclonal variation. This micro-propagation protocol facilitates long-term use of cultures without initiating fresh cultures time and again.

Protected Cultivation

Highest fruit yield of 48.13 t/ha was obtained with fertigated (with water-soluble solid fertilizers) capsicum (hybrid *Green Gold*) mulched with black polyethylene and irrigated at 0.7 Epan level. The high yield was the result of better plant growth coupled with yield components like more number of marketable fruits per plant and bigger fruit size (125 g each). The highest fruit yield of 178 t/ha was recorded in tomato hybrid *SH 7611* with the close spacing of 60 X 20 cm and maintaining two stems per plant (180 days crop duration).

Foliar Nutrition in Banana

The supply of nutrients through foliar application has been standardized at IIHR for banana to help farmers to realize more yields with less cost. The plants can take nutrients through foliar application 10-times more efficiently and faster than through soil application.

The standardized technology includes soil application of 200g urea and 100g MOP in 2 splits at 60 and 90 days after planting; 6 foliar sprays with 0.5% urea + 0.5% SOP + 2g zinc sulphate + 1g borax; 120 to 300 days after planting at 30 days interval, and 2 sprays of the above mixture on bunches at 30 and 60 days after bunch emergence. The pH of spray mixture is adjusted by adding juice of 2 acid lime/ litre and better coverage can be achieved by adding 1 shampoo sachet per litre of spray mixture. By adopting this technology, the farmers of 5 villages adopted by IIHR in Doddaballapur taluk of Bangalore north district obtained Rs 25, 000 to Rs 50, 000 additional profit over soil application of nutrients.

Crop Protection

The IIHR has developed IPM strategies for diamondback moth (DBM) damage in cabbage and cauliflower and fruit borer in tomato and has managed these pests.

IPM in Cabbage and Cauliflower

Having developed at IIHR in 1989, the technology has been successfully adopted by the farmers in the southern region. Under this IPM, two rows of bold-seeded Indian mustard are taken up for every 25 rows of cabbage/cauliflower. The first row of mustard is sown 15 days prior to planting and second row is sown 25 days after planting. The mustard attracts more than 80 % pests of cabbage/cauliflower. The mustard foliage is protected by spray of dichlorovos and the incidence is controlled in cabbage/cauliflower by 2-3 sprays of NSKE/NSPE/NKPE/Neem soap/ pongamia soap. The economics of IPM in cabbage are presented in Table 4.3 (Moorthy *et al.* 2003a).

Table 4.3. Economics of IPM of cabbage cultivation, 2003

Treatments	Yield (tonnes/ ha)	Net returns (Rs/ha)	Benefit-cost ratio
IPM plots	55	30,085	2.42
Non-IPM plots (farmers' practice)	35	5,090	0.83

IPM of Tomato Fruit Borer

This IPM developed in 1992 is being widely adopted by the tomato growers by using tall African marigold as a trap crop for the management of tomato fruit borer, *Helicoverpa armigera*. Forty-five days old marigold seedlings were planted after every 16 rows of 21-day old tomato to synchronize flowering in both the crops. Most of the eggs of fruit borer were laid on marigold flowers or flower buds, and negligible in tomato. The incidence in tomato was controlled by the spray of 0.7 per cent endosulfan/NPV at 28 and 35 days after planting. The economics of IPM in tomato are presented in Table 4.4.

Table 4.4. Economics of IPM of tomato cultivation, 1998

Particulars	IPM	Non-IPM
Number of spray (per ha)	8	17
Cost of spraying (per ha)	6628	11362
Yield (q/ha)	622.8	494.0
Cost of cultivation (Rs/ha)	39,282	44,016
Gross return (Rs/ha)	99,450	91,375
Net return (Rs/ha)	60,168	47,359
B : C ratio	1.53	1.08

Use of Botanicals

The use of neem seed kernel extract (NSKE) has been recommended on a variety of crops like cabbage and cauliflower, against all pests; in tomato and cucurbits against serpentine leaf miner and in french bean against stem fly, *Ophimyia phaseoli*. In cabbage and cauliflower, NSKE sprays provided excellent control of all the pests and the crop could be raised without single insecticide application. NSKE sprays also reduced tomato fruit borer, brinjal shoot and fruit borer, bean fly in french beans and fruit fly in cucurbits. An alternative to NSKE, neem seed kernel powder (NSKP) and neem seed powder (NSP) were used and both were found effective in controlling diamondback moth. Further, NSP can be stored up to 5 months in polythene bags without the loss of efficacy. Neem formulations (commercial) were moderately effective as compared to NSKE, perhaps the only exception was a recent powder formulation (Soluneem) with 6 per cent azadirachtin. This was found highly effective against diamondback moth in cabbage at the dose of 1 g/ litre (Moorthy and Kumar 2002).

The use of oil cake for controlling nematodes is well known. It also reduces soil-borne insects like termites, white grubs, etc. However, the use of neem cake for the management of many insect pests of brinjal, okra and cucurbits has been demonstrated recently at IIHR and also in the farmers' fields (Tables 4.5 and 4.6).

Table 4.5. Efficacy of botanicals for the management of diamondback moth in cabbage

Treatments	Yield of cabbage (tonnes/ha)
Pongamia soap	116.67
Neem soap	111.33
Neem Sed Kernel Extract (NSKE)	109.60
Control	43.87

Table 4.6. Economics of integrated pest management of brinjal fruit and shoot borer

Treatments	Borer incidence (%)	Brinjal yield (tonnes/ha)	Net returns (Rs/ha)
Neem cake IPM	8	18.33	47,033
Non-IPM (farmers' practice)	40	9.37	-8,343

Biological Control

Inundative releases of the egg parasitoid, *Trichogramma pretiosum* @ 2.40 lakh adults/ha is recommended for fruit borer control. Six releases at weekly intervals @ 40,000 adults / ha with the first release coinciding with 50% flowering in tomato is recommended (Moorthy and Mani 2001). This IPM along with NPV sprays on tomato was demonstrated. Use of Nuclear Polyhedrosis Virus (NPV) was found effective in controlling tomato fruit borer. Results indicated that 5 applications at weekly intervals with first spray coinciding with flowering, reduced pest incidence significantly as compared to that in control (Mohan *et al.* 1996). Using live barriers like maize, shoot and fruit borers of brinjal were very effectively controlled by reducing wind effect when cakes were applied.

Integrated Nutrient Management in Banana

A strategy was developed to manage root-knot and burrowing nematodes in banana by application of farm yard manure (FYM) enriched with bio-agents (*Pochonia chlamydosporia* and *Paecilomyces lilacinus*) at 2 kg per plant at the time of planting and subsequently at an interval of three months. The results of these trials indicated significant reduction of root and soil populations of root-knot by 65% and 59%; burrowing nematodes by 64% and 68%, respectively.

The technology of enrichment of FYM with bio-agents (*Pochonia chlamydosporia* and *Paecilomyces lilacinus*) along with neem cake was demonstrated and disseminated through the Institute Village Linkage Programme (IVLP) team and achieved sustainable management of root-knot and burrowing nematodes in banana at Kestur village adopted by the Institute.

Crop Utilization

Nearly 20-30 per cent of vegetables are lost due to seasonal glut, improper handling, grading, packing and poor storage facilities. Prevention of post-harvest losses is essential to overcome off-season shortages and also to meet the demand throughout the year. The IIHR has done some pioneering work in post-harvest management of vegetable crops. The following are the salient accomplishments:

Cold Storage

- Optimum low temperature requirements for extending storage-life without causing chilling injury and maintenance of fresh market qualities for important tropical vegetables like okra, tomato, brinjal, cucumber, french bean, etc. were standardized. These findings were demonstrated to Horticultural Extension Officers for transfer and were recommended to fresh vegetable handlers and exporters for commercial use.

- Storage-life of carrot was extended up to 5 months by packing in ventilated plastic crates with polymeric film linings (bulk packing) and storing at 0 to 2 ^{o}C. The cold-stored carrots reached the consumers in very good condition through the HOPCOMS outlets.
- The shelf-life of capsicum was enhanced to 20-28 days at 8 ^{o}C as compared to 5-6 days at room temperature. This recommendation has helped in bulk handling of capsicum to distant markets.
- Keeping of mature green/breaker stage harvested tomato fruits in evaporative cool storage (zero energy cool chamber) extended their storage life by 5 days with good fresh market qualities like colour and firmness during summer, with a reduced weight loss during storage and ripening. It was demonstrated as a farm gate technology to the extension workers through transfer of technology program (Rao and Moorthy 1993).

Shrink Wrapping

By shrink-wrapping technology, the storage-life of capsicum fruits was extended from 4 days to 12 days at room temperature and to 30 days at 8^{o} C. The shrink-wrapped and cold-stored capsicum had an increased shelf-life of another 5 days at room temperature. This technology was demonstrated to a capsicum growing company, who adopted to transport their produce to distant markets such as Delhi and Kolkata using this technique.

- The storage-life of cucumber was extended to 21 days at 10^{o} C and cabbage to 100 days at 0^{o} C by shrink-wrapping.
- Fresh cut (lightly processed) carrot in MAP was stored in good condition for 6 days at 0^{o} C. The storage-life of lightly processed cauliflower packaged in polythene (100 gauge) bags was found to be 14 days at 0^{o} C.

Processing

- Tomato varieties, viz. *Arka Ashish*, *Arka Ahuti* and *Arka Shreshta* were found best for processing and were recommend to the processing industries.
- *Arka Pitambar,* the onion variety, was found best for dehydration and was recommended for dehydration to industries for commercial exploitation.
- Methods developed for production of culinary pastes from onion, garlic, ginger, coriander, tamarind and mixed vegetables have been transferred to the processing industries.
- Processing of watermelon to juice has been developed and is ready for commercialization.
- Method for brining preservation of gherkins was developed and transferred to the growers. The variety *NCUH-32* was found best for brine stock preservation.

Lactic Acid Fermentation

Lactic acid fermentation technique was used to preserve a wide range of vegetables, viz. carrot, french beans, cabbage, onion, capsicum, bitter gourd and tomato.

Conclusions

The IIHR has played a major role in developing different technologies for vegetable production, protection, and utilization. The Institute has released 76 varieties and hybrids in 25 vegetable crops resistant to biotic and abiotic stresses. Of these, 34 are being widely grown all over the country and the remaining 42 have got regional acceptance and are being grown commercially. Amongst the crop production techniques, using drip irrigation, replenishment of 50 per cent evaporation loss is observed as compared to 75-100 per cent loss with furrow irrigation. Fertigation studies on tomato, watermelon, and capsicum have revealed the possibilities of higher yield during the summer months. The spraying of tomatotone on the tomato cultivar *Arka Saurabh,* a highly temperature-sensitive cultivar, has varied the per cent fruit set from 20 to 78 per cent in the sprayed plant compared to no fruit set in the unsprayed plant. A package of practices utilizing VAM in vegetables like tomato, brinjal, capsicums and chilli has been developed. The VAM-treatment supplemented with neem-cake, has controlled nematode infection in tomato by 50 to 60 per cent. The IPM technologies developed at the Institute in 1989 and 1992 have been successfully adopted by farmers in the southern region of the country. Use of NSKE has been recommended on a variety of crops like cabbage and cauliflower, against all pests; in tomato and cucurbits against serpentine leaf miner; and in French bean against stem fly. The Institute has also done some pioneering work in post-harvest management of vegetable crops.

Notable achievements have been made in development of varieties/ hybrids for high yield and resistant to biotic and abiotic stresses. The productivity and production scenario will be improved only when the technology and materials reach the farmers' field. Government agencies must take steps to reduce the gaps between the farmers and the laboratories. Extension techniques such as participatory approach and farmers field school approach have to be utilized for successful technology dissemination. Government agencies must take the responsibility to produce and supply healthy seedlings for growing successful crops. There are nearly 20 types of vegetables grown but maximum emphasis has been given on important vegetables like tomato, eggplant, chilli, cauliflower, cabbage, pea, beans, and some cucurbits. Other important vegetables like faba bean, summer bean, lima bean, winged bean, velet bean, welsh onion, Brussels sprouts, Chinese cabbage, kakrol kundru, oriental long melon, curry leaf, drumstick, sweet corn and baby corn, etc. should be given emphasis.

A more cooperative approach with liberal and accommodative spirit in sharing the genetic resources and their testing among the pathologists, entomologists, nematologists and breeders on the one hand and among the different centres, including the private sector R&D centres on the other will contribute a greater impact in increasing country's vegetable production.

To conclude, the challenges ahead are formidable, but equally gratifying would be to sustain vegetable production leading to comprehensive household, food and nutritional security to the people of India.

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5. Status of Onion and Garlic Research in India

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Abstract

The impact of research on important cash crops of onion and garlic is reported. The public sector institutions have released more than 35 varieties of onion and 15 varieties of garlic so far. A wide gap has been found between farmer's yield and on-farm trials. The yield gap II has been 50 per cent in the case of onion and 80 per cent in the case of garlic. It has been estimated that the contribution of released varieties in total production is about 20% in the case of onion and 10 per cent in garlic. Crop protection research studies have emphasized the need for developing resistant varieties to pests and diseases to improve productivity. Due to lack of information, the farmers have not adopted the post-harvest techniques to reduce different types of losses. Of the total seed requirements, only about 20 per cent has been made available from the organized sector and the rest 80 per cent is met from the farmers' own seeds. It is emphasized that seed production for onion and garlic is a less attended aspect by both seed agencies and farmers.

Introduction

Onion and garlic are the crops grown in India for centuries; these are used for spicing food and food products. India has been a traditional exporter of both these crops. Onion is grown in over 4.2 lakh hectares area and garlic on nearly 1.2 lakh hectares with the production of 57.2 lakh tonnes and 4.5 lakh tonnes, respectively. Onion is an important cash crop in India for small and marginal farmers, generating substantial income. Both the crops are, however, highly susceptible to market fluctuations, because of which farmers suffer during the lean period, whereas traders derive the benefit during the off-period.

India is the second largest producer of onion and garlic after China. The states of Maharashtra, Gujarat, Karnataka, Uttar Pradesh, Orissa and Andhra Pradesh are the major onion-producing states while Madhya Pradesh, Gujarat, Rajasthan, Orissa and Maharashtra are the main states for garlic production.

Productivity-wise, India ranks much below than China, the USA, the Netherlands, etc. The low productivity of onion and garlic in India is mainly due to the poor-yielding genotypes/land races, non-availability of quality seeds, non-availability of F_1 hybrids, shortage of irrigation water at critical stages of growth and large fluctuations in market prices. These result into differential approaches of farmers towards newer technology adoption.

Although the statistics indicate a static position in productivity, the production has been increasing over time, ensuring enough availability of onion, barring few exceptions (year 1997). Assuming that 50 per cent of the population consumes onion @ 20 gram per person per day, nearly 70 lakh tonnes production and 10 lakh tonnes as loss during handling and storage, make a total requirement of 80 lakh tonnes. The present production of 44 lakh tonnes comes from 4 lakh hectares, with the average productivity of 11 tonnes/ha. There has been some impact of research but the level of productivity is not yet satisfactory.

Research Contributions

(a) Varietal Improvement

Improved varieties had made a significant contribution to the success of Green Revolution. The contribution of genotypes in increasing the productivity has been found to vary from 50 to 100 % in different crops. Hybrids and high-yielding varieties, resistant to biotic and abiotic stresses, have made a significant contribution in vegetable production.

In onion, the varietal improvement commenced as early as 1950 in Maharashtra. N-53 and N-2-4-1 were the first varieties released by the Government of Maharashtra. Later, 33 varieties were developed by the state agricultural universities, ICAR institutes and National Horticultural Research and Development Foundation, Nasik (Table 5.1). In garlic, 15 varieties have been released (Table 5.2). However, the contribution of the released varieties in the total production is not more than 20 per cent in onion and 10 per cent in garlic.

Table 5.1. Performance of important onion varieties in all India co-ordinated trials

Important varieties	Year of release	Yield (q/ha)
Light Red rabi varieties		
ALR	1987-93	297 (59)
Punjab Red Round	1988-93	300 (22)
Line No. 102	1988-93	355 (61)
N 2-4-1	1988-90	414 (56)
Arka Niketan	1988-90	285 (99)
Kharif varieties		
N 53	1982-87	347 (21)
Basant 780	1982-87	298 (29)
ADR	1984-87	337 (19)
Arka Kalyan	1982-87	319 (20)
White varieties		
N 257-9-1	1982-87	250 (17)
Phule Safed	1982-87	231 (35)
Pusa White Flat	1982-87	300 (20)

Note: Figures within the parentheses indicate the number of locations at which performance was tested.

Table 5.2. Yield of important garlic varieties in all India co-ordinated trials, 1980-90

(quintal per ha)

Varieties	Experiment station trials (8)*	Multi-location trials (10)*	Adaptive trials (42)*	Coordi-nated trials (23)*	Mean yield
Godavari (Sel. 2)	168	92	119	91	117.50
Sweta (Sel. 10)	150	94	117	-	120.33
G.1	190	-	-	115	152.50
G.41	236	-	-	119	117.50
IC-49383	173	-	-	101	137.00
Jamnagar local	80	65	84	-	76.33

* Figures within the parentheses indicate the number of locations at which performance was tested.

Why Poor Spread of Released Varieties?

The poor spread of released varieties has been due to:

(i) Non-availability of genuine breeder seeds in sufficient quantities.

(ii) A majority of (80 %) farmers produce their own seeds of land races, which suffers from bolting, twin bulbs, and variations in shape, size, colour and maturity period.

(iii) Seed companies and agencies do not find good business vis-à-vis tomato, cabbage, brinjal, chilly, etc. Therefore, there has been a poor push of new varieties in the market.

(iv) Breeder and extension agencies have not been able to prove superiority of the released varieties over the farmers' material beyond doubt through frontline demonstrations.

(v) Hybrid onion is still a researchable issue in India.

(vi) Sharp fluctuations in onion prices lead to develop a casual approach towards new innovations in varietal and technological development.

(b) Crop Production

The results of adaptive trials on seasons of planting, fertilizer applications, weed management, pest and disease control are made available by various research organizations across the onion growing areas of the country. Good extension work has helped in adoption of improved cultural practices, which has definitely contributed towards increasing the productivity to some extent. However, there exists a wide gap between farmers' yield and on-farm trials (Table 5.3). It is observed that progressive farmers' yield in case of onion is slightly lower and this may be due to gap in technical know-how. However, micro-nutrient management and micro-irrigation are other important means for increasing productivity of onion and garlic. A project on frontline demonstrations would help in bridging the gap between the lab results and farm yields.

Table 5.3. Average yield obtained of onion and garlic

(tonnes per ha)

Yield	Onion	Garlic
On-farm trials	25-35	15-20
Progressive farmers' yields	25-30	15-20
Average farmers' yields (national average)	12-15	3-4

(c) Crop Protection

The crops of onion and garlic are susceptible to different foliar diseases, viz. purple blotch stemphyllium, blight colletotrichum, thrips, etc. Kharif crop of onion is more sensitive to these diseases because of more congenial climate during June to September. The high incidence of diseases leads to reduction in productivity. Research recommendations on management of diseases and *thrips* through various approaches such as IPM and pesticide sprays has helped in stabilizing genetic potential of *rabi* and late-*kharif* (*randga)* crops. There is a good adoption of these recommendations. However, development of resistant varieties is needed to improve the productivity of onion and garlic crops.

(d) Post-harvest Handling and Storage

The post-harvest handling and storage losses in onion are 20-50 per cent due to physiological weight loss (12-30%), sprouting (4-10%) and rotting (4-10%), whereas in garlic, the losses are around 10-20 per cent. Shelf-life in onion and garlic is a function of genotypes, cultural practices, pre-harvest treatments and proper storage environment. Moreover, quite a good number of varieties having longer shelf-life have been screened.

Several cultural practices recommended are: (i) use of more organic manures, (ii) no nitrogen application after 60 days of transplanting, (iii) withholding of irrigation water 15 days before harvesting, (iv) harvesting after 50% neck fall, (v) field curing for 3-4 days along with tops, (vi) cutting with long neck up to 3-4 cm, (vii) shade curing, and (viii) grading. Although some farmers have adopted these recommendations, it is the market forces that ensure the adoption of recommended cultural practices. The farmers do not go for curing and grading when the prices are high in the market. At the time of harvesting, farmers try to utilize the opportunity of getting maximum, since there is no assurance that the prices would remain stable.

(e) Storage Environment

Storage environment is an important aspect in post-harvesting handling of onion and garlic. Stored onion and garlic offer buffer stock from June to November and about 20 lakh tonnes of onion goes into storage during April-May, which is slowly made available in the market up to November. The ideal storage conditions for minimizing losses are 25-30°C temperature and 65-70 per cent humidity. Nearly 80 per cent farmers are dependent upon primitive and old storage chawls, where the losses are high. The bottom ventilation storage structures designed by MPKV, Rahuri, and NHRDF, Nasik, and further improved by National Research Centre for Onion and Garlic, Rajagurunagar, Pune, have demonstrated that the storage losses could be reduced by 20-30%. Research recommendations on storage have not been adopted by a majority of farmers due to high cost of construction of storage structure which is the main hurdle in creating the needed impact. Subsidy component needs to be introduced for making a good impact in post-harvest management of these crops. Government of Maharashtra has developed on-farm storage capacity to the tune of 5 lakh tonnes through research. Other onion growing states may follow this development.

(f) Seed Production

About 3,500 tonnes of seeds of onion and 50,000 tonnes of garlic bulbs are required for planting in India. In case of onion, 20 per cent of seed comes from the organized sector (such as NHRDF, Nasik, NSC, MPKV, Rahuri and National Research Centre on Onion and Garlic, Rajgurunagar), and 80 per cent is met from the seed produced and maintained by the farmers themselves. The land races/genotypes maintained by the farmers suffer from various drawbacks such as bolting, twin bulbs and variation in size, shape, colour, etc. In the case of garlic, the supply of genuine seed is less than 1% although garlic is propagated vegetatively, where there is less variation in progeny. There is a need for the change of planting material after certain period to maintain high productivity level. The seed production in onion and garlic is a less attended aspect of crop production by breeders, seed agencies and even farmers. Therefore, the impact of seed research is highly limited.

Conclusions

The study of onion and garlic research in India has revealed as follows:

- There is a limited impact of limited research work in both the crops though there is an increase in the total production, the per unit productivity suffers from marginal increase.
- In some aspects, research has not reached the farmers.
- Adoption of improved technology and varieties which depends on the potential benefits for that particular commodity in the market, has not been forthcoming at the desired level.
- Absence of a proper database leads to improper perception and analysis in onion and garlic production.

6. AICRP on Vegetables in India: Evolution and Achievements

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Abstract

Achievements of All India Coordinated Research Project (AICRP) on vegetables are briefly described. It is reported that AICRP on vegetables was started in July 1971 with the objectives of screening suitable varieties for different agro-ecological conditions, evolving suitable agro-techniques and controlling of diseases and pests. Presently, 15 vegetables being given major emphasis are tomato, brinjal, chilli, cauliflower, cabbage, peas, onion, muskmelon, watermelon, okra, french bean, pumpkin, carrot, radish and garlic. More than 250 varieties of 22 vegetable corps have been developed. Of these, 173 are high-yielding open-pollinated, 25 are disease-resistant and 55 are hybrids. Besides, 105 production technologies, 62 diseases resistant and 28 insect management technologies have been evolved. A large number of germplasm lines of gourd vegetables have been collected, evaluated and conserved by the coordinated centres. It is underlined that AICRP on vegetables has proved highly promising in increasing the vegetable production, and thereby increasing the per capita consumption.

Background

The concept of the All India Coordinated Research Project (AICRP) was introduced with the reorganization of the Indian Council of Agricultural Research (ICAR) in 1956-57, and the first AICRP was initiated on maize. The conceptualization of AICRP is believed to be an important landmark in the history of agricultural research in India. At the national level, AICRP through its interdisciplinary multi-location research provides opportunities for evaluation of the improved technologies in terms of their adaptability in a wide range of agro-ecological conditions. The objective of AICRP has been to undertake problem-oriented applied research and testing of the technology under different agro-climatic conditions with a view to solving the national level problems and improve production. This paper briefly describes the history, mandate, priorities and programs covered under AICRP on

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vegetables. The major technologies of vegetables, impact of AICRP research, and constraints to vegetable production have also been described.

AICRP on Vegetables in India

(a) History

The AICRP on vegetables started functioning in July 1971, with its headquarters at IARI, New Delhi. It was elevated to the status of a Project Directorate of Vegetable Research in 1986 and was shifted to Varanasi (Uttar Pradesh) in April 1992. The AICRP on vegetables consists of 8 main centres, 18 sub-centres and more than 30 voluntary centres, situated across the country in ICAR institutions, State Agricultural Universities (SAUs) and private organizations. It is considered as one of the most vibrant research units in the country. In the beginning, the major task of AICRP was to undertake multi-locational testing to identify the vegetable varieties suitable for specific agro-climatic zones. Later, trials were also included on production techniques like plant population density, fertilizer requirements and chemical weed control. Subsequently, research programs on chemical control of diseases and insect pests were also added.

Initially, only 14 vegetables were covered under the AICRP research programs, but later more vegetable crops were added and presently 24 crops are being dealt with. The major emphasis however, is on 15 vegetables mentioned already.

(b) Mandate

The mandate of AICRP on vegetables is:

- To collect, evaluate and conserve the vegetable biodiversity that exists in different agro-climatic zones of the country
- To develop improved varieties and hybrids resistance to biotic and abiotic stresses through multi-locational testing of mandated vegetable crops
- To develop appropriate production technology for selected vegetable crops
- To develop and standardize appropriate protection technology for major diseases and insect pests

- To standardize the seed production technology of the mandated vegetable crops
- To undertake basic, strategic and applied research for developing technology to enhance productivity of vegetable crops
- To provide scientific leadership in coordinated network research for solving location-specific problems of production and to monitor breeder seed production of released / notified varieties

(c) Priorities

To fulfill the objectives of vegetable research, keeping the manpower resources in view, the priorities of AICRP are as follows:

- To initiate problem-oriented multidisciplinary research (i.e. basic, applied and strategic) in different agro-ecological zones of the country
- To confirm the research findings of various multi-locational trials and to recommend them to the growers
- To coordinate and monitor the vegetable research activities of multi-locational centers, i.e. SAUs, ICAR institutes and private organizations situated in different agro-climatic zones of the country
- To provide leadership in human resource management

(d) Programmes

Based on the mandate and the priorities, the following research programs have been chalked out to conduct trials in vegetable crops:

(i) Crop Improvement

- Germplasm enhancement, evaluation, catalouging, documentation, exchange and conservation
- Development of varieties resistant to biotic and abiotic stresses
- Development of hybrid varieties
- Development of breeding materials in important vegetable crops

- Coordination and monitoring of the program of multi-locational trials

(ii) Crop Production

- Development of vegetable-based cropping system
- Development of production technology using integrated nutrient management practices, weed management and irrigation technology
- Development of production technology for hybrids and off-season vegetables

(iii) Physiology, Biochemistry and Processing

- To screen vegetable germplasm lines against abiotic stresses
- To identify vegetable varieties suitable for processing
- To standardize the shelf-life and keeping quality of different vegetable crops

(iv) Crop Protection

Management of important diseases and insect pests of vegetable crops, utilizing integrated disease management practices with special reference to biological approaches

(v) Seed Production

- Production of nucleus and breeder seeds of vegetables crops
- Conduct research on seed production and seed technology
- Monitoring of breeder seed production in the country.

Brief Achievements of AICRP on Vegetables

Crop Improvement

The research work on vegetables has been accorded priority to the management of biodiversity / genetic resources under the coordinated programs. A large number of germplasm lines in tomatoes, brinjal, chillies, okra, peas, muskmelon, watermelon, bitter gourd, bottle gourd and pointed gourd have been developed. These lines are being utilized to evolve new varieties of vegetables. The National Bureau of Plant Genetic Resources, New Delhi, has taken a lead in the collection, maintenance, documentation and conservation of germplasm of vegetable crops.

The AICRP on vegetables has contributed immensely by developing more than 250 varieties for 22 vegetables, which have been recommended for cultivation in different regions. Out of these, 173 are high-yielding varieties, 25 are resistant to diseases, and 54 are hybrids of tomatoes, brinjal, chillies, okra, cole crops, onion, garlic, peas, beans, melon, and gourds (Appendix I).

Crop Management

Under the crop management technology, the major emphasis is on the management of fertilizers and plant spacing, weed control and crop rotation. In tomatoes, 26 production technologies comprising 15 for fertilizer and spacing, 5 for weed control, and 6 for crop rotations have been evolved (Table 6.1). Similarly, nearly 80 technological recommendations have been made for growing brinjal, chillies, peas, onions, garlic, cabbage, cauliflower, cucurbits and some other crops in different agro-climatic zones of the country.

To protect vegetable crops against pests and diseases, several recommendations have been made. In tomato, an effective control for buck eye rot, late blight, early blight, spotted wilt virus and damping off has been recommended. To control diseases of brinjal, viz. blight, phomopsis blight, cercospora leaf spot and little leaf, integrated management, right from the nursery to standing crop has been recommended. Twelve recommendations have been made to control chilli diseases. Similarly, adoption of the recommendations has managed the diseases in crops like garden pea, okra, onion, garlic, cauliflower, muskmelon and watermelon. Several insecticides have also been tested against important vegetable pests; in tomato, 4; brinjal, 7; chilli, 1; okra, 13; onion, 4; and cauliflower, 3. A number of sprays have been recommended for effective control of pests.

Impact of Vegetable Research

(a) Increase in Area, Production and Productivity

During the past three decades, India has made a commendable progress in vegetable production, from 58.5 million tonnes in 1991 to 87.5 million

Table 6.1. Number of technologies developed under the AICRP on vegetables, 1975-2001

Vegetables	Production	Protection		Total
		Diseases	Insects	
Tomato	26	11	2	39
Brinjal	6	6	7	19
Chillies	9	12	1	22
Capsicum	2	2	-	4
Peas	8	3	-	11
Cowpea	1	-	-	1
French bean	2	1	-	3
Okra	7	8	9	24
Onion	16	11	5	32
Garlic	4	1	-	5
Cabbage	8	-	3	11
Cauliflower	7	2	-	9
Muskmelon	2	2	-	4
Watermelon	1	2	-	3
Other cucurbits	5	1	1	7
Carrot	1	-	-	1
Total	**105**	**62**	**28**	**195**

Source: Anonymous (1975-2001)

tonnes in 1999. The yield per hectare during this period has increased from 10.5 tonnes to 14.3 tonnes. Besides, India is the leading producer of brinjal, cauliflower, pumpkin, squash gourd, and green pea in the world.

(b) Nutritional Security

In the components of a balanced diet, vegetables occupy the prime place in a predominantly vegetarian country like India. Vegetables supply several nutrients such as vitamins, minerals, carbohydrates, essential amino acids and proteins. In addition, vegetables add variety, taste, colour and texture to diet. It is believed that increasing availability of vegetables would contribute to the balanced diet. It would be possible due to the adoption of improved varieties and efficient methods of vegetable production. The per capita availability of vegetables and other food items is shown in Figure 6.1. It is clearly seen that the per capita daily availability of vegetables has increased from 76 g in 1951 to 256 g in 2001, but it is still less than the minimum requirement of 285 g per person per day.

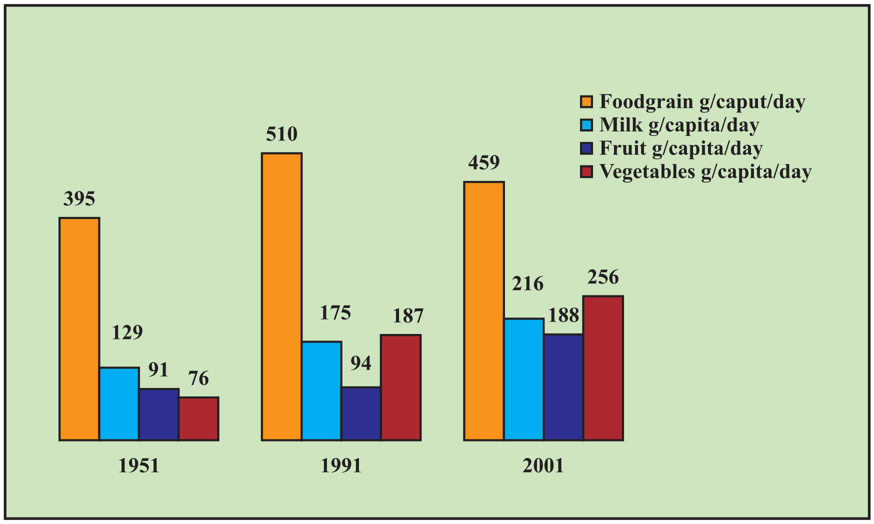

Figure 6.1. The per capita availability of vegetables and other food items per day, 1951-2001

(c) Seed Availability

To improve the productivity of any crop, use of quality seeds is essential. Presently, a majority of vegetable varieties grown on farmers' fields are the results of AICRP efforts. Among the identified varieties/hybrids, share of open pollinated varieties (OPVs) is high, although the yield potential of OPVs is lower than that of hybrids. Resistant varieties of major vegetables have also been identified, which have minimized the use of pesticides. The seed replacement in varieties of important vegetables varied from 42 per cent in leafy vegetables to 99 per cent in tomato, the overall replacement of the seed being nearly 80 per cent (Table 6.2). Such a high rate of seed replacement indicates the importance given by the farmers to utilize good quality seeds for increasing production and getting higher net returns from vegetable cultivation.

Round-the-year Availability of Vegetables

It is well known that most the vegetable crops are thermo-sensitive in nature, but through the strategic research under AICVIP, several varieties of vegetables have been developed which can be grown even under adverse conditions. Vegetables like cauliflower, cabbage, radish, cucurbits and

Table 6.2. Availability of quality seeds of vegetable crops in India

Vegetable crops	Total requirements (tonnes)	Seed availability (tonnes)	Availability (%)
Beans	11880.1	7983.4	67.2
Brinjal (eggplant)	239.6	151.9	63.4
Cabbage	228.1	197.1	86.4
Cauliflower	228.1	197.1	86.4
Cucumber	54.1	39.3	72.6
Chilli	2046.4	1504.1	73.5
Gourd	2046.4	1504.1	73.5
Leafy vegetables	5530.0	2328.1	42.1
Melons	423.4	377.7	89.2
Okra	4645.8	4292.7	92.4
Onion	4849.4	4233.5	87.3
Peas	17037.2	15929.7	93.5
Radish	745.8	719.7	97.5
Tomato	169.9	168.8	99.3
Others	3718.4	2699.6	72.6
Total	**53842.7**	**42326.8**	**78.6**

Source: Arora (1998)

tomatoes are available to the consumer's round-the-year. Some of the tomato varieties developed for rainfed conditions are gaining momentum during rainy season in the areas where either drainage facilities or drought conditions exist. During the off-season, farmers are getting good returns which ultimately increase income levels and living standards of farmers.

Constraints in Vegetable Production

(a) Low Productivity

The productivity of vegetable crops is very low on farmers' fields as compared to that in the coordinated trials. It has been observed that productivity in the coordinated trials is not only higher than the farmers' fields in India, but also in most of the developed countries (Table 6.3). The yield gap between the coordinated trials and on-farm trials could be bridged by adopting improved varieties and recommended production practices, and thereby help achieving the production target of 150 million tonnes by 2020.

Table 6.3. **Average productivity of major vegetable crops**

Vegetables	Productivity, tonnes per ha				
	Developed countries	Developing countries	World	India	
				On-farm	Coordinated trials
Brinjal	14.3	15.9	15.4	16.2	26.3
Okra	12.2	10.1	5.0	13.1	14.5
Cabbage	25.2	17.6	21.6	14.3	36.0
Cauliflower	16.8	10.6	13.6	14.2	26.6
Tomato	33.7	18.9	25.0	15.8	30.0
Cucumber	15.1	13.9	14.5	6.4	13.6
Chilli (green)	15.9	6.7	8.2	2.0	7.5
Onion (green)	18.3	11.6	13.7	11.3	34.0
Beans (green)	7.6	6.2	6.9	2.5	11.5
Peas	7.2	3.7	6.0	14.3	16.5
Watermelon	12.9	15.8	14.7	12.7	17.6

Source: Singh (2003)

(b) Post-harvest Losses

Nearly, 30 per cent post-harvest losses have been observed in handling of vegetables (Table 6.4). This high extent of losses indicates non-availability of cheap and adequate post-harvest facilities, particularly for storage of green vegetables which are highly perishable. Also, the vegetable processing industries are far away from the production sites. Low cost technologies for post-harvest handling and packaging for domestic and export markets have not been developed adequately. Transport facilities specifically suited to vegetables are also lacking.

(c) Losses due to Pests and Diseases

Technologies for integrated pest and disease management of vegetable crops have not been developed for major pests. Agro-chemicals which are strictly banned in other countries, are frequently used in our country by the farmers due to their ignorance.

Appropriate and cheap plant protection equipments are not readily available. Nursery management is a bottleneck during the rainy season due to fungal and bacterial diseases.

Table 6.4. Post-harvest losses in vegetable crops

Vegetables	Post-harvest loss (%)	Problems
Onion	6.0-40.0	Storage and transportation
Potato	30.0-40.0	Harvesting and storage
Garlic	0.9-2.7	Storage
Tomato	6.7-33.5	Transportation and marketing
Brinjal	3.7-13.4	Marketing
Cabbage	3.0-13.4	Marketing
Cauliflower	10.0-13.2	Transportation and marketing
Benas	7.5	-
Smooth gourd	8.0-15.0	-
Bottle gourd	7.0-10.0	Transportation and marketing
Okra	5.0-10.0	Marketing
Chilli	4.0-35.0	Farm and storage
Beet root	10.0-15.0	Marketing
Radish	3.0-5.0	Marketing
Carrot	3.0-5.0	-
Pointed gourd	19.8	Marketing and storage
Garlic	0.9-2.7	Marketing and storage

Source: Singh (2003)

(d) High Cost of Hybrids

According to an estimate, only about 12 per cent of vegetable area is under hybrids in India, of which the percentage coverage by tomatoes is 36, cabbage 30, brinjal 18, okra 7, melon, 5, gourds, 5, cauliflower 2 and chilli 1. It is expected that in the next 10 years, more than 30 per cent vegetable area would be under hybrids. Vegetable production is still dominated by the locally available genotypes or inferior cultivars. However, there is an ample scope in replacing the local cultivars with the improved high-yielding and disease-resistant varieties/hybrids.

Of the total hybrids of vegetables developed in India, public sector's (including AICRP) share is about 58 per cent (Table 6.5). Still farmers are not getting the hybrid seeds developed by the public sector at an affordable price, mainly because of the inability of the public seed agencies like NSC, TDC, SSFCI, etc. to compete with the private sector in the supply of seeds.

Table 6.5. Status of hybrids of vegetable crops in India

Vegetables	Vegetable hybrids developed (Number)			Share of public sector (%)
	Total	Private	Public	
Brinjal	18	5	13	72.2
Tomato	15	10	5	33.3
Cabbage	6	5	1	16.6
Okra	3	0	3	100
Bottle gourd	3	0	3	100
Watermelon	2	1	1	50
Chilli	2	2	0	0
Sweet pepper	1	0	1	100
Carrot	1	0	1	100
Cauliflower	1	0	1	100
Muskmelon	1	0	1	100
Bitter gourd	1	0	1	100
Cucumber	1	0	1	100
Total	55	23	32	58.18

Source: Anonymous (1975-2001)

(e) Spurious Seed Supply

Non-availability of quality seeds is one of the most important constraints for low productivity of vegetables in India. Because of limited availability, the cost of good quality seeds is high. Also, inefficient distribution systems restrict their availability. This is the reason that farmers are still growing local varieties / land races of many crops to a large extent (Table 6.6).

Table 6.6. Per cent share of different types of vegetable cultivars

Vegetable crops	Hybrid	Open- pollinated	Local
Cabbage	36.2	63.8	-
Cauliflower	3.29	50.00	46.71
Chilli	2.44	37.56	60.00
Gourds	2.44	20.0	77.56
Melon	4.02	25.98	70.00
Okra	7.38	78.00	14.62
Tomato	39.51	42.00	18.49
Brinjal	11.80	50.00	32.20

Source: Arora (1998)

(f) Lack of Multiple Resistant Varieties

Considering the importance of biotic stresses, there is a need to develop a variety which would be resistant to major diseases and pests. The major biotic stresses of different vegetables are described in Table 6.7.

Table 6.7. Major biotic stresses in vegetable crops

Vegetables	Major biotic stresses
Tomato	Tomato leaf curl virus, Early blight, Bacterial wilt, Root rot nematode
Brinjal	Phomopsis, Bacterial wilt, Fruit and shoot borers
Chilli	Leaf curl, Thrips, Mites, Anthracnose
Capsicum	Phytophthora, Thrips, Mites
Okra	Yellow vein mosaic virus, Enation leaf curl virus, Jassid, Mite, Fruit borer
Onion	Stemphyllium, Purple blotch, Thrips
Cucumber	Downy mildew, Mosaic
Muskmelon	Powdery mildew, Downy mildew, Anthracnose, Fusarium
Watermelon	Powdery mildew, Downy mildew, Anthracnose
Cabbage	Black rot, Diamondback moth
Cauliflower	Black rot, Diamondback moth

Source: Kalloo *et al.* (1998)

(g) Lack of Technology Transfer

The availability of trained manpower who could deliver effective extension services in vegetable sector is limited and the linkages between extension personnel, researchers and farmers are weak. In-service training opportunities for development / extension personnel are also limited. Demonstrations to transfer technology from the laboratory to farmers are inadequate in view of the number of vegetables grown in diverse agro-climatic conditions.

(h) Germplasm Extinction

In our country, there are two types of situations: (a) a large number of vegetable crops, such as pointed gourd, radish, chillies, brinjal, cauliflower (early and mid), muskmelon, watermelon, cowpea, bottle gourd, bitter gourd, etc., are grown by the farmers using local land races, or poor quality seeds available in the local market, and (b) land races available at farmers' fields are facing extinction due to the arrival of hybrids and high-yielding varieties. So, it is the high time to collect all the possible local land races for their utilization in the breeding programs in future.

(i) Lack of Database

In the vegetable sector, many a times the data provided by the National Horticulture Board and the Food and Agriculture Organization (FAO) for the same crops and years differ largely, which creates confusion. It is suggested that an appropriate network be established at the earliest to collect, maintain and disseminate reliable data on various aspects of vegetable crops in India.

Future Thrust

The suggested future thrust in vegetable production is as follows:

- Emphasis on exploration, cataloguing and conservation of germplasm of minor vegetablesfrom the underprivileged and forest areas
- Breeding for high yield and quality attributes
- Identification of cultivars resistant to major biotic and abiotic stresses and development of inbred lines
- Development of multiple diseases and pest-resistant hybrids
- Use of biotechnological approaches for transfer of resistant gene
- Development of production technologies and identification of varieties for the protected conditions
- Package for organic farming
- Technology development to reduce post-harvest losses
- Package for nursery management
- Refinement of indigenous technology for river-bed cultivation
- Database development on area, production and requirement of seeds of different kinds
- Assessment of yield potential of varieties / hybrids under organic farming for export

- Development of integrated approach for the pests and diseases of vegetable crops
- Soil solarization for effective control of insects, pests and weeds
- Development of cost-effective hybrid seed production techniques to reduce seed costs
- Marketing network through cooperative system
- Planning to achieve the targets of vegetable production for domestic and export markets at national, state and regional levels
- Increasing the processing of vegetables, and
- Molecular characterization of varieties and promising genotypes.

Conclusions

There has been a significant progress in the production of vegetables in the country with the establishment of AICRP on vegetables. It has paved the way for increasing vegetable production in the country, enabling it to attain second rank in the world. Presently, vegetables occupy 5.8 million hectares of area and 91 million tonnes of production. Due to the advent of hybrid varieties and increase in awareness about nutritional security among consumers, vegetable production in the country is getting continuous momentum. During the last decade, the increase in the area under vegetable crops was 42 per cent, with increased production of 79 per cent. It has been due to development of improved varieties/hybrids and advanced crop management technologies. The technology for vegetable production has been able to make a commendable impact on the socio-economic status and social equity of farmers, particularly small farmers and has also provided ecological balance.

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Appendix 6.1. Vegetable crop varieties released through AICVIP, 1975-2001

Vegetable crops	Varieties released
Brinjal	Pusa Purple Long, Pusa Purple Cluster, S-16, Pusa Kranti,
Open pollinated	PB -129-5, Pant Samrat, Arka Sheetal, Azad Kranti, PB -91-2, ARU-1, T-3, H-4, Kat- 4, ARU-2C, K-202-9, Aruna, H-7, NDB-25, H-8, BB-26, Punjab Barsati, Sel-4, DBSR-31, KS-224, DBR-8, DBSR-44, AB-1, PLR-Lbb-26, BB-13, JB-64-1-2, KS-331, JB-15, CHBR-1, DBSR-91, JB-64-1-2, Green Long, Punjab Sadabahar, NDB-28-2
Hybrids	Arka Kusumkar, Arka Navneet, Pusa Hybrid-5, Pusa Hybrid-6, ARBH-201, NDBH-1, ABH-1, MHB-10, MHB-39, NDBH-6, ABH-2, Phule Hybrid-2, Pusa Hybrid-9, ARBH-541, PBH-6, JBH-1
Disease resistant	BB-7, BWR-12, SM-6-7, SM-6-6, BB-44
Tomato	
Open pollinated	S-12, Pusa Ruby, HS-101, SL-120, Sweet-72, T-1, Pusa Early Dwarf, Sionx, Sel-152, Punjab Chhuhara, KS-2. AC-238, GO-3, Pb. Kesari, La Bonita, Pant T-3, Arka Vikas, Arka Saurabh, Sel-7, Sel-1-6-4, Sel- 32, DT-10, BT-12, KS-17, BT-116-3-2, NDT-3, KS-118, DVRT-2, BT-20-2-1, NDT-9
Hybrids	ARTH-4, MTH-6, ARTH-3, Pusa Hybrid-2, FMH-2 (A. Vardhan), NA-501, DTH-4, KT-4, NA-601, FMH-2, BSS-20, Avinash-2, HOE-303, Sun-496
Disease resistant	BWR-5 (Arka Alok), FMH-1 (A. Vardhan), FMH-2, BT-10, H-24, BRH-2
Chillies	
Open pollinated	G-4, G-5, K-2, J-218, X-235 (LCA-235), X-235, Muslawadi, Sel-1, LAC-206-B, AKC-86-39, BC-14-2, RHRC-Cluster Erect
Hybrids	HOE-888, ARCH-236
Capsicum	
Hybrids	KT-1, SEL-II
Pea	
Open pollinated	Bonneville, GC-141, GL-195, Arkel, Early December, IP-3, P-88, PM-2, Lincon, VL-3, VL-7, Ageta-6, VL-6, PH-1, NDVP-8, NDVP-10, VL-8, VRP-2, NDVP-12, VRP-3, Organ Sugar Podded,
Disease resistant	PRS-4, JP-4, JP- 83, NDVP-4, DPP-68, KS-245
Cowpea	
Open pollinated	L-1552, Sel-61-B, Sel-263, Sel-2-1, IIHR-6
Dolichos bean	
Open pollinated	Deepali
French bean	
Open pollinated	VL-Boni-1, Arka Komal, UPF-191, IIHR-909, CH-812, CH-819

Contd.

Appendix 6.1. Contd.

Vegetable crops	Varieties released
Okra	
Hybrids	DVR-1, DVR-2, DVR-3
Disease resistant	Sel-2, P-7, PB-57, Sel-10 (A. Anamika), Sel-4 (A. Abhay), HRB-55, HRB-9-2, VRO-3
Onion	
Open pollinated	Punjab Selection, Pusa Red, Pusa Ratnar, S-131, N-257-9-1, N-2-4-1, Line-102, Arka Kalyan, Arka Niketan, Agri Found Dark Red, VL-3, Agri Found Light Red, Punjab Red Round, PBR-5
Garlic	
Open pollinated	G-41, G-1, G-50, G-282, VLG-7
Cabbage	
Open pollinated	Sel-8
Hybrid	Pusa Synthetic, Shri Ganesh Gol, Nath-401, BSS-32, Nath-501, Quisto
Cauliflower	
Open pollinated	Early Kunwari, 327-14-8-3, 351-4-1, Improved Japanese, Synthetic-1, EC 1201, Pusa Snowball, K-1, 114-S-1, Line 6-1-2-1, Early Synthetic, 235-S, KT-25
Hybrid	Pusa Hybrid-1
Muskmelon	
Open pollinated	Pusa Sarbati, Hara Madhu, SI-45 (Pusa Madhuras), Arka Rajhans, Arka Jeet, Durgpura Madhu
Hybrid	Hybrid M-3
Disease resistant	DMDR-1
Watermelon	
Open pollinated	Durgapura Meetha, Sugar Baby, Arka Manik, MHW-6
Hybrid	Arka Jyoti
Pumpkin	
Open pollinated	CM-14, Pusa Vishwas, Arka Chandan, Arka Suryamukhi, CM-350, NDPK-24
Cucumber	
Open pollinated	CHC-1, CH-20, DCUC-28
Hybrid	PCUCH-1
Ridge gourd	
Open pollinated	CHRG-1, PRG-7, IIHR-7
Bottle gourd	
Open pollinated	Pusa naveen, OBOG-61, NDBG-104
Hybrid	PBOG-1, PBOG-2, NDBH-4
Sponge gourd	
Open pollinated	Selection 99

7. Conservation of Genetic Resources and Its Impact on Potato Breeding

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Abstract

The national repository of potato germplasm maintained at the Central Potato Research Institute, Shimla, has more than 2,200 parental lines and varieties of cultivated potatoes *(Solanum tuberosum)* and 134 wild and semi-cultivated species. The collection has been screened for important biotic and abiotic factors from time-to-time. This has helped in variety development programmes resulting in the release of 35 improved varieties for different agro-climatic zones of the country. Pedigrees of two varieties, viz. *Kufri Safed* and *Kufri Red* have represented the clonal selections from indigenous cultivars *Phulwa* and *Darjeeling Red Round*, respectively and the remaining 33 are hybrids. Resistance to late blight in some of these has been derived from *S. demissum* and for cyst nematodes from *S. vernei.* The gene pool is being used to overcome the problems associated with the commercial exploitation of True Potato Seed (TPS) technology. Attempts are also being made to combine durable resistance to late blight with immunity to viruses. It is argued that there is a need to evaluate the germplasm more extensively for diseases like bacterial wilt and potato viruses like X, Y and leaf roll. Development of improved parental lines of indigenous and wild species for features like tuber colour, shape, eye depth, size, etc. is necessary. It is suggested that studies on DNA fingerprinting should be accelerated for monitoring genetic integrity of germplasm collection in the light of WTO and TRIPRs.

Introduction

Potato, basically an exotic crop, was introduced into India from the Europe during the late sixteenth century, possibly by the Portuguese or the Spaniards. By the close of the nineteenth century, the potato cultivation had spread throughout northern India (Pushkarnath 1976). The main cultivated potato species *Solanum tuberosum* L., a tetraploid (2n= 48) is believed to be originated in Andes of Peru and Bolivia in South America, more specifically the lake Titicaca basin in Peru-Bolivian region (Ross 1986). It has two subspecies, viz. ssp. *tuberosum* adapted to long days and ssp. *andigena* adapted to short days. *S. tuberosum* ssp. *andigena* is widely distributed in the Andean regions of Venezuela and northern Argentina, whereas *S. tuberosum* ssp. *tuberosum* occurs naturally in only southern Chile. Two main centres of diversity of tuber bearing species are Central America, and Andean region of north-western Argentina, Peru and southern Bolivia.

The genus *Solanum* contains about 2000 species of which nearly 235 are tuber bearing (Hawkes 1990). They are found from sea level to 4,000 m in hills and from the Equator to 40^o S. The tuber bearing species have been placed in sub-section Hyperbasarthrum (now called Potatoe) of section Tuberarium (now called Petota) of sub-genus Potatoe (Hawkes 1990). New species continue to be discovered on one hand and several species on the other have been relegated to synonymy after detailed biosystematic studies. The basic chromosome number of the genus *Solanum* is x = 12 (Howard 1970). The ploidy level of potato species varies from 2x to 6x with 73% of these being diploids, 4% triploids, 15% tetraploids, 2% pentaploids and 6% hexaploids (Hawkes 1990).

Potato Germplasm in India

In India, studies on potato germplasm were initiated soon after starting the organized research on potato during 1930s. After the establishment of the Central Potato Research Institute (CPRI) in 1949, the collection, conservation, evaluation and documentation of potato germplasm and its utilization have been the ongoing activities of this sole organization in India. The first attempt to register variability in potato was made during 1940s, about 400 indigenous samples were collected with the help of the State Department of Agriculture. Within this mass of variability, 16 varieties were identified as exotic cultivars, while the rest were grouped into 16 distinct morphotypes whose original identity could not be established (Table 7.1). These cultivars represented some of the earliest introductions or their clonal variants and were termed as *desi* varieties (Pal and Pushkarnath 1951).

Morphologically, these varieties resemble ssp. *andigena* (Sinha and Pushkarnath 1964). With the introduction of high-yielding potato varieties, much of the earlier variability seems to have been lost; some genetic variability still exists in remote and difficult areas of the country. Attempts were made to collect this variability, for which several surveys were conducted during 1983-1992. A total of 621 samples were collected and studied for various morphological characters (Table 7.2). These were grouped into 125 distinct morphotypes (Anonymous 1992-93).

Table 7.1. Old indigenous (*desi*) and exotic potato varieties in India

Indigenous varieties	Exotic varieties
Agra Red	Ally
Chamba Red	Arran counsal
Coonoor White	Ben Cruachan
Coonoor Red	Craig's Defiance
Darjeeling Red Round	Dunbar Cavalier
Desi	Great Scot
Dhantauri	Italian White Round
Gola Type A	Late Carman
Gola Type B	Magnum Bonum
Gola Type C	Majestic
Phulwa	Northern Star
Phulwa Purple Splashed	President
Red Long Kidney	Raeburn's Gregor Cups
Sathoo	Red Rock
Shan	Royal Kidney
Silbilati	Up-to-date

Source: Pal and Pushkarnath (1951).

Since potato is not native to India, not much genetic variability can be expected in the material collected within the country. Acquisition of exotic germplasm from different countries has, therefore, been a continuing activity of CPRI. This activity has been accelerated after the establishment of the International Potato Centre (CIP) at Lima, Peru in 1972. The collection at CPRI now has over 2,600 accessions, consisting of cultivated species (*tuberosum* and *andigena*) as well as wild and semi-wild species (Table 7.3). These germplasm accessions have been procured from 30 countries based on our requirements of resistance or tolerance to various biotic and abiotic stresses.

Conservation

The potato genetic resources can be maintained sexually as true seeds, or asexually as clones through field propagation as tubers or through tissue culture. The preservation of germplasm as true seeds, however, is practicable only when total genetic diversity is to be maintained. Since potato is highly heterozygous, for maintaining the exact genotype of the elite parental lines, clones or varieties, asexual propagation is followed. On the other hand, preservation of germplasm as true seed is less laborious and cheaper than the preservation through vegetative propagation. In

Table 7.2. Indigenous potato variability collected during explorations in India (1983-1992)

Year	Months	Survey days (Number)	State	Districts surveyed	No. of samples collected
1983-84	November-March	130	UP*	Farukhabad	20
1985	November	5	UP*	Uttarkashi	18
1986	March	18	UP*	Azamgarh, Barabanki, Ballia, Basti, Deoria, Faizabad, Gonda, Gorakhpur, Jaunpur, Lucknow, RaiBareilly, Sultanpur, Varanasi	160
1986	August-September	10	HP	High hills of Shimla	41
1986	November	11	Assam,	Kokrajhar and Nawgaon	10
			Meghalaya	Jawai and Khasi Hills	16
1986	December	5	Assam	Karbi, Aanglong,	11
			Meghalaya	Naswgaon East Khasi hills and Jaintia hills	9
1987	February	20	Bihar*	Begusarai, Bhojur, Darbhanga, Gopalganj, East Champaran, Gaya, Khagaria, Madhubani, Muzaffarpur, Nalanda, Patna, Purnea, Ranchi, Rohtash, Saharsa, Samastipur, Saran, Sitamarhi, Siwan	125
1988	February-March	22	Bihar*	Bhagalpur, Devgarh, Dumka, Gonda, Kishanganj, Munger, Sahibganj	23
			W. Bengal	Barrackpore, Birbhum, Cooch Behar, Hooghly, Jalpaiguri, Midnapore, Siliguri	30
1988	October-November	22	HP, UP*	Kinnaur, Shimla Uttarkashi	55
1991	September	18	HP	Rampur, Kinnaur	55
1992	November	7	HP	Chamba	38
Others+			HP	Kulu	2
			HP	Kinnaur	11

+ amples received from NBPGR Regional Station, Shimla (HP)
* Refer to undivided states
Source: Gopal and Gaur (1997)

Table 7.3. Potato germplasm collection at CPRI (2003)

Material	No. of accessions				No. of donar countries
	Tuber	*In vitro*	True seed	Total	
Tuberosum cultivars/ parental lines (Indian)					
Cultivars bred at CPRI	33	33	-	33	
Old indigenous cultivars	16	8	-	16	
Parental lines	11	1	-	11	
Indigenous samples	89	79	-	89	
Exotic	980	1000	-	1290	30
Andigena	834	-	200	834	5
Wild semi-cultivated species	124	-	246	370 (134 species)	5

Source: *Annual Report* (2002-03), CPRI, Shimla

addition, it is easier to maintain the material free of pathogens, as only few viruses are known to be seed transmitted. As true seeds have low moisture content, these can be kept at low temperatures for many years.

At CPRI, the available germplasm is being maintained through three methods: (1) *in vivo* clonal propagation, (2) *in vitro* clonal propagation, and (3) true seeds. *In vivo* clonal propagation is done in glasshouses at Shimla and as duplicate sets in fields at Kufri and Jalandhar. All *tuberosum* and a part of *andigena* accessions are being maintained and multiplied by this method to facilitate their evaluation for adaptability to different agro-climatic regions as well as for resistance/tolerance to various biotic and abiotic stresses. A part of the accessions belonging to *andigena* and wild species is being maintained in the true seed form. True seeds for short-term storage are maintained at CPRI at 10-15 ^{o}C and for long-term, in cold modules at the National Bureau of Plant Genetic Resources, New Delhi. The true seeds are produced by selfing and/or sibmating. Sibmating is often resorted to in the case of diploid species most of which are self-incompatible. *In vitro,* only a part of the germplasm is being maintained. Till date about 900 *tuberosum* accessions have been conserved in this form. For this, minimal growth conditions are used in which nodal cuttings are micropropagated on MS medium containing 40g/litre sugar and 20g/litre mannitol. Plantlets are incubated under 16 h photo-period at 5-6^{o} C. Under these conditions potato plantlets can be preserved up to 30 months without sub-culturing. As facilities for long-term storage develop, it is proposed to conserve all or at least most of the valuable material *in vitro.*

Facilities and protocols are also being developed for cryopreservation of the meristem tips or axillary buds.

Evaluation

Evaluation of germplasm is a continuous process at CPRI. The germplasm accessions have been evaluated for economic characters like resistance to late blight (Barua *et al.* 1976; Anon 1991-92; Gopal and Singh 1993), bacterial wilt (Shekhawat *et al.* 1980; Chakrabarti *et al.* 1992; Nagesh *et al.* 1993), wart (Singh and Gopal 1990; Singh and Gopal 1994), nematodes (Nirula *et al.* 1967, 1969; Anon 1983), potato tuber moth (Anon 1991-92), charcoal rot (Thirumalachar and Pushkarnath 1953; Paharia *et al.* 1962), hopper burn (Chaudhary *et al.* 1983; Anon 1995-96) and viruses (Anonymous 1991-92; Garg and Gopal 1994; Garg *et al.* 1999), besides maturity, tuber dormancy (Joseph and Gopal 1994), storage quality (Kang and Gopal 1993), tuber drymatter and protein content (Gaur and Gupta 1981; Misra *et al.* 1991), etc. The results of evaluation have been compiled and presented in annual reports of CPRI and the catalogues on potato germplasm collection have been published. (Gaur *et al.* 1984; Gopal *et al.* 1992; Birhman *et al.* 1998). A large number of accessions have been found suitable for use as parents in potato breeding programmes.

To identify good general combiners among the germplasm accessions found promising for various characters, combining ability studies were conducted (Dayal *et al.* 1985; Gaur *et al.* 1983, 1985, 1993; Gopal 1998a, 1998b, 1998c; Gopal and Mincoha 1998; Pandey and Gupta 1997; Kaushik *et al.* 2000). A list of good general combiners for various characters along with the poor combiners is given in Table 7.4.

Information on flowering and fruiting behaviour is important not only from morphological and taxonomic points of view but is also of special significance to the breeders engaged in the production of new potato varieties. An intimate knowledge of the subject saves time and energy, which might otherwise be spent on futile efforts in producing incompatible or otherwise impossible crosses. The flowering and fruiting behaviour of 872 *andigena* (tetraploid), 344 *tuberosum* (tetraploid) and 319 dihaploids of *tuberosum* under short-day subtropic conditions has already been compared (Gopal 1994a). Bud initiation was observed in most of the genotypes, but bud development leading to mature flowers was found only in 6 per cent genotypes of *andigena* (tetraploid) and 28 percent dihaploids of *tuberosum*.

None of the tetraploid *tuberosum* genotypes was found flowering. The genotypes which flowered regularly constituted only 0.6 per cent in *andigena* and 11.9 per cent in dihaploids. However, none of the dihaploids produced berries, whereas 9.6 per cent of the flowering *andigena* genotypes produced berries regularly and 82.7 per cent in one or the other years. The number of seeds per berry was 28 to 188 in various genotypes with an average of 99 seeds. These results suggested that tetraploid *tuberosum* to which most of the cultivated potatoes belong can't be used as parents for TPS production under natural short-days in plains. However, dihaploids and *andigena* could be exploited for the purpose. In another study (Gopal 1994b), 676 accessions of cultivated ssp. *tuberosum* from 25 countries were evaluated for flowering behaviour under natural long-day (12-14 h) conditions at Kufri. The majority (58.3%) of the accessions bloomed profusely, though 20.4% of the accessions did not bloom at all. "Weeks to flowering" ranged from 6 to 15 and the majority (66.5%) of the flowering accessions bloomed within 8 to 9 weeks after planting. "Duration of flowering" ranged from 1 to 10 weeks and the majority (68.1%) of the flowering accessions bloomed for 1 to 4 weeks only. Twenty-three percent of the flowering accessions were completely male sterile. No berry setting was observed in 31.8% of the flowering accessions. Premature bud abscission was the major cause of sterility.

Genetic divergence studies have also been conducted with potato germplasm being maintained at CPRI (Gaur *et al.* 1978; Gopal 1999; Joseph *et al.* 1999). It has been found that such studies could be conducted even in the *in vitro* propagated germplasm. This approach was found to be rather more efficient than the *in vivo* one for the *per se* differentiation of the genotypes. However, for cross prediction, genetic divergence studies should be conducted in the conditions under which crosses are likely to be evaluated (Gopal and Minocha 1997). Genetic divergence between *andigena* and *tuberosum* germplasm showed that the present day Indian varieties were closer to *tuberosum* than to *andigena* group (Gopal 1999).

For characterization of various accessions, morphological characters like tuber skin colour, tuber shape, eye depth, tuber flesh colour, flower colour, etc. have been recorded using the descriptors of the International Bureau of Plant Genetic Resources (IBPGR). The information on these characters for *tuberosum (*Gopal *et al.* 1992) and *andigena* (Birhman *et al.* 1998) accessions has also been compiled.

Table 7.4. General combining ability of some germplasm accessions

Character	General combining ability		
	Good	Average	Poor
Tuber yield	CP 2000 (I-1062), CP 2110 (CFK 69.1), CP 2334 (AL-575), CP 2346 (F-6), CP 2359 (Yankee chipper), CP 2370 (Muziranzara), CP 2378 (Poos. 16), Katahdin, K. Jyoti, K. Badshah. K. Bahar, K. Pukhraj, EX/A 680-16, EX/B 687	CP 2407 (Monstama), CP 2417 9MEX 750838), K. Jeevan, K. Kundan, K. Khasigaro, K. Dewa, Up-to-date, EX/A 679-10	CP 1710 (Kerr Pondy), CP 2132 (Tollocan), CP 2351 (Tobique), CP 2401 (CIP 702867)
Tuber number	CP 2378 (Poos. 16), CP 2413 (Piratini), K. Kuber, K. Khasigaro, K. Dewa, K. Pukhraj, EX/A680-16, EX/A 723, EX/A-687	CP 2346 (F-6), CP 2351 (Tobique), CP 2401 (CIP 702867), CP 2417 (MEX 750838), Dekama, Up-to-date, K. Jeevan, K. Sheetman, K. Kundan	CP 1710 (Kerr Pondy), CP 2334 (AL-575), CP 2370 (Muziranzara), CP 2407 (Montsama), CP 2132 (Tollocan), CP 2416 (MEX 750826), Katahadin, K. Jyoti, K. Badshah, K. Bahar
Average tuber weight	CP 2334 (AL-575), Katahdin, K. Jyoti, K. Badshah, K. Bahar, K. Pukhraj, EX/A 680-16	CP 2407 (Montsama), CP 2416 (MEX 750826), CP 2417 (Mex 750838) CP 2346 (F-6), CP 2370 (Muziranzara), CP 2378 (POOS.16), Dekama, Up-to-date, K. Jeevan, K. Kundan, EX/B 687	CP 2401 (CIP 702867), CP 2413 (Piratini), CP 2132 (Tollocan), CP 2351 (Tobique), K. Sheetman, K. Kuber, K. Khasigaro, EX/A 679-10, EX/ A723
Tuber dry matter	CP 2346 (F-6), CP 2370 (Muziranzara), CP 2378 (Poos.16), CP 2416 (MEX 750826), CP 2417 (MEX 750838)	CP 2334 (AL-575), CP 2407 (Montsama), CP 2413 (Piratini)	CP 2351 (Tobique), CP 2401 (CIP 702867)
Resistance to late blight	CP 1673 (Dr. McIntosh), CP 2030 (G.6246), CP 2333 (AL624), CP 2378 (Poos.16)	CP 2011 (CIP 676082), CP 2370 (Muzranzara), CP 2381 (CFJ 69.1), Desiree	CP 2013 (Atzimba), CP 2110 (CFK 69.1), Dekama, K. Badshah
Resistance to early blight	EX/A 680-16	CP 2132 (Tollocan)	CP 1710 (Kerr Pondy), EX/A 723

Source: Gopal and Gaur (1997)

Impact on Potato Breeding

During the early stages of potato research in India, evaluation of a large number of European varieties was undertaken. These efforts were, however, largely unsuccessful because the exotic cultivars being adapted to temperate long-day growing conditions in the west were unsuitable under the sub-tropical short-day conditions prevailing in nearly 90 per cent of the potato growing areas in India. Requirements of short-duration varieties that could be stored at high temperatures prevailing after the harvest of crop in plains, further necessitated the initiation of indigenous potato breeding programmes. Attention was, therefore, focused on identification of suitable parental lines for Indian potato breeding programmes. The available germplasm is being utilized in various breeding programmes at CPRI. It has resulted in release of 35 improved varieties of potato. *Kufri Safed* and *Kufri Red* represented clonal selections from indigenous cultivars *Phulwa* and *Darjeeling Red Round*, respectively and the other 33 varieties were hybrids. Pedigrees of these varieties showed that in 9 varieties, both of the two immediate parents were of Indian origin (Table 7.5), 16 varieties had one parent of Indian origin and one of exotic origin (Table 7.6) and 8 varieties had both parents of exotic origin (Table 7.7). The exotic cultivars that have figured more frequently as parents in the release of Indian varieties were Adina, Craigs Defiance, Ekishiraju, Kathadin and Up-to-date, and parental lines obtained from late Dr. William Black of the UK.

In recent years, there has been a shift in the choice of parents in favour of Indian cultivars and parental lines. Whereas the first batch of cultivars released during 1950-59 had mainly exotic varieties in their parentage,

Table 7.5. Cultivars developed using both parents from indigenous germplasm

Cultivar	Year of release	Parentage
Kufri Sindhuri	1967	Kufri Red x Kufri Kundan
Kufri Neelamani	1968	Kufri Kundan x 134-D
Kufri Chandramukhi	1968	Seedling 4485 x Kufri Kuber
Kufri Badshah	1979	Kufri Jyoti x Kufri Alankar
Kufri Megha	1988	SLB/K 31 x SLB/273
Kufri Jawahar	1996	K. Neelamani x K. Jyoti
Kufri Sutlej	1996	K. Bahar x K. Alankar
Kufri Anand	1998	Kufri Ashoka x PH/F 1430
Kufri Giriraj	1998	SLB/J132 x EX/A 680-16

Table 7.6. Cultivars developed using one parent from indigenous germplasm and one from exotic germplasm

Cultivar	Year of release	Parentage
Kufrii Kumar	1958	Lumbary x Katahdin
Kufri Jeevan	1968	M 109-3 x Seedling-698-D
Kufri Khasigaro	1968	Taborky x Seedling-698-D
Kufri Naveen	1968	3070d (4) x Seedling 392-D
Kufri Alankar	1968	Kennebec x ON-2090
Kufri Chamatkar	1968	Ekishirazu x Phulwa
Kufri Sheetman	1968	Craigs Defiance x Phulwa
Kufri Dewa	1973	Craigs Defiance x Phulwa
Kufri Bahar	1980	Kufri Red x Gineke
Kufri Lalima	1982	Kufri Red x AG-14 (Wis x 37)
Kufri Swarna	1985	Kufri Jyoti x $(VTn)^2$ 62.33.3
Kufri Ashoka	1996	EM/C 1021 x CP 1468
Kufri Pukhraj	1998	Craig's Defiance x JEX/B 687
Kufri Chipsona 1	1998	CP2416 (MEX 750826) x MS78- 79
Kufri Chipsona 2	1998	CP 2346 (F-6) x QB/B 92-4
Kufri Kanchan	1999	SLB/Z 405 (a) x Pimpernel

Table 7.7. Cultivars developed using both parents from exotic germplasm

Cultivar	Year of release	Parentage
Kufri Kisan	1958	Up-to-date x Sd. 16
Kufri Kuber	1958	*(S. curtilobum* x *S. tuberosum)* x *S. andigenum*
Kufri Kundan	1958	Ekishirazu x Katahdin
Kufri Neela	1963	Katahdin x Shamrock
Kufri Jyoti	1968	3069 (4) x 2814a (1)
Kufri Muthu	1971	3046(l) x M 109-3
Kufri Lauvkar	1972	Serkov x Adina
Kufri Sherpa	1983	Ultimus x Adina

those released during 1960-69 often involved one indigenous variety as one of the parents. At present, the choice of parents falls more often on newly bred Indian cultivars and Indian parental lines. Thus, the cultivars Kufri Badshah, K. Swarna, K. Jawahar, K. Sutlej, K. Chipsona 1, K. Chipsona 2 and K. Kanchan have improved Indian cultivars and hybrids in their parentage.

The utilization of wild and semi-cultivated tuber bearing *Solanum* species in Indian potato breeding programmes has been poor. Only four species from the collection available at CPRI have been used for developing parental lines. Wild species *S. verrucosum* and *S. microdontum* with durable resistance (horizontal) to late blight have been used for transferring this resistance to *tuberosum* background (Sharma *et al.* 1982; Birhman *et al.* 1991). Resistance to charcoal rot from *S. chacoense* has also been transferred to *tuberosum* background (Upadhyay *et al.* 1977). Resistance to cyst nematodes in variety Kufri Swarna has been derived from *S. vernei.* In most of these programmes, dihaploids of ssp. *tuberosum* have been utilized because the species involved were diploids (2n =24). Attempts are being made to combine durable resistance to late blight with immunity to viruses.

Gaps and Thrust Areas

CPRI has been recognized as the national repository for potato germplasm collection, which though modest at present is the best in South-East Asia. This collection is likely to serve the entire South Asian region, for which quarantine facilities are being developed. Infrastructural facilities are being improved and technology for cryopreservation of potato collections is being developed.

On the evaluation front, there is a need to evaluate the germplasm more extensively for diseases like bacterial wilt, potato viruses X, Y and leafroll, and race non-specific resistance to late blight. Higher attention needs to be paid to *Solanum tuberosum* ssp. *andigena* which is adapted to short-days and is thus more suitable for sub-tropical plains. This ssp. possesses a much wider genetic variability than *tuberosum* and has been found to be a good source of resistance to several diseases and pests. *Tuberosum* x *Andigena* crosses have also resulted in heterosis for tuber yield and its components (Cubillos and Plaisted 1976; Gopal *et al.* 2000). Only one *andigena* culture EXA 680-16 was identified as a good general combiner for yield and its components (Gaur *et al.* 1983, 1985; Gopal 1998a, 1998b) are presently being extensively used in both the variety improvement as well as TPS programmes. This is mainly because ssp. *andigena* is late maturing and has undesirable tuber characters. Thus, development of improved parental lines of *andigena* for various agronomic characters like tuber colour, tuber shape, eye depth, tuber size, etc. is must if it is to be exploited extensively in the breeding programmes. Assessment of semi-cultivated and wild species for resistance to late blight, bacterial wilt and potato tuber moth also needs to be accelerated. Studies on DNA fingerprinting need to be accelerated to have a catalogue for monitoring genetic integrity of germplasm collection from time to time in the light of World Trade Organization and Trade Related Intellectual Property Rights regimes.

Though a vast genetic variability exists in potato, very little has been actually used in the improvement of cultivated potato. This is true for India as well as for other countries. In the "Index of European Potato Varieties (1985)", one can find that only 10 primitive cultivars or species had been used in the pedigrees of 62 per cent of the 627 cultivars listed. Remaining varieties involved only ssp. *tuberosum*. It has been estimated that only 13 species have been used so far in the variety improvement programmes of the world (Ross 1986). Clark (1925) reported that the parentage of as many as 171 American varieties could be traced to a single variety Rough Purple Chili introduced from Chiloe region of southern Chile. Though tetraploid and diploid crosses are not very difficult to develop, in one direction at least, the viability of the hybrids is not very high (Hawkes and Hjerting 1969). Undesirable tuber traits of the wild species and crossability problem of certain species also act as deterrents to their use by the breeders. Pre-breeding of the wild species at diploid level for combining disease resistance to various diseases and pests with agronomic characters thus needs to be paid special attention. The use of bridging species belonging to other series in the inter-specific crosses can be exploited. Further, somatic hybridization with conventionally non-crossable species could be the other alternative (Helgeson *et al.* 1986). Incidentally, potato was one of the first species to be hybridized with another genus (tomato) through protoplast fusion (Melchers *et al.* 1978). Molecular biology of endosperm balance number which determines the inter-specific compatibility, needs to be studied so as to facilitate the use of various species in all the desired combinations.

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8. Prospects of Vegetable Production in the Arid Zone of India

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Abstract

The possibility of growing vegetables in favourable environments of arid region has been explored and suitable cropping systems and strategies for increasing vegetable production in the country have been suggested. Indian arid zone is characterized by high temperature and low and variable precipitation which limit scope for good yield. That is why systematic production of vegetables is rare in the arid zone. It is felt that there is a lack of suitable varieties which could be grown successfully. It is suggested that most hardy vegetable types should be commercially exploited using hardy genetic resources. Irrigation given through flooding method causes great losses of scarce water and it is suggested to use improved method of irrigation. Some approaches have been suggested for successful vegetable cultivation in the arid region. These are i) breeding of early maturing and pests-resistant vegetable varieties as well as tolerant to high temperature and drought, and ii) regular supply of quality seeds of recommended varieties to vegetable growers.

Introduction

Vegetables provide food and nutrition security, generate income and employment and also earn foreign exchange. India is bestowed with varied agro-climatic conditions, which allow growing of several types of vegetables in the country. Presently in India, vegetables are grown on 6.2 million hectares of area with production of over 90 million tonnes per year. However, the present per capita daily consumption of 175 grams of vegetables in the country is far below the recommended level of 285 grams per capita per day. There is a definite shift in the dietary pattern of people with rise in income and living standard and increase in awareness about quality of food. Assuming a population growth rate of 1.7 per cent per annum and country's commitment for export, at least 220 million tonnes of vegetables would be required by 2020 AD.

Since there is a limited scope for a quantum jump in vegetable production in traditionally growing areas, thrust is to be laid on harnessing potential of unutilized vast wasteland spread over more than half of the geographical area of the country, of which arid region forms a major component. Arid region is a vast untapped land resource where several indigenous horticultural species can be commercially exploited for vegetable industry. Systematic production of vegetable crops has been rare in the arid region mainly because of lack of suitable crop varieties and appropriate production technologies for stress conditions. This paper describes the vegetable production in the arid region under favourable environments and suggests suitable cropping systems and strategies for increasing vegetable production in the country.

The Indian Arid Regions

The Indian arid zone is one of the largest sub-tropical deserts of the world, of which 20 per cent is arid and rest is semi-arid with varied habitats. The hot arid region is spread over 31.7 million hectares area, mainly in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab and Haryana (Table 8.1). The Indian arid zone is characterized by high temperature and low and variable precipitation which limits the scope for high productivity, diversification and choice of crops and varieties. However, drier conditions of arid region largely favour development of several high-quality vegetables, particularly cucurbits, chillies and spices. Besides, these situations also help in low incidence of diseases and insect pest infestation in vegetable crops.

Table 8.1. Arid regions of India

(area in million ha)

Regions	Arid Area	Arable area	Cultivable wasteland
Rajasthan	19.60	9.20	4.20
Gujarat	6.20	0.02	1.66
Punjab	1.50	1.05	0.03
Haryana	1.30	1.15	0.02
Peninsular India	3.10	1.63	0.11
Total	31.70	13.15	6.03

Source: Vision 2020, NRC for Arid Horticulture, Bikaner

Arid Zone of Rajasthan

Rajasthan covers 271 thousand hectares (79 per cent) of arid and semi-arid climate spread over 21 districts. These areas are characterized by low precipitation, high variations in annual rainfall, high temperature, high evaporation, acute water stress and high wind speed. The annual rainfall is low (180-600 mm), erratic and is confined to a short-duration of July to September. By and large, soils are coarse texture, sandy, and poor in fertility as well as water-retention capacity. Vegetable production and productivity in the arid region largely depend upon availability and management of limited irrigation water. The production and productivity of arid vegetables can be increased, if due consideration is given to the *in situ* runoff harvest, moisture conservation, watershed management and adoption of improved agro-techniques.

The western part of Rajasthan state, covering an area of 209 thousand square kilometres is under hot arid climate. The mean annual rainfall is 100-450 mm, which is largely monsoon-driven and comes between July and September (9-21 spells). About 90 per cent of the rainfall is received during the months of July and August. Erratic distribution of monsoon rainfall often leads to prolonged droughts and failure of rainfed crops. The mean maximum temperature in May-June varies from 42 ^{0}C in the west to 40 ^{0}C in the east, but it is not uncommon to experience 48-50 ^{0}C. Strong winds with sand storms are experienced during May-July, when the south-west monsoon sets in.

Agro-ecological Settings for Vegetable Production

Based on rainfall, soils types, surface water, groundwater and land-use, the arid western Rajasthan has been classified into three agro-ecological sub-regions: (i) Western sandy plain sub-region, (ii) Central alluvial plain sub-region, and (iii) Northern canal irrigated sub-region. Six zones and fifteen sub-zones have been identified within these sub-regions and are described in Appendix I (Faroda *et al.* 1999). Based on intensive surveys undertaken during last seven years (Samadia 2003) in arid and semi-arid regions, potential vegetable crops have been identified for cultivation under rainfed, partially irrigated and /or assured irrigated conditions of the western Rajasthan; these are also listed in Appendix I. Some perennial species having commercial importance as vegetables in fresh, dehydrated or processed forms, have also been found to possess potential, considering the larger size of landholdings to develop conventional and intensive farming systems.

Indian arid zone can grow a large number of vegetable crops compared to any hot arid desert in the world. Some of the potential vegetable crops are listed in Table 8.2. Since there is a significant variability within the zone, micro-level planning based on field performance would be required for gainful utilization of agro-climatic zone. Wider adaptability, climatic acclimatization, response to various production systems and wider genetic base of vegetable crops are advantageous for extending the area under different zones of arid and semi-arid regions for harnessing the maximum potential.

Vegetable Production in Rainfed Arid Areas

A systematic production of vegetables is rare in the arid region mainly because of lack of suitable crop varieties and production techniques. The vegetables in arid areas are exposed to biophysical constraints which limit their growth and productivity. Among vegetable crops, the most-hardy

Table 8.2. Potential vegetable groups for cultivating in the arid zone

Group	Name of vegetables
Cucurbitaceous	Watermelon [*meteera*] (*Citrullus lanatus*), muskmelon (*Cucumis melo*), snapmelon (*Cucumis melo* var. *momordica*), *kachri* (*Cucumis callosus*), *kakri* (*Cucumis* spp.), roundmelon (*Praecitrullus fistullosus*), bottlegourd (*Lagenaria siceraria*), ridgegourd (*Luffa acutangula*), spongegourd (*Luffa cylindrical*), bittergourd (*Momordica charantia*), *kundru* (*Coccinia grandis*)
Leguminous	Clusterbean (*Cyamopsis tetragonoloba*), cowpea (*Vigna unguiculata*), Indian bean (*Lablab purpureas*), pea (*Pisum sativum*), sword bean (*Canvalia gladiata*)
Solanaceous	Chilli (*Capsicum annum*), brinjal (*Solanum melongena*), tomato (*Lycopersicon esculentum*)
Cole crops	Cabbage (*Brassica oleracea* var *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), knoll-khol (*Brassica oleracea* var. *caulorapa*)
Bulbous	Onion (*Allium cepa*), garlic (*Allium sativum*)
Root crops	Radish (*Raphanus sativus*), carrot (*Daucus carota*)
Okra	Okra (*Abelmoschus esculentus*)
Leafy/herbal vegetable	*Methi* (*Trigonella foenum graecum*), *palak* (*Spinacia oleracea* and *Beta vulgaris*), coriander (*Coriandum sativum*), chaulai (*Amaranthus* spp), *bathua* (*Chenopodium* spp.) *sowa* (*Anethum sowa*)
Perennial vegetables	*Khejri* [*Sangri*] (*Prosopis cineraria*), drumstick [*Sehjana*] (*Moringa oleifera*), Indian-aloe [*Gurarpatha*] (*Aloe barbadensis*), *phog* (*Callgonum polygonoides*), *khimp* (*Laptadenia pyrotechnica*)

types belong to cucurbitaceous and solanaceous crops; these include watermelon, muskmelon, snapmelon, *kachri,* chilli, cumin, fenugreek, etc. Cowpea, cluster bean, dolichos bean, sword bean and okra are also drought hardy. There is a need to select the most hardy and short-duration cultivars for cultivation in the arid region. There is also a need to develop vegetable based-agri-horti-pastoral system, incorporating perennial horticultural crops like khejri, drumstick, *kair*, kumat, *lasora* khimp, phog and Indian aloe. The crops like brinjal, tomato, chilli, cauliflower and onion can be taken in dryland using run-off concentration techniques, provided the seedlings are kept ready in the nursery for transplanting with the onset of monsoon in early July. Most of the rain occurs in 9 to 21 rainy days during July to September. The occurrence of summer rainfall has a thunderstorm pattern resulting in run-off generation which varies between 25 and 40 per cent, depending upon the rainfall distribution. The utility of run-off could be increased by treating the catchments, i.e. cleaning of natural vegetation, compactness of the catchments, putting chemical covers like *asphalt* and *bitumens* based sealants and plastic and polythene covers. Run-off offers possibilities of *in situ* water harvesting for vegetable production, particularly of deep root cucurbits in the sandy desert. In arid areas of Rajasthan, vegetables are grown since long in macro plots (*khadins*) and micro plots (*bari*) using run-off water collected from the surrounding rocky catchments. The productivity of vegetables in such systems can be further improved by conserving soil moisture and adopting innovative and improved agro-techniques.

Vegetable Production in Irrigated Areas

Most of the vegetables in the arid region are cultivated in small pockets having assured irrigation facilities around towns. But it is a matter of concern that such a vast area under arid and semi-arid regions has negligible cultivation of vegetables. Irrigation provided through flood method causes great loss of scarce water. This loss can be minimized by using improved method of irrigation such as sprinkler and drip system and increasing water-use efficiency. Adoption of these irrigation methods can bring additional area under irrigation by replacing field crops such as wheat, mustard and gram during *rabi season* and cotton, groundnut, guar and bajra during *kharif* season. There has been a considerable increase in the number of sprinklers and over 38,800 sprinklers were installed in the arid and semi-arid regions of Rajasthan by 1997. Crop improvement programs and large-scale production of improved seeds have increased the scope of vegetable production in the arid region. A careful selection of vegetable crops and their varieties for specific micro-regions is essential for their successful production (Table 8.3). Commercial production of seeds of cucurbits, tomato, chilli, brinjal, okra, cauliflower, pea, clusterbean, cowpea, palak, methi, coriander and cumin; and truck gardening of vegetables (for distant market) like cauliflower, cabbage, knol-khol, chilli, onion, potato, carrot and watermelon; and production of tomato, pea, kachri, methi, chilli and watermelon for processing industries have enormous scope in the arid region.

Table 8.3. Vegetable crops for irrigated arid and semi-arid areas of Rajasthan

Districts	Vegetables being grown	Vegetables that need intensification
Jodhpur, Jaisalmer, Barmer, Bikaner, Churu	Chilli, cluster bean, cabbage, cauliflower, radish, round melon, long melon, cowpea, palak, methi	Watermelon (*mateera*), muskmelon, bottle gourd, sponge gourd, ridge gourd, bitter gourd, snapmelon, kachri, long melon, okra, pea, cabbage, cauliflower, knol-khol, onion, garlic, brinjal, tomato
Ganganagar, Hanumangarh	Potato, chilli, brinjal, cauliflower, cabbage, pea, cluster bean, bottle gourd, radish, leafy vegetables	Watermelon, muskmelon, bottle gourd, bitter gourd, sponge gourd, ridge gourd, long melon, round melon, cucumber, kakri, onion, radish, carrot, tomato, cabbage, cauliflower, knol-khol
Nagour, Sikar, Jhunjhunu	Chilli, onion, brinjal, leafy vegetables	Chilli, tomato, brinjal, okra, watermelon, muskmelon, bottle gourd, sponge gourd, ridge gourd, bitter gourd, round melon, snapmelon, beetroot, cluster bean, cowpea
Pali, Jalore, Sirohi	Chilli, onion, tomato, cauliflower, leafy vegetables	Chilli, brinjal, tomato, cauliflower, cabbage, pea, cucurbits, beans, radish, onion, garlic
Jaipur, Ajmer, Tonk	Cabbage, cauliflower, chilli, tomato, brinjal, onion, bottle gourd, round melon, and leafy vegetables	Cucurbits, cauliflower, chilli, brinjal, tomato, onion, garlic, cluster bean, asparagus, radish, carrot, cowpea

Cropping System for Vegetable Production in Arid Zone

Farmers in the arid zone are resource poor and undertake subsistence farming. Food, fodder, fuel, fibre, timber, etc. are the primary requirements of the farmers in the arid tropics. Therefore, proper cropping or farming systems should be developed, which are able to meet these requirements, depending upon the land and water resources. In the rainfed areas, the cropping system has to be a combination of perennial horticultural crops alongwith watermelon, *kachri,* snapmelon, tinda and clusterbean as ground crops and potentially useful multi-storey combination in a very low rainfall situation of western Rajasthan. The choice of crop combination under irrigated system is far wider, i.e. based on the microclimate of sub-region and region, crop potentiality and marketing system (Table 8.4).

Table 8.4. Vegetable crop components for cropping system in the hot arid regions

Rainfall divider	**High storey crops**	**Medium storey crops**	**Ground crops**			**Micro-wind break, bio-defence or field plants**
			Vegetables	**Agronomic**	**Grasses**	
Rainfed areas (150-300 mm rainfall)	*Khejri, ber*	*Ber, ker*	*Mateera, kachri,* snapmelon, tumba	*Guar, moth, bajra, til*	Cenchrus, Laisurus	Ker, phog, khimp, jharber
Rainfed areas (300-500 mm rainfall)	*Ber, lasora, khejri*	*Sehjana, lasora*	*Mateera, kachri,* snapmelon, tinda, Brinjal, Indian bean, clusterbean, cowpea	*Guar, moth, bajra, til*	Cenchrus, Dicanthium, Panicum	Ker, khimp, jharber,
Irrigated areas	Date palm, *ber, anola*	Lime, guava, pomegranate	Cucurbits, chilli, tomato, brinjal, cole crops, peas, beans, onion, okra and leafy vegetables	Cumin, isabgol, groundnut, mustard	-NA-	*Lasora, Sehjana, karonda*

Production Techniques of Vegetable Cultivation in Arid Areas

For successful vegetable cultivation in the arid regions, improved and innovative production technologies are to be adopted after proper selection of vegetable crops and varieties/hybrids. These include:

- Proper and timely field preparation in accordance with season and crop and timely sowing/ transplanting through proper adjustment of dates.
- Run-off harvesting, irrigation scheduling and efficient utilization of rain and irrigation water; proper adoption of soil water conservation practices and irrigation systems.
- Nutrient management through judicious and efficient use of manures and fertilizers and use of organic and bio-fertilizers.
- Proper management of weeds, insect, pests and diseases to stabilize vegetable production.
- Use of plant growth substances for improvement in fruit setting, early harvesting and high quality yield under aboitic stresses.
- Crop regulation, timely harvesting, storage and marketing and adoption of post-harvest and value-addition techniques to maximize net returns, reducing the losses in vegetables.

Strategies for Successful Vegetable Production in Arid Region

To produce vegetables successfully on commercial basis in arid regions, it is required to focus on the following strategies:

i) Breeding of early maturing and high-yielding varieties/hybrids with desired quality characters and resistance to abiotic and biotic stresses.

ii) Evaluation of germplasm including varieties and hybrids for biotic and abiotic stresses and value-addition, etc. as each crop needs attention for effective utilization in various production systems in the vast arid region.

iii) Strengthening of research on conservation of genetic resources, crop improvement and quality seed production technology in major vegetable crops under arid environment.

iv) Maintenance of high quality standards in seed production of important vegetable varieties/hybrids and making availability of seeds in market at minimal costs. Also, streamlining of seed production programme so that even small farmers could get quality seeds of vegetables in the arid regions.

v) Development and popularization of full packages of production practices varying across seasons, zones and production systems. Popularization of low cost protected cultivation system using locally available resources in specific crops and areas for off-season farming and non-traditional crops and quality produce.

vi) Intensive publicity including frontline demonstrations and on-farm trials about proper varieties/hybrids and production technology.

vii) Popularizing irrigation facilities such as micro-sprinkler, sprinklers and drip irrigation. Also, increasing the availability of moisture in light texture soil of arid situation using mulches and other means.

viii) Development of integrated approaches for management of weeds, insects-pest and diseases so as to reduce the cost of chemicals and avoid environmental degradation.

ix) Studies on post-harvest technologies in vegetable crops in arid areas. Special attention need to be paid, for example, to sun drying of vegetables, extraction of seed kernels *(Maghaz)* in cucurbits, oleoresins from chilli, production of curry powder from *kachri,* etc. to develop small-scale/ cottage industries in the arid region.

Conclusions and Policy Implications

The vegetables are widely distributed in different agro-climatic zones, including arid regions in India. Their distribution patterns play a major role in extending their availability for a longer period of time in the country. Interactive knowledge of agro-climatic regions added with information on climatic response of vegetable crops and varieties can be gainfully utilized to set higher productivity and economic returns from vegetable-based farming system in the arid regions. Studies made by the ICAR, SAUs, state department of agriculture, and other agencies have demonstrated the adoption of production technologies in many vegetable crops in a wide range of agro-climatic conditions. Traditionally, watermelon, snapmelon, *kachri*, clusterbean and tinda are grown under rainfed conditions in arid regions during monsoon. Because of remunerative price and production opportunity, a large number of vegetables like cucurbits, brinjal, chilli, beans and leafy vegetables are being grown in the limited areas near towns using supplementary irrigation. Cole crops confined to temperate and mild sub-tropical areas have also been extended to arid region, with the development of heat-tolerant cultivars. Besides, onion, garlic, radish, herbal and spice vegetables have potential with a modification in production technology and crop cultivars. With supplemental irrigation, vegetables like tomato, chilli, watermelon, muskmelon, beans can be grown for extended harvesting. *Kharif* onion, watermelon, chilli and tomato in monsoon season have excellent potential for high quality in the arid region.

Availability of quality seed is of utmost importance for increasing vegetable production and productivity in the stress-prone regions. Limited rainfall and low humidity restricts the incidence of diseases and pests. The vegetables produced in the desert are of high quality owing mainly to low humidity conditions which also offers great potential for production of high quality seeds. Availability of irrigation water, wider adaptability of crops and drier climatic conditions in the vast arid region provide opportunity for successful seed production of vegetables in this region.

Amongst strategies for successful vegetable production in arid areas are popularization of irrigation facilities like micro-sprinkler and low cost cultivation systems, development of integrated approaches for the creation of vegetable crop production adopting micro-climate, resource management, control of weeds, insects pest, etc. and evolving post-harvest technologies which could lead to development of small-scale/ cottage industries in the arid region.

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Appendix 8.1. Agro-ecological zones and suitable vegetable crops

Agro-ecological zones/ sub-region	Mean annual rainfall (mm)	Area (%)	Dominant land – use/ major crops	Suitable vegetable crops*: Rainfed vegetables with water conservation practices and life saving watering on cultivable wastelands	Suitable vegetable crops*: Potential vegetable under assured irrigation system as field crops	Suitable vegetable crops*: Perennial horticulture species as wind break, hedge row, bio-fenced or field-divider
A) Western sandy plain sub-region						
1. Hyper arid zone						
1.1. Hyper arid	100	4.12	Sandy waste	Mateera, kachri, snapmelon	Mateera, snapmelon, brinjal, bottle gourd, tinda, leafy vegetable	Khejri, ker, Indian aloe, phog, khimp
2. Dune complex with scrub and grasses						
2.1. Western dune complex with grassland	100-150	9.87	Open grazing	Mateera, kachri, snapmelon, clusterbean	Mateera, snapmelon, bottle gourd, tinda, brinjal, leaf vegetables	Khejri, ker, Indian aloe phog, khimp
2.2. Western dune complex with scrub	100-150	1.25	Open grazing	Mateera, kachri, snapmelon clusterbean	Mateera, snapmelon, bottle gourd, tinda, brinjal, leafy vegetables	Khejri, ker, Indian aloe, phog, khimp
3. Hand pan zone						
3.1. Hard pan soil	150-250	7.52	Limited kharif cultivation, grazing	Mateera, kachri, snapmelon clusterbean	Mateera, snapmelon, bottlegourd, tinda, brinjal, leafy vegetables	Khejri, ker, indian aloe, phog, khimp, lasora, sehjna
4. Sandy plain with scattered dunes						
4.1. Eastern dune complex with limited cultivation	250-350	6.32	Kharif: Bajra, mong, moth. Rabi: Gram	Mateera, kachri, snapmelon clusterbean	Mateera, snapmelon, bottlegourd, tinda, brinjal, leafy vegetables	Khejri, ker, Indian aloes, phog, khimp, lasora, sehjna,

Contd

Appendix 8.1. Agro-ecological zones and suitable vegetable crops – Contd

Agro-ecological zones/ sub-region	Mean annual rainfall (mm)	Area (%)	Dominant land – use/ major crops	Suitable vegetable crops*		
				Rainfed vegetables with water conservation practices and life saving watering on cultivable wastelands	**Potential vegetable under assured irrigation system as field crops**	**Perennial horticulture species as wind break, hedge row, bio-fenced or field-divider**
4.2. Sandy plain with < 300 mm rainfall	250-300	17.63	Kharif: Bajra moth, guar	Mateera, kachri, snapmelon, clusterbean	Mateera, snapmelon, bottle gourd, tinda, brinjal, leafy vegetables, cowpea, Indian bean, leafy and herbal, radish and cole crops	Khejri, ker, lasora, sehjna, Indian aloe, phog, khimp,
4.3. Sandy plain with > 300 mm rainfall	300-450	2.63	Kharif: Bajra, mong, til	Mateera, kachri, snapmelon, culsterbean	Mateera, snapmelon, bottle gourd, tinda, brinjal, leafy vegetables, cowpea, Indian bean, leafy and herbal, radish and cole crops	Khejri, ker, lasora, sehjna, Indian aloe, phog, khimp,
4.4. Sandy plain with island drainage	300-400	5.94	Kharif:Bajra, mong, til Rabi: Wheat, mustard	Mateera, kachri, snapmelon, culsterbean	Mateera, snapmelon, bottle gourd, tinda, brinjal, leafy vegetables, cowpea, Indian bean, leafy and herbal, radish and cole crops	Khejri, ker, lasora, sehjna, Indian aloe, phog, khimp
B) Central Alluvial Plain sub- region						
5. Luni basin						
5.1. Luni basin with coarse loamy soils	300-450	12.75	*Kharif*: Bajra, guar, mong and til	Mateera, snapmelon, kachri, tinda, clusterbean	Watermelon, muskmelon, bottle gourd, ridge gourd, tinda, brinjal, chilli, onion, garlic, leaf and herbal vegetables, radish, cole crops, clusterbean, kherji, lasora,	Khejri, ker, lasora, senjna, Indian aloe, phog, khimp

Contd

Appendix 8.1. Agro-ecological zones and suitable vegetable crops – Contd

Agro-ecological zones/ sub-region	Mean annual rainfall (mm)	Area (%)	Dominant land – use/ major crops	Suitable vegetable crops*		
				Rainfed vegetables with water conservation practices and life saving watering on cultivable wastelands	Potential vegetable under assured irrigation system as field crops	Perennial horticulture species as wind break, hedge row, bio-fenced or field-divider
					sehjna, Indian aloe	
5.2. luni basin with fine loamy soils	300-450	6.90	*Kharif*: Bajra, jowar, til and maize	Mateera, snapmelon, kachri, tinda, clusterbean	Watermelon, muskmelon, bottle gourd, ridge gourd, tinda, brinjal, chilli, onion, garlic, leaf and herbal vegetables, radish, cole crops, clusterbean, kherji, lasora, sehjna, Indian aloe	Khejri, ker, lasora, senjna, Indian aloe, phog, khimp
5.3. Mendha basin	400-450	1.34	*Kharif*:Cotton Rabi: Wheat, mustard and spices	Cowpea, Indian bean, brinjal, bottle gourd, ridge gourd, snapmelon, kachri, tinda, clusterbean	Watermelon, muskmelon, bottle gourd, ridge gourd, tinda, brinjal, chilli, onion, garlic, leaf and herbal, vegetables, radish, cole crops, clusterbean, kherji, lasora, sehjna, Indian aloe, Indian bean, tomato, okra, bittergourd, kakdi	Khejri, ker, lasora, senjna, Indian, aloe, phog khimp
5.4. Arvalli foot hills	450-500	11.02	Kharif: Maize, jowar, til, cowpea, Rabi:Wheat, mustard and spices	Cowpea, Indian bean, brinjal, bottle gourd, ridge gourd, snapmelon, kachri, tinda clusterbean	Watermelon, muskmelon, bottle gourd, ridge gourd, tinda, brinjal, chilli, onion, garlic, leaf and herble vegetables, radish, cole crops, clusterbean, kherji, lasora, sehjna, Indian aloe, Indian bean, tomato, okra,	Khejri, ker, lasora, senjna, Indian aloe, phog, khimp

Contd

Appendix 8.1. Agro-ecological zones and suitable vegetable crops – Contd

Agro-ecological zones/ sub-region	Mean annual rainfall (mm)	Area (%)	Dominant land – use/ major crops	Suitable vegetable crops*: Rainfed vegetables with water conservation practices and life saving watering on cultivable wastelands	Suitable vegetable crops*: Potential vegetable under assured irrigation system as field crops	Suitable vegetable crops*: Perennial horticulture species as wind break, hedge row, bio-fenced or field-divider
					bittergourd, kakri	
C) Northern canal irrigated sub-region						
6. Canal irrigated sandy plain						
6.1. Dune complex with canal irrigation	150-250	5.66	*Sand dunes*: Silvi pasture, groundnut, *Rabi*: Wheat and mustard	Mateera, snapmelon, kachri, clusterbean	Watermelon, muskmelon, bottle gourd, ridge gourd. Cowpea, clusterbean, brinjal, cole crops, radish, leaf vegetables, onion kherji, lasora, sehjna, Indian aloe	Khejri, kumat, lasora, sehjna
6.2. Aeolian plain of north-east	250-300	2.01	*Kharif*: Bajra, guar, cotton, *Rabi*: Wheat and mustard	Mateera, snapmelon, kachri, clusterbean	Water melon, muskmelon, bottle gourd, ridge gourd. cowpea, clusterbean, brinjal, cole crops, radish, leaf vegetables, onion kherji, lasora, sehjna, Indian aloe	Khejri, kumat, lasora, sehjna
6.3. Ghaggar flood plain	250-300	4.27	Cotton, wheat, rice and sugarcane	Mateera, snapmelon, kachri, clusterbean	Water melon, muskmelon, bottle gourd, ridge gourd. cowpea, clusterbean, brinja, cole crops, radish, leaf vegetables, onion, kherji, lasora, sehjna, Indian aloe	Khejri, kumat, lasora, sehjna

Source: Faroda *et al.* (1999) and modified by Samadia (2003) for vegetable crop planning in Rajasthan
* On the basis of intensive surveys in arid and semi-arid regions of Rajasthan

Part III.

Adoption and Impact of Vegetable Research

9. Adoption and Impact of IPM in Cabbage Production

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Abstract

Factors influencing the adoption of IPM and its impact on pesticide use, costs and returns have been studied using farm-level data from 70 cabbage producers spread over a cluster of three villages in Dharmpuri district of Tamil Nadu during 1998-99. It is observed that higher education and better access to information are crucial to adoption of IPM. It is found that adoption of IPM lowers the unit cost of production by 5 per cent and the net benefits realized are higher by Rs 2009 per ha, compared to the farms using chemical control. Lack of adequate and timely supply of bio-pesticides, lack of timely expert advice, etc. have been reported as the main constraints in switching over to IPM technology.

Introduction

Insect pests and diseases are important biotic constraints in vegetable production in India, causing considerable losses. Farmers use a number of pest control methods to mitigate these losses. Chemical pest control being the preferred strategy in practice, fruits and vegetables are important recipients of chemical pesticides in India. These together account for 3.2 per cent of the gross cropped area and 7.3 per cent of the total pesticide used in the country. On an average, 1.11 kilograms of pesticides are applied on one hectare area of fruits and vegetables (Chand and Birthal 1997).

In recent years, the use of pesticides in agriculture has become a controversial issue because of their potential adverse effects on public health and environment. Moreover, the effectiveness of pesticides is reported to be declining with time. A number of insect pests and diseases have developed resistance to pesticides that were being used to control them. For instance, *Helicoverpa armigera* has developed resistance to almost all the important insecticides, and has turned out to be a polyphagus pest for vegetables and other crops. With rising public concerns about economic and ecological externalities of the chemical pesticides, the emphasis of plant protection research and development strategies has gradually been shifting from chemical to non-chemical approaches.

Among the non-chemical approaches, Integrated Pest Management (IPM) has emerged as one of the important alternatives. It includes application of bio-organism in conjunction with chemical pesticides, agronomic practices and mechanical control. Empirical evidences from several studies (Kumar 1992; Kishor, 1997; Chowdry and Seethraman 1997; Birthal *et al.* 2000) have provided a broad indication that IPM is as profitable as the chemical pesticides. These evidences, however, are based on a limited number of observations collected from farmers identified for IPM demonstrations and issues concerning adoption, consumption and impact of IPM are yet to be investigated properly. In this paper, the adoption and impact of IPM in cabbage have been reported.

Methodology and Data

The study was based on the farm-level data collected through field surveys of 70 cabbage producers (35 IPM adopters and 35 non-IPM adopters) spread over a cluster of three villages in Dharampuri district of Tamil Nadu during 1998-99. The selection of IPM adopters was purposive because of small number of adopters, while non-adopters were selected randomly. Although the IPM is a package consisting of a number of technologies and agronomic practices, for the purpose of this study, a farmer was considered an IPM adopter if he had applied any of the bio-pesticides. The main bio-pesticides used by the farmers were *Bacillus thureingensis* (Bt) and neem formulations (extract, oil and pesticide).

Partial budgets were constructed to assess the farm level effects of IPM. The results were up-scaled through economic surplus model to the target area under cabbage in the Dharampuri and adjoining districts of Tamil Nadu.

Adoption of IPM

The measurement of adoption of IPM is rather difficult as it encompasses a number of technologies and practices. Nevertheless, farmers adopt a few of its components, depending on their knowledge level and attitude towards them, and availability of the technology. Agronomic practices which are advocated as a part of IPM, are mostly followed by a majority of the farmers as routine crop husbandry practices. And therefore, the 'dominant technique' approach was used to measure adoption of IPM. Biological pest management inputs included neem products and Bt on cabbage. It was seen that a majority of the cabbage growers used chemical pesticides. Application of the biological pest management inputs was limited to 24 per cent of the area and 20 per cent of the farmers (Table 9.1).

Table 9.1. Adoption of IPM technologies in cabbage crop in the sample villages

	Particulars		IPM adoption
1.	Number of cabbage farmers		522
	(a)	Per cent using bio-agents/ bio-pesticides	19.5
	(b)	Per cent using chemical pesticides alone	80.5
	(c)	Per cent using none	0.0
2.	Area under crop in hectares		356
	(a)	Per cent protected with IPM	24.2
	(b)	Per cent protected with chemical pesticides	75.8
	(c)	Per cent unprotected	0.0

Adoption of Pest Management Practices

The survey results showed that farmers took both preventive and curative measures to limit the crop loss due to pests and diseases. These were classified into chemical, biological and cultural measures. Frequency distribution of the adopters and non-adopters following different practices is presented in Table 9.2. Use of insecticides was found indispensable in cabbage production, irrespective of the use of biological technologies. About 97 per cent cabbage IPM farmers applied insecticides, in addition to fungicides and herbicides. A similar pattern was observed in the non-adopters. Use of Bt was widespread in cabbage by adopters. Neem-based pesticides and neem oil was also used by about 29 per cent farmers. These bio-pesticides were absent on the non-adopters' fields. A majority of the farmers, consciously or unconsciously, were found following a number of agronomic practices that reduced the pest build up. These included: summer ploughing, synchronized sowing, proper plant spacing, seed replacement and crop rotation. Most of these practices are routine farm management practices. The study revealed that these farm practices were being followed at both the adopted and non-adopted farms in a similar pattern (Table 9.2). Other direct cultural interventions like hand picking of insect larvae, manual weeding, and trap cropping were also followed to reduce pest infestation.

Table 9.2. Response of adopters and non-adopters to pest control practices in cabbage production

(per cent)

Pest management practices	Adopters	Non-adopters
Chemicals		
Insecticides	97.1	100.0
Fungicides	68.6	60.0
Herbicides	0.0	0.0
Bio-control		
Tricho-cards	0.0	0.0
NPV	0.0	0.0
Bt	97.1	0.0
Neem products	28.6	0.0
Pheromone traps	0.0	0.0
Cultural		
Dry period ploughing	100.0	100.0
Adjusting sowing dates	71.4	71.4
Proper plant spacing	17.1	28.6
Seed replacement	100.0	100.0
Trap/ border cropping	28.6	34.3
Hand picking of larvae	0.0	0.0
Manual weeding	62.9	71.4
Crop rotation	0.0	8.6

Characteristics of IPM Adopters and Non-Adopters

The choice of a technology is largely dictated by its profitability in comparison to other options. Besides, a number of socio-economic, institutional and environmental factors also influence the choice of technology. Studies have demonstrated that early adopters of the new innovations were generally youngers, having higher level of education, and possessing larger landholdings (Feder 1985; Thomas *et al.* 1990; Harper *et al.* 1990; Polson and Spencer 1991; Nkonya *et al.* 1997; and Lapar and Pandey 1999).

Important characteristics of adopters and non-adopters of IPM have been compared in Table 9.3. The adopters were relatively younger; the difference, however, was not statistically significant. The education level of the adopters was significantly higher than that of the non-adopters.

There was no significant difference in the sizes of landholding of adopters and non-adopters. Fragmentation of holdings was considered to be an

Table 9.3. Mean (standard deviation) of the variables distinguishing the adopters from the non-adopters in cabbage production

Particulars	Adopters	Non-adopters
Personal characteristics		
Age (years)	38.0 (5.4)	38.2 (5.3)
Years of schooling	10.1 (2.1)	7.0* (4.3)
Farm characteristics		
Size of landholding (acres)	4.9 (4.6)	4.4 (2.5)
Number of fragments	2.1 (1.0)	2.0 (1.2)
Number of adult workers/ acre	0.8 (0.3)	0.7 (0.4)
Area under crop (%)	18.8 (6.0)	18.2 (0.1)
Awareness of pesticide externalities (score)		
Technological failure	1.5 (0.8)	1.2 (0.9)
Ecological ill effects	1.9 (1.1)	0.9* (1.7)
Health impairments	3.6 (1.3)	2.4* (1.3)
Pesticide residues in food	3.4 (2.3)	2.0* (2.4)

Note: Figures within the parentheses are standard deviations
* indicates significance at 1 per cent level.

important hindrance in technology adoption; the adopters had less number of land fragments compared to those in the non-adopters. IPM is considered to be a labour-intensive method; its components such as collection of insect larvae, release of *Trichogramma*, etc. require more labour, compared to that in the spraying of pesticides. This might discourage adoption of such technologies and practices. The study data showed that family labour availability per unit of operated area was slightly higher in the adopter households.

Negative externalities of the chemical pesticides to crops, ecology and public health are also important considerations in the promotion of IPM technologies. These negative externalities include technological failure (resistance to insecticides, pest resurgence and secondary pest outbreak), damage to beneficial organisms (beneficial insects, predators and soil microorganisms), human health impairments as a result of direct exposure to pesticides (effects on eyes, skin, nervous system, and gastro-intestinal system), and entry of pesticides into the food chain (residues in foodgrains, livestock products and animal feed and fodder). Farmers' knowledge of such externalities can be a critical factor in technology choice. A composite awareness score was computed for each externality class by adding up the awareness (yes/no) response of the decision-makers. Analysis showed that both the adopters and non-adopters had a fairly good knowledge of the negative externalities of the chemical pesticides to crops, ecology and human health. The mean awareness score of the adopters, however, was higher than that of the non-adopters. Probit model was used to identify the factors influencing adoption of IPM technologies, and the results are presented in Table 9.4.

Age of the decision-maker did not appear as a significant factor in the adoption process, while the education emerged as the important

Table 9.4. Factors influencing adoption of biological technologies in cabbage cultivation

Factors	Cabbage IPM farmers	
	Coefficient	Marginal effect
Personal characteristics		
Age (years)	-0.0229	-0.0049
	(0.55)	
Years of schooling	0.1809**	0.0384
	(2.186)	
Farm characteristics		
Size of landholding (acres)	0.0174	0.0037
	(0.231)	
Number of fragments	-0.6982*	-0.1483
	(2.718)	
No. of adult workers/ acre	0.4998	0.1062
	(0.681)	
Area under crop (percent)	0.0031	0.0007
	(0.139)	
Awareness of pesticide externalities (score)		
Technological failure	-0.4135	-0.0878
	(1.079)	
Ecological ill effects	0.7975*	0.1694
	(2.819)	
Health impairments	0.1338	0.0284
	(0.648)	
Pesticide residues in food	0.0014	0.0003
	(0.010)	
Constant	-1.5171	
	(0.860)	
log-likelihood function	-24.6934	
Restricted log-likelihood	-48.5359	
Chi-square	47.6851	

Figures within the parentheses are t-values.
* and ** were significant at 1 and 5 per cent levels, respectively.

determinant of the adoption. The estimates of marginal probability indicated that with one per cent increase in the level of education, the adoption of biological pesticides increased by 3.8 per cent in the case of cabbage. Fragmentation of landholding had a discouraging effect on the adoption of IPM. The share of area under cabbage in the total cropped area was not a significant determinant of the adoption. IPM was adopted first by the innovative farmers who generally had larger landholdings and better access to information. Likelihood of adoption of the IPM increased with the increase in the farmers' awareness about the economic and environmental costs of chemical pesticides. The mean value of these parameters was not significantly different between the adopters and non-adopters. This indicated that farmers, in general, were aware of the negative externalities of chemical pesticides, but due to newness of the technology and economic considerations, environmental concerns overrode the adoption decisions. Provision of adequate information and timely availability of inputs might accelerate adoption of IPM technology.

Impact of IPM

Pesticide Use and Crop Yield

IPM adopters used less of pesticides; use of chemical pesticide was estimated to be 2.5 kg per ha, which was 50 per cent of that used by the non-adopters (5 kg per ha). Crop yield was also marginally higher on IPM farms; it being 466 kg per ha on IPM farms and 445 kg per ha on non-IPM farms.

Cost of Cultivation

The estimates of variable costs, with and without IPM, are given in Table 9.5. Total costs included costs of human labour and draught power, seed of the main as well as inter/trap crop, organic and inorganic fertilizers, irrigation, chemical pesticides and biological pesticides.

The costs of cabbage cultivation with and without IPM were not much different. Human labour accounted for 46 per cent of the total cost, followed by plant nutrients (21 per cent), plant protection inputs (16 per cent) and seed (11 per cent) costs. There was only little difference in the per hectare costs of these inputs between the IPM and non-IPM farms.

Table 9.5. Cost of cultivation of cabbage on sample farms

(Rs/ha)

Particulars	Adopters	Non-adopters
Human labour	11,068 (2,582)	11,040 (2,572)
Seed	2,582 (669)	2,626 (748)
Plant nutrients	5,155 (1,642)	5,055 (1,723)
Plant protection inputs	3,841 (1,905)	3,876 (1,331)
Draught power	1,391 (524)	1,410 (535)
Irrigation	-	-
Others	11 (19)	15 (34)
Total	24,049 (4,482)	24,022 (4,864)

Note: Others include cost of inter/ trap/ border crop seeds
Figures within the parentheses are standard deviations

Gross and Net Returns

With positive effect on crop yields and lesser cost of protection, IPM is expected to yield higher net returns, compared to that from the conventional chemical control. The estimates of the gross and net returns with and without IPM are reported in Table 9.6.

Table 9.6. Gross and net returns with and without IPM in cabbage cultivation

(Rs/ha)

Returns	Adopters	Non-adopters	Change over non-IPM (%)
Gross returns	42,611 (3,305)	40,575 (4,139)	5.0 *
Variable cost	24,049 (4,482)	24,022 (4,864)	0.1
Net returns	18,562 (4,812)	16,533 (5,602)	12.1**

Note: Figures within the parentheses are standard deviations
* and ** denote significance at 1 and 5 per cent levels, respectively

A perusal of Table 9.6 reveals that application of IPM in cabbage generated higher returns; the values being Rs 42,611 per ha for IPM and Rs 40,575 per ha without IPM. The net returns were also higher; these being Rs 18,562 per ha with IPM, and Rs 16,553 per ha without IPM. Thus, the adoption of IPM yielded higher benefits of Rs 2,029 per ha.

The results established that IPM had the economic potential to substitute the chemical pesticides without demanding any additional resources or affecting the crop yield. This advantage is largely due to the better pest control efficacy of IPM. A full accounting of the costs and benefits of

IPM in terms of its positive externalities to the environment and public health would further improve the benefit-cost ratio.

Aggregate Economic Effects

Farm level economic benefits of IPM can be scaled-up to the regional level by multiplying the per ha net benefits from IPM and the area on which it is applied. This, however, does not properly characterize the benefits as it considers only the supply-side aspects. Demand-related factors are also equally important for assessing the impact. The economic surplus approach considers both the supply and demand factors influenced by the technological change, and assumes the distribution of gains from the technology adoption between the consumers and the producers. On this basis, one could say that application of IPM in cabbage could generate economic surplus worth Rs 6,53,000; about 79 per cent (Rs 5, 15,000) of it was accrued to the producers and about 21 per cent (Rs 1,38,000) to the consumers.

Sensitivity Analysis

At present, producers get supplies of bio-pesticides from the market as well as from the state department of agriculture; the supplies from the latter are subsidized. This brings distortion in costs and net profits. The sensitivity of IPM that effects the changes in prices of inputs has been described here.

At the farm level, application of biological pesticides (Bt and neem products) at market prices, were found to add Rs 129 per ha to the cost of IPM (Table 9.7). The existing cost disadvantage over chemical control

Table 9.7. Farm level impact of changes in prices, and supply arrangements of bio-pesticides in cabbage cultivation

Impact	Existing average price situation		Market price situation		Subsidized price situation	
	IPM	Non-IPM	IPM	Non-IPM	IPM	Non–IPM
Cost of pest control (Rs/ha)	7092	7058	7221 (1.8)	7058 (0.0)	6661 (-6.1)	7058 (0.0)
Total cost (Rs/ha)	24049	24022	24178 (0.5)	24022 (0.0)	23623 (-1.8)	24022 (0.0)
Net returns (Rs/ha)	18562	16533	18433 (-0.3)	16553 (0.0)	18988 (2.3)	16553 (0.0)
Unit cost (Rs/q)	51.6	54.0	51.9 (0.5)	54.0 (0.0)	50.7 (-1.8)	54.0 (0.0)

Note: Figures within the parentheses indicate percent change over the existing price scenario increased from Rs 34 per ha to Rs 163 per ha, and net returns declined by Rs 156 per ha. The unit cost of production increased by Rs 0.3 per quintal. At the subsidized prices, the cost of pest control and the total variable cost on IPM farms declined by 6.1 and 1.8 per cent, respectively. This renders IPM application cost-effective, compared to the chemical pest control (Rs 399 per ha). The unit cost of production declined to Rs 50.70 per quintal.

The farm level effects upscaled using economic surplus analysis showed that with the entire supply of IPM inputs coming at market prices, cabbage surplus was reduced by 17 per cent. Provision of subsidies on the IPM inputs added 39 per cent to the existing surplus. It was 56 per cent higher than the market prices.

These results indicated that at the existing prices of IPM inputs, IPM was marginally profitable. That means input prices are one of the key determinants of the adoption of IPM. An increase in the prices of inputs would erode farm profitability, and would act as a disincentive to its adoption. However, considering its social and environmental benefits, it is appropriate to encourage farmers to adopt IPM as a cardinal principle of plant protection, as well as to the industry to invest in the production and promotion of the bio-pesticides through price and non-price incentives.

Conclusions and Implications

The commercialization and use of bio-pesticides are limited, despite their potential to reduce chemical pesticides. One of the reasons is the lack of a sound economic analysis of their production and use. Technologists often judge the performance of IPM technology in terms of crop yield, which is a necessary, but not a sufficient condition for its commercialization. The sufficient condition for off-take of a technically efficient IPM technology by the stakeholders is the adequate returns to the investment made in its promotion and adoption.

Field investigations have indicated that an overwhelming majority of the farmers, both users and non-users of bio-pesticides, were using a number of cultural and mechanical methods, which now comprise IPM components. Farmers were found aware of the bio-pesticide methods, as well as drawbacks in the existing technologies. A number of factors had influenced adoption of IPM technologies; farmers, with higher education level and better land and labour resources, exhibited a greater tendency to adopt IPM technologies, while the fragmentation of landholdings acted as a disincentive to adoption of IPM. Farmers were aware of the negative externalities of chemical pesticides, but these could not influence their adoption decisions in a significant manner.

IPM was found cost-effective. The unit cost of production was being less by 5 per cent. The net benefits realized with IPM were Rs 2,009 per ha. This indicated that adoption of IPM technology could result in higher profitability without incurring additional financial expenses.

Farm level effects of IPM when scaled up at the regional level could generate considerable economic benefits to both the producers and the consumers. About 80 per cent of the benefits from the adoption of IPM accrued to the producers. The sensitivity of farm and market level welfare effects has also been tested with respect to the changes in the prices of the technologies used by the farmers. Results have indicated that raising prices to the market level would reduce the profitability of IPM, while the subsidization of technology would generate substantial benefits to consumers as well as producers. As the pests do not recognize the spatial and seasonal boundaries, the effectiveness of IPM can be further improved if the pests were managed area-wise and collectively.

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10. Economic Evaluation of Neem Botanicals to Control Pests in Cabbage

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Abstract

The potential of IPM in managing pests in cabbage is highlighted. The IPM technology has been validated through on-farm trials for three consecutive years, from 1996 to 1998. Cabbage cultivation has been affected by two major factors, viz. prices and pests, particularly diamondback moth (DBM) infestation. Farmers indiscriminately spray large quantitities of chemical pesticides to manage the infestation of DBM, but DBM has developed resistance against many of them, resulting in higher costs of production. It is reported that on-farm trials with IPM technologies, viz. Neem Seed Kernel Extract (NSKE) and mustard as a trap crop during 1996, could control the pest effectively, and farmers have not accepted mustard as trap crop as it replaces some of the rows of cabbage and have also expressed practical difficulties in sowing mustard seeds twice. It is reported that in 1997, only NSKE had been sprayed which effectively reduced the pest damage. Results have shown that farmers spraying NSKE could get 23% higher yields and incur 15% less cost on production; and realize 43% higher net returns. The only difficulty expressed by the farmers is the labourious preparation of NSKE and emission of bad smell during its preparation. NSKE technology has been further refined and neem seed kernel powder (NSKP) and neem seed powder (NSP) are reported to be used to overcome this problem in 1998 trails. This technology has proved as effective as NSKE, in terms of both efficacy and costs.

Introduction

Cabbbage, one of the important vegetables grown in India, shares about 4.1 per cent of the total vegetable area and contributes about 5.4 per cent to the total vegetable production. In Karnataka, it accounts for 3.8 per cent of the area and 5.1 per cent of the vegetable production (NHB 1998). The productivity of cabbage, especially during summer, is low due to production losses from a variety of insect pests. Diamondback moth (DBM) is the most severe pest and it sometimes causes complete yield loss, leading to ploughing of the ravaged crop.

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Farmers spray a variety of insecticides to control this pest but with little success, as this pest has gradually developed resistance to many synthetic chemicals.

Researchers have been trying to reduce the application of pesticides by adopting other measures, one of which is the integrated pest management (IPM) strategy. Neem has been identified as a potential component of IPM for many crops. Several attempts have already been made to take these technologies to farmers' fields and the present study is based on one such experiments of taking the technologies developed at the Indian Institute of Horticultural Research (IIHR), Bangalore. This was a part of the pilot project on 'Technology Assessment and Refinement' (TAR) through the Institution Village Linkage Program (IVLP) being implemented by the IIHR, Bangalore. A series of such on-farm trials (OFT) were taken-up to manage the problem of DBM in the project villages. The results of three years experiments have been discussed in this paper.

Methodology

Study area

The project villages, Kesthur and Neraleghatta of Doddaballapur taluk of Bangalore Rural District are located 40 km away from the Bangalore City. There are 386 families in these two villages and more than 80 families undertake vegetable cultivation throughout the year.

Problem Identification and Experiment Layout

During the agro-ecosystem analysis using the participatory rural appraisal (PRA) technique, the farmers prioritized the low yield in cabbage as one of their main problems. The problem cause analysis revealed that the incidence of DBM was the real cause affecting the productivity, particularly during the summer (Anonymous 1996). Farmers revealed that even 12 to 15 sprays of chemicals were not able to control the pest. The cabbage growers were facilitated to find the alternatives so as to get rid of the problem of DBM. Group discussions with the farmers resulted in taking up OFT with the following treatments during 1996 summer (Table 10.1).

Table 10.1. Treatment details of cabbage crop during 1996

Treatments	Treatment details	Justification/Hypothesis
Farmers' practice (T_1)	Dichlorophos — 5 times Cypermethrin — 5 times BHC dusting — once	Used chemical pesticides to control the pest but without success
T_2	Neem seed kernel extract (NSKE 4%) —3 times, 20, 30 and 40 days after planting (DAP)	NSKE acts as a repellent (botanical pesticide)
T_3	*Bt* formulations — 4 times, 20, 30, 40 and 50 DAP	*Bt* controls the pest (bio- pesticide)
IPM (T4)	Mustard as a trap crop + NSKE (4%) on cabbage + Dichlorophos — 2 times on mustard	Mustard attracts diamondback moth

Based on the farmers' reactions to these treatments and the practical difficulties that emerged, the technologies were refined. Accordingly, only two treatments, viz. T_1– farmers' practice and T_2 – neem seed kernel extract (NSKE) were taken-up for OFT during 1997. Based on the farmers' reactions and their difficulties, the following refinements in the treatments were formulated for the 1998 summer (Table 10.2).

Data Collection and Analysis

Cost accounting method was used for collection of data by visiting the villages every week. Simple tabular analysis was used to estimate the costs and returns in cabbage cultivation.

Table 10.2. Treatment details after technology assessment for 1998 season

Treatments	Treatment Details	Justification/Hypothesis
Farmers' practice T_1	Neem seed kernel extract (NSKE 4%) —3 times, 20, 30 and 40 DAP + pesticide	This has become farmers' practice as most of the farmers have started using it as a control measure against DBM
T_2	Neem kernel powder (4%) —3 times, 20, 30, and 40 DAP	Reduces the drudgery of preparation of NSKE
T_3	Neem leaf extract (5%) —3 times, 20, 30 and 40 DAP	As an emergency when seeds are not available

Results and Discussion

The results relating to economics of the OFT conducted during 1996 are presented in Table 10.3. It was clear from these results that T_2 (NSKE-4%), T_3 (*Bt*) and T_4 (IPM) were equally effective and significantly superior to the farmers' practice and realized 71 per cent, 71 per cent and 57 per cent higher yields over the control plot of the farmers (T_1), respectively. The marketable heads in all these three treatments were 95%. Due to these twin factors, the farmers were able to realize Rs 35,410, Rs 33,160 and Rs 30,085 as net returns per hectare in the T_2, T_3 and T_4 treatments, respectively.

Table 10.3. Economic assessment of technologies used to manage DBM in summer cabbage, 1996

Particulars	Technologies			
	T_1	**T_2**	**T_3**	**T_4**
Treatment details	**Farmers' practice 11 sprays**	**NSKE (4%) 3 sprays**	***Bt* 3 sprays**	**Mustard as trap crop + NSKE (4%), 3 sprays**
Cost of pesticides (Rs /ha)	6000	1000	3750	1625
Cost of cultivation, excluding pesticides cost (Rs/ha)	24090	23590	23090	23290
Total cost of cultivation (Rs/ha)	30090	24590	26840	24915
Marketable heads (per cent)	50	95	95	95
Yield (t/ha)	35	60	60	55
Cost of production (Rs/t)	859.70	409.8	447.3	453.0
Gross returns (Rs/ha)	25,000	60,000	60,000	55,000
Net returns (Rs/ha)	-5090	35,410	33,160	30,085
Benefit-cost ratio	0.83	2.44	2.23	2.42

Farmers preferred spraying NSKE alone (T_2) in spite of some difficulties in its preparation than using treatment T_3 *(Bt)* or T_4 (mustard as a trap crop). The outcome of the detailed discussions held with the farmers and their reactions to different treatments are given briefly in Table 10.4. They desired further simplification of NSKE technology and development of ready-to-use products, similar to chemical pesticides. The farmers felt that dry neem seeds could be powdered and stored for at least one cropping season. It

Table 10.4. Farmers' reactions to technologies used for managing DBM, 1996

Sl No.	Particulars	Technologies			
		T_1	T_2	T_3	T_4
1.	Treatment details	Farmers' practice—11 sprays	NSKE (4%) – 3 sprays	Bt – 3 sprays	Mustard as trap crop + NSKE (4%)—3 sprays
2.	Cost	Expensive	Cheap and cost-saving	Moderately expensive	Cheap and cost-saving
3.	Effectiveness	Very less	Effective	Effective	Effective
4.	Practical difficulties	No pest control method, though very easy to use. Even 100 per cent crop loss in some cases during severe pest incidence	1. NSKE preparation is cumbersome, laborious and irritating to eyes 2. Obnoxious smell emitted even after 12 hours 3. NSKE preparation could not be stored for a long time 4. Neem seeds are not readily available, particularly during summer months	1. Discolouration of head 2. Delayed head formation	1. Early land preparation for sowing one row of mustard 2. Sowing second row of mustard—25 days after planting cabbage 3. Reluctance to leave two rows of mustard as it reduces area available for cabbage, resulting yield loss 4. NSKE preparation is cumbersome, laborious and irritating to eyes 5. Obnoxious smell emitted even after 12 hours 6. NSKE preparation could not be stored for a long time 7. Neem seeds are not readily available, particularly during summer months

would save them from the drudgery of grinding and would facilitate storage of the product. An OFT was again carried out on the farmers' field during 1997 with two treatments only, viz. farmers' practice and NSKE treatment alone. The results of these experiments are given in Table 10.5.

Table 10.5. Assessment of technologies to manage DBM in summer cabbage, 1997

Particulars	Technologies	
	T_1	T_2
Treatments	**Farmers' practice— 8 sprays**	**NSKE (4%)— 3 sprays**
Cost of pesticide (Rs/ha)	5670	1500
Cost of cultivation excluding pesticides cost (Rs/ha)	27832	26832
Total cost of cultivation (Rs/ha)	33502	28332
Marketable heads (%)	60	95
Yield (t/ha)	45	54.5
Cost of production (Rs/t)	722.0	520.0
Gross returns (Rs/ha)	88,875	1,09,167
Net returns (Rs/ha)	56,373	80,835
Benefit-cost ratio	2.65	3.85

As was evident from the results of 1996 studies, spraying cabbage with NSKE was found not only effective in reducing the pest damage but also in lowering costs of cultivation in 1997 also. The insect intensity was less than one per plant in NSKE plots as against 35-40 insects in chemical control plots. The comparative economics indicated that farmers spraying NSKE had obtained 23 per cent higher yields, incurred 18 per cent less cost on cultivation and realized 43 per cent higher net returns. Again the only difficulty expressed by the farmers was regarding preparation of NSKE, which was found by them as not only laborious but also irritating to eyes and emitted bad smell during its preparation.

Meanwhile, based on the feedback during 1996 experiment, laboratory studies were taken up during summer 1997 in the Division of Entomology and Nematology at IIHR, Bangalore, to test bio-efficacy of the neem seed kernel powder stored for different durations and also of the fresh extract of neem leaf as a contingent measure in case neem seeds were not readily available. The laboratory results indicated the efficacy of the kernel power stored up to 30 days after powdering. Neem leaf extract (5 per cent) was also found effective but to a lesser degree than the kernel powder (Anonymous 1997).

Based on these lab findings, an OFT was carried out during the 1998 summer with modified treatments. With the success of the NSKE, all the farmers in the project villages were convinced about the utility of this botanical pesticide and started using NSKE as a pesticide to manage the DBM. Hence, during 1998, the control measure was NSKE spray only. The results pertaining to the economics of cabbage cultivation conducted during 1998 are presented in Table 10.6.

Table 10.6. Economic assessment of technologies used to manage DBM in summer cabbage, 1998

Particulars	Technologies T_1	T_2	T_3
Treatment details	**NSKE (4%)— thrice, 20, 30 and 40 DAP with insecticide**	**NSK (4%) powder— thrice, 20, 30 & 40 DAP**	**Neem leaf extract (5%) — 3 sprays, 20, 30 & 40 DAP**
Cost of pesticides (Rs/ ha)	2950	2520	300
Cost of cultivation excluding pesticides cost (Rs/ ha)	32,500	29,450	30,100
Total cost of cultivation (Rs/ ha)	35,450	31,970	30,400
Marketable heads (%)	95	95	80
Yield (t/ ha)	80	82	65
Cost of production (Rs/t)	443.12	389.87	467.70
Gross returns (Rs/ha)	1,60,000	1,64,000	1,30,000
Net returns (Rs/ha)	1,24,550	1,32,030	99,600
Benefit-cost ratio	4.51	5.12	4.28

The results revealed that neem seed kernel powder was as effective as NSKE in managing DBM and farmers were able to realize almost the same level of yield. They could reduce the cost of cultivation as less labour was required for the preparation of the NSK powder. By adopting these technologies, the cost of production of cabbage came down to less than Rs 450/t from Rs 860/t. However, farmers still expressed some difficulties in the preparation of NSK powder (Table 10.7).

Based on the feedback from the farmers' participatory studies during summer 1998, the technology was further refined and the whole seeds were powdered and tried during *rabi* 1998 on farmers' field. The field day could serve the purpose of spreading the technology fast among the cabbage growers as it happened in the project village. Discussions with the farmers revealed that use of neem seed powder was convenient and more practicable.

Table 10.7. Farmers' reaction to refined technologies during 1998

Treatments	Treatment details	Farmers' reactions
T_1	NSKE (4%)—thrice, 20, 30 and 40 DAP with insecticide	Farmers were convinced about the efficacy of the NSKE in managing the pests but could not give up additional sprays of insecticide to be sure of controlling the pests.
T_2	NSK (4%) powder — thrice, 20,30 & 40 DAP	Neem kernel powder was equally effective but shelling the seeds by the stoneroller to extract the kernel again involved the scarce labour for shelling and cleaning; the bad smell emitted during the preparation still persisted.
T_3	Neem leaf extract (5%) —thrice, 20, 30 & 40 DAP	Neem leaf extract (5%) was not as effective as the other two treatments but could be used as an emergency measure, though it involved extra labour in collection and grinding.

Conclusions

To manage DBM in cabbage during summer, the neem-based plant protection technologies have been successfully tried on farmers' fields for three years. The neem-based pesticide has been assessed and refined starting from laborious method of spraying NSKE with mustard as a trap crop to ready-to-use neem seed power. These refined technologies are not only helping the farmers in controlling the pest but also in reducing the cost of production substantially. Further, the use of neem as a pesticide has been found economically viable and environmentally sustainable which are reflected in higher benefit-cost ratio and less use of pesticides.

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11. Feasibility and Economics of IPM Techniques in Tomato

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Abstract

The financial feasibility of IPM module in comparison with insecticidal control has been studied. It is revealed that in IPM module the control of leaf miner is 25 per cent compared to 10 per cent in insecticidal management, over the control using no pesticide. The reduction in number of eggs laid by Heliothis is reported to be 59 per cent in IPM as against 37 per cent in insecticidal application. The fruit borer control has been observed to be 82 per cent in IPM module and 50 per cent in insecticidal application. This shows the higher effectiveness of the IPM over insecticidal application. The yield increase over 'no pesticides use' has been found to be 28 per cent in IPM and 25 per cent in insecticidal application. The cost-benefit ratio has been observed to be 1:2.2 in case of IPM, and 1:1.2 in insecticidal application. It has been suggested that trap crop of marigold and spray of NSKE and HaNPV could be integrated and utilized effectively for eco-friendly and economical management of tomato pests.

Introduction

Tomato is an important vegetable crop which is cultivated over 5 lakh hectares in India. The crop is attacked by thrips (*Thrips tabaci* L.), whitefly (*Bemisia tabaci* G.), mite (*Tetranychus neocalodonicus*), leafminer (*Liriomyza trifolii* Burgess) and fruit borer (*Helicoverpa armigera* Hub.). To manage these pests, a huge quantity of pesticides is used. The indiscriminate use of pesticides creates problems like pest resurgence, resistance of pest to pesticides, destruction of natural enemies, environmental pollution and health hazards to animals and birds. Taking these problems into account, the integrated pest management (IPM) practices have been developed and are being provided to farmers. In this paper the effectiveness of the IPM module (system) in comparison to the regular insecticidal control has been studied. The feasibility of the system has also been investigated.

Analytical Techniques

The study was conducted in an exploded plot design. The treatments were IPM module and insecticidal sprays, and an untreated control.

- **IPM Module**

In the IPM module, steps of pest management practices were followed right from the seed sowing to harvesting at different timings. These were:

a) Nursery Management

(i) Seed treatment with *Trichoderma* @ 5 g/kg seed, (ii) Application of Carbofuran 0.6 kg a. i./sq m, (iii) Putting cloth net on seedling of nursery and one spray of monocrotophos 15 mL/10 L of water, and (iv) Preparation of seedlings of *Tagetis* sp.

b) Before Transplantation

Seedling dip in imidacloprid @ 1 mL/L of water for three hours.

c) During Transplantation

Two rows of marigold *Tagetis* spp were planted after every 10 rows of tomatoes.

d) After Transplantation

(i) For leafminer, 15 days after transplanting, two sprays of neem seed kernel extract (3%) were carried out.

(ii) After locating eggs of *Helicoverpa* on marigold, two sprays of endosulfan @ 20 mL/10L water were given on marigold. While on tomato crop sprays, of HaNPV @ 10mL/10L water and NSKE at 3% were done alternatively at 15-day intervals.

(iii) The eggs parasitoid *Trichogramma pretiosum* @ 1,00,000 per ha were released in tomato crop twice at weekly interval.

(iv) Insectical sprays, regular sprays of recommended insecticides, viz. monocrotophos 0.05 per cent and endosulfan 0.07 per cent were given at 15-day intervals.

The observations were recorded only on leafminer and fruit borer infestations and the incidence of other pests was not observed. For leaf miner, the number of healthy and infested leaflets was recorded (on three leaves) from five randomly selected plants. For fruit borer, infested number of eggs laid by the pest on tomato was recorded. Similarly, healthy and infested fruits from each plot were noted at each harvest. From the generated data, the per cent fruit infestation was worked out.

Results and Discussion

The results revealed significant differences among the treatments in respect of leaf miner, fruit borer control and yield (Table 11.1). The per cent incidence of leaf miner in IPM module was less than that in the recommended insecticidal sprays and untreated control. The control of pest over insecticidal method was 17 per cent more in the IPM module. The number of eggs laid by *Helicoverpa* was 0.66/plant in the IPM module and 0.9/plant in the insecticidal control. The per cent reduction in the number of eggs laid by *Helicoverpa* on tomato was 26 per cent in case of the IPM module while it was zero in the insecticidal control. The incidence of fruit borer was 3 per cent in the case of IPM module and 6.7 per cent in insecticidal control.

The control of *Helicoverpa* over insecicidal control was more than 50 per cent in IPM module. This showed the better effectiveness of IPM system over the insecticidal control. The yield of tomato fruits was 3 per cent higher in the IPM module (129.15 q/ha) than that in the insecticidal control (124.88 q/ha). The economics showed that the net profit obtained in the case of IPM module was Rs 9,723/ha while it was Rs 8,224/ha in

Table 11.1. Effectiveness of IPM module in controlling tomato pests in kharif during 1999

Treatments	Leaf miner control Over insecticidal spray		Fruit borer control Over insecticidal spray			
	Leaves affected (%)	Reduction in leaves affected (%)	No. of eggs laid/ plant	Reduction in egg laying (%)	Fruit infestations (%)	Reduction in fruit infestation (%)
IPM module	34.56	17.3	0.66	26.7	3.04	54.6
Insecticidal spray	41.80	-	0.90	-	6.70	-
Untreated control	46.35	-	1.43	-	16.65	-

the insecticidal control. The cost benefit ratio was 1:2.2 in IPM module, and 1:2 in regular insecticidal sprays.

The effectiveness of marigold as a trap crop in tomato has been reported (Srinivasan *et al.* 1993). Similarly, the HaNPV has already been reported effective against *Helicoverpa armigera* in tomato (Krishna Murthy *et al.* 1993). NSKE at 5 per cent was reported effective against leaf miner of tomato (Pawar *et al.* 1996). Looking at the effectiveness of these treatments, they were integrated into the present IPM module. It could be concluded from this study that the treatments, viz. trap crop of marigold, sprays of NSKE and HaNPV and release of *Trichogramma* parasitoids could be integrated and utilized effectively, for eco-friendly and economical management of tomato pests.

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12. Assessing Farmers Behaviour in Adoption of Improved Technologies of Vegetable Crops in Karnataka

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Abstract

The knowledge of farmers on vegetable varieties and their behaviour in adopting these varieties and other technologies have been assessed. This study is based on a total sample of 100 farmers selected randomly in Kolar district of Karnataka. A majority of the farmers are reported to have high and medium level knowledge of improved technologies of tomato and French bean cultivation. However, only 16 per cent in Malur and 32 per cent in Chikkaballapur are reported to be high adopters of the improved technologies in French bean. A majority of the farmers have expressed lack of control measures for leaf curl in tomato, high cost of fertilizer, lack of marketing, impure seeds and timely labour availability as major reasons for non-adoption of improved technologies. A significant correlation between extension contact and knowledge and adoption of improved vegetable technology has been found. It is suggested that there is a need to strengthen communication methods like TV and radio by extending the durations of farm programs and providing training to the growers. Research efforts should be strengthened to develop multiple disease and pest-resistant varieties and direct supply of these varieties to farmers. It is observed that co-operative and contract farming may solve the problems of small farmers of post-harvest management and value-addition.

Introduction

The average productivity of a majority of vegetables in India is low (11.5 t/ha) compared to that in other countries of the world. It could be enhanced through adoption of improved vegetable technologies. Although several improved and hybrid varieties /technologies of vegetable crops have been developed, their adoption has not been very encouraging. In this study, the adoption behaviour of vegetable growers has been examined, along with finding the reasons for non-adoption of these varieties/technologies. The specific objectives of the study were:

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- Assessment of the existing knowledge level of farmers about vegetable varieties/technologies.
- Study of the adoption behaviour of vegetable growers towards recommended varieties/technologies.
- Identification of the reasons for non-adoption of improved vegetable varieties/cultivation practices.

Analytical Framework

The study was conducted in Malur and Chikkaballapur talukas of Kolar district of Karnataka. A total of ten sample villages, five in each taluka, were selected in consultation with the local Agriculture Office. Ten farmers from each selected village were chosen on random basis from both the talukas making a total sample of 100 farmers. These selected farmers were personally visited to collect data on the recommended package of practices being adopted, using a pre-tested survey schedule developed in consultation with some vegetable scientists.

To understand the process and level of adoption, certain parameters were considered such as farm size, extension participation, extension contact, mass media, and social participation as explanatory variables and knowledge of farmers, adoption level, consultancy pattern, and reasons for non-adoption as dependent variables.

In the case of vegetables, potato, tomato, onion, cabbage and cauliflower account for around 60 per cent of the total vegetable production in the country. Tomato and french bean were found as the predominant crops grown by the farmers in this region, and therefore these crops were taken for the survey. Necessary data were collected from farmers personally at either their home or farm in the villages. The variables were scored according to scales already developed and in-use in the extension research studies.

Results and Discussion

It was found that two-thirds of the farmers in both the talukas had up to medium level of knowledge about tomato growing (Table 12.1). However, farmers having high level of knowledge about tomato cultivation were considerably more in the Chikkaballapur taluka than in Malur taluka.

Table 12.1. Number of farmers having knowledge of improved technology of vegetable crops

Knowledge level	Tomato		French bean	
	Malur	**Chikkaballapur**	**Malur**	**Chikkaballapur**
High	12 (24)	22 (44)	7 (14)	14 (28)
Medium	25 (50)	17 (34)	-	2 (4)
Low	13 (26)	11 (22)	43 (86)	34 (68)

Note: Figures within the parentheses are per cent to total

It was found that a majority of farmers were high and medium adopters in tomato cultivation, whereas in French bean cultivation, a majority were low adopters (Table 12.2). The high adopters of improved technology were 28 and 32 per cent in tomato cultivation and 16 and 32 per cent in French bean cultivation at these locations, respectively. The results suggested that strengthening of the extension facilities could increase the knowledge and adoption behaviour of farmers on improved technologies of vegetable crops in the study areas.

Table 12.2. Adoption of the improved technology of vegetable crops by farmers

(in number)

Adoption level/ crops	Tomato		French bean	
	Malur	**Chikkaballapur**	**Malur**	**Chikkaballapur**
High	14 (28)	16 (32)	8 (16)	16 (32)
Medium	31(62)	26 (52)	-	-
Low	5 (10)	8 (16)	42 (84)	34 (68)

Note: Figures within the parentheses are per cent to total

In tomato cultivation, a majority of the farmers were medium adopters of practices like suitable soil, seed rate, fertilizer application, weed control, plant protection measures and disposal of produce (Table 12.3). In French bean cultivation, a majority of farmers were low adopters of these practices. Technologies like number of stakes and timing of staking were adopted by a low percentage of farmers because of their poor knowledge. It suggested that there was a need for strengthening the training and extension services for farmers at the village level.

In Chikkaballapur taluka, a majority of the tomato cultivators had high knowledge about suitable soils, spacing, number of stakes required and

Table 12.3. Adoption of improved practices in vegetable cultivation by farmers in Malur taluka

(in number)

Practices/Crops	Tomato			French bean		
	High	**Medium**	**Low**	**High**	**Medium**	**Low**
Soils	-	40 (80)	10 (20)	3 (6)	-	47 (94)
Seeds and nursery preparation	3 (6)	41(82)	6 (12)	8 (16)	-	42 (84)
Transplantation	15 (30)	15 (30)	20 (40)	-	-	-
Manures and fertilizers	1 (2)	44 (88)	5 (10)	8 (16)	-	42 (82)
Inter-culture and weed control	8 (16)	37 (74)	5 (10)	8 (16)	-	42 (84)
Plant protection	-	44 (88)	6 (12)	8 (16)	-	42 (84)
Harvesting and marketing	-	46 (92)	4 (8)	-	8(16)	42 (84)

Note: Figures within the parentheses are the farmers response measured in percent

Table 12.4. Adoption of improved practices in vegetable cultivation by farmers in Chikkaballapur taluka

(in number)

Practices	Tomato			French bean		
	High	**Medium**	**Low**	**High**	**Medium**	**Low**
Soils	34 (68)	2 (4)	14 (28)	6 (12)	0	44 (88)
Seeds and nursery	18 (32)	24 (48)	8 (16)	16 (32)	0	34 (68)
Transplantation	29 (58)	9 (18)	12 (24)	-	-	-
Manures and fertilizers	6 (12)	36 (72)	8 (16)	16 (32)	0	34 (68)
Inter-culture and weed control	11 (22)	31(62)	8 (16)	16 (32)	0	34 (68)
Plant protection	1 (2)	39 (78)	10 (20)	15 (30)	0	35 (70)
Harvesting and marketing	3 (6)	38 (76)	9 (18)	15 (30)	0	35 (70)

Note: Figures within the parentheses are the farmers response measured in percent

timing of staking (Table 12.4). It was revealed that a majority of them were medium adopters in adoption of seed rate, fertilization, weed control, plant protection and harvesting and marketing. However, a majority of the farmers had low knowledge about the package of practices/ technologies recommended for French bean cultivation.

Awareness about technology costs and distance of market could be the reasons for medium and low adoption of improved technology in tomato and French bean cultivation. There was a need to educate and strengthen the credit and transportation facilities for high adoption of all vegetable technologies.

An attempt was also made in the study to identify the knowledge source of farmers for growing vegetables. It was found that horticulture assistant was the major preferred source of knowledge in both the talukas (Table 12.5). Horticulture Officer and extension personnel of the university were the other major agents who were providing knowledge to vegetable cultivators in the study area.

Table 12.5. Information consultancy pattern of vegetable growers

Source of information	Malur		Chikkaballapur	
	Score	Rank	Score	Rank
Horticulture Assistant	45	I	48	I
Assistant Horticulture Officer	35	II	35	II
Extension guide from UAS*	10	III	10	III
Assistant Director of Horticulture	7	IV	12	IV
Scientists from IIHR, Bangalore	1	V	3	V
Radio	1	VI	1	VI
Television	-	-	1	VIII

* UAS

Information revealed that mass media like radio and television were not at all the preferred sources of knowledge of these growers. It could be due to non-suitability of time to listen to the programs on vegetable production; and no hands-on knowledge was being provided by the mass media communications methods. The recent introduction of farm advisory service on radio is a welcome step and farmers were found taking interest in listening to programs and getting solutions of their problems using expert advice.

A majority of the farmers indicated lack of control measures for leaf curl virus in tomato, and high cost of fertilizers as major reasons for non-adoption of improved technologies in vegetable crops in both the talukas (Table 12.6).

Other major reasons revealed by the farmers were lack of marketing facilities, impure seeds and non-availability of timely labour for production activities. However, some farmers opined that poor texture of soil, poor quality and high cost of plant protection chemicals, lack of awareness about technologies, and lack of irrigation facilities were the reasons for non-adoption of improved technologies in vegetables.

Table 12.6. Reasons for non-adoption of improved vegetable technologies

Reasons	Farmers' response, per cent	
	Malur	Chikkaballapur
Seeds		
• Impure seeds	14	8
• Non-availability of tomato seeds resistant to leaf curl virus and bacterial wilt	10	16
Fertilizers		
• High cost of fertilizers	40	38
• Non-availability of required fertilizers at proper time	-	6
Plant protection measures		
• Lack of control measures for leaf curl virus in tomato	90	60
• Lack of awareness about IPM technologies	-	6
• High cost of plant protection chemicals	-	4
• Adulterated plant protection chemicals	2	-
Others		
• Lack of regulated marketing facilities	40	58
• Non-availability of timely labour	10	20
• Suitable price at the time of harvesting	10	8
• Lack of irrigation facilities	4	2
• Poor texture of soil	2	4

Implications and Recommendations

Research efforts should be strengthened to develop multiple disease and pest-resistant varieties and F_1-hybrids in tomato and their direct supply to farmers. Alternative fertilizers, i.e. bio-fertilizers should be made available to farmers to reduce the costs involved in using chemical fertilizers and also for sustainable production. Strengthening of communication methods like radio and television by increasing the duration of farm programs and training of the growers for complete adoption of improved technologies are also important. Cooperative and contract farming may solve the problems of small farmers and improve yield and product quality in the long-run. Application of integrated pest and disease management technologies would help farmers and environment in future. There is a need to check exploitation of farmers by strengthening regulated market, easy accessibility to credit and transportation facilities, and organised direct access to supermarkets. Establishment of small-scale fruit and vegetable processing units would help reduce the post-harvest losses, increase farm income through value-addition, and make availability of vegetables round the year.

13. Yield Gap and Constraints in Potato Cultivation in Nilgiris District of Tamil Nadu

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Abstract

The yield gap and constraints in potato production in the Nilgiris, the most promising potato-growing tract of Tamil Nadu, have been studied based on a sample of 120 farmers possessing different features. The estimation of yield gap and identification of constraints have been reported. Results have shown that yield gap II has been highest on the small farms (55 per cent) and lowest on progressive farms (21 per cent). Among the technical constraints, lack of suitable varieties, irrigation and poor quality inputs are the major ones; while major socio-economic constraints identified are lack of funds, high cost of inputs and lack of proper marketing and storage facilities. This study has suggested evolving a comprehensive policy for both production and post-harvest management of potato in this district.

Introduction

Among the major tuber crops, potato has the largest share in both area and production followed by cassava and sweet potato. While the productivity of potato in India is 17 t/ ha which is at par with the world average, there still exists scope for increasing it. As regards Tamil Nadu, though it ranked first in the productivity of potato, its performance in terms of area and production are of great concern. There is a need to study the yield gap and constraints in potato production in this state and the present study is an attempt in that direction. It has been focused on the Nilgiris district, the most prominent potato-growing tract of Tamil Nadu.

Methodology

The study was carried out in Uthangamandalam taluka of the Nilgiris district. Six villages out of the twenty in the taluka having the largest area under potato cultivation and simultaneously exhibiting a declining trend, were selected for the present study. From each village, fifteen farmers were selected randomly. Besides, five progressive farmers were also selected randomly from each of the six villages. Thus, a total of 120 farmers constituted the sample for the study. For a comparative analysis, sample farmers were stratified into three groups: (a) farmers having a farm holding of less than two hectares, (b) farmers possessing more than two hectares, and (c) progressive farmers.

Yield Gap Analysis

To study the yield gap and technology adoption on farmers' fields, data on field experiments conducted at the Horticultural Research Station, Vijayanagaram, were collected. The difference between experiment station yield and maximum farm yield was termed as yield Gap I (Gomez 1977; Swaminathan 1977; Parthasarathy 1986; and Meenakshisundaram and Sundaresan 1988), and the difference between maximum farm-level yield and the average yield obtained on farmers' field was termed as yield Gap II (Ramasamy *et al.* 1994; and Thiruvenkatachari *et al.* 1991). The estimation of yield gaps I and II is attempted in this study.

Yield Gap II was regressed on the deviation with regard to seeds, farm yard manure, potato mixture, agro-chemicals, number of irrigations from their recommended levels, including educational level of the respondents. After examining the scatter diagrams, the linear regression analysis was used.

Garrett's Ranking Technique

Garrett's ranking technique was used to convert the ranks into scores when number ranked items differed from respondent-to-respondent. The respondents were asked to rank the constraints in the order of importance. The per cent position of each rank was measured using the following formula:

$$\text{Percent position} = \frac{(Rij - 0.5)}{Nj} \times 100$$

where, Rij = Rank given to the i^{th} item by j^{th} individual, and
Nj = Number of items ranked by j^{th} individual.

Thus, the per cent position of each rank obtained was converted into scores by referring to Garrett's Table. For each constraint, the scores of different respondents were added together and divided by the total number of respondents to arrive at the mean score. Based on the mean score, the items were arranged in a descending order and ranks were allotted.

Results and Discussion

Land-use Pattern

The details about land-use pattern on sample farms have been furnished in Table 13.1. It could be seen that net area sown per farm was the highest in the case of progressive farms followed by large farms and small farmers. Area sown more than once also varied in a similar fashion. As regards the cropping intensity, the small farms had an edge over the large and progressive farms in the study region.

It is evident from Table 13.1 that the major crops cultivated were potato (28 per cent), cabbage (26 per cent), carrot (13 per cent) and tea (25 per cent). On progressive farms also about 29 per cent of the cropped area was occupied by potato, followed by cabbage (25 per cent), tea (23 per cent) and carrot (14 per cent).

Table 13.1. Farm size and cropping pattern per sample farm

Particulars	Small farms	Large farms	All farms (small+large)	Progressive farms
Number of farmers	55	35	90	30
Net sown area (ha)	1.04	2.22	1.49	2.43
Gross cropped area (ha)	1.88	2.81	2.24	3.99
Cropping intensity (%)	181	127	150	164
Crops grown on sample farms (area in ha)				
Potato	0.37 (19.8)	1.02 (36.3)	0.62 (27.7)	1.15 (28.8)
Cabbage	0.43 (22.5)	0.81(28.8)	0.57 (25.5)	1.00 (25.1)
Carrot	0.29 (15.5)	0.27 (9.6)	0.28 (12.5)	0.57 (14.3)
Beet root	0.05 (2.7)	0.05 (1.8)	0.05 (2.2)	0.07 (1.7)
Beans	0.04 (2.1)	0.04 (1.4)	0.04 (1.8)	0.11(2.9)
Peas	0.01 (0.5)	0.02 (0.7)	0.02 (0.9)	0.03 (0.7)
Garlic	0.14 (7.5)	-	0.09 (4.0)	0.14 (3.5)
Oats	0.0018 (0.1)	0.01 (0.4)	0.0056 (0.3)	0.0067 (0.2)
Radish	-	0.057 (0.2)	0.0022 (0.1)	-
Tea	0.55 (29.6)	0.59 (21.0)	0.56 (25.0)	0.91 (22.8)
Total	1.88 (100.0)	2.81(100.0)	2.24 (100.0)	3.99 (100.0)

Note: Figures within the parentheses are per cent to total

Changes in Potato Area

Though the cropping pattern of potato-cabbage-carrot / beetroot was being followed by a majority of the sample farms for more than five years, there had been perceptible change in the area under different crops. The change in area under potato during the last five years is presented in Table 13.2. It could be seen that there was about 58 per cent decline in area under potato on the sample farms for the entire region. In the case of progressive farms, this decline was comparatively low (46 per cent). Thus, all the sample farms depicted a reduction in area under potato during the last five years.

Table 13.2. Percent changes in potato area on sample farms

Change in area	Small farms	Large farms	All farms (small+large)	Progressive farms
During last 5 years	2.24	3.61	2.77	3.63
During study year	0.95	1.51	1.17	1.97
Percent change	-57.59	-58.17	-57.76	-45.73

Reasons for Shift to Other Crops

A study of the reasons for the shift from potato to other crops like cabbage and carrot, presented in Table 13.3, revealed high cost of cultivation as the major reason for this shift. The second important was the fluctuating prices. The lack of marketing and storage facilities was attributed as the second major reason by the progressive farms for shift in the cropping pattern.

Table 13.3. Ranking given by sample farmers for shifting from potato to other crops

Reasons for shift	Small farms	Large farms	All farms (small+large)	Progressive farmers
High cost of cultivation	I	I	I	I
Fluctuating prices	II	II	II	III
Lack of marketing and storage facilities	IV	-	IV	II
High incidence of pests and disease	III	III	III	IV

Yield Gap

The data on yield gap in potato crop, presented in Table 13.4, revealed that there existed considerable yield gaps in potato crop. Yield Gap I was the highest among small farmers (45 t/ha) followed by large farmers (41 t/ha). This yield Gap I was the lowest on progressive farms (31 t/ha) and it was caused by slackness in transfer of technology. Therefore, a more effective transfer of technology system is required enabling the farmers to have a better access to the modern technology and adoption of improved production techniques.

Table 13.4. Estimation of yield gap of potato

(tonnes per ha)

Particulars	Small farms	Large farms	All farms (small+large)	Progressive farms
Experimental station yield	71. 8	71. 8	71. 8	71. 8
Maximum yield at farmers' field	26. 3	30. 0	30. 0	40. 5
Average yield at farmers' field	11. 8	21. 5	15. 6	32. 1
Yield Gap I	45. 5	41. 8	41. 8	31. 3
	(63.4)	(58.2)	(58.2)	(43.6)
Yield Gap II	14. 4	8. 4	14. 4	8. 4
	(55.0)	(28.1)	(48.0)	(20.7)

Yield Gap II was the highest among the small farms (55 per cent), followed by large farms (28 per cent) and progressive farms (21 per cent). It indicated that the constraints in the adoption of improved technology on small farms were the highest. It is believed that other farmers can also obtain the maximum yields as obtained by one farmer under similar agro-climatic conditions. Yet, there were inter-farm differences in yields due to specific farm constraints that affected managerial efficiency. Hence, this 'management gap' has to be bridged by appropriate policies that would facilitate decision-making of farmers.

Yield Gap Function

The results of the yield gap function for progressive farmers are presented in Table 13.5. The coefficient of seed rate was significant at 5 per cent level. It implied that an increase of seed rate by one kilogram would reduce the yield gap by 13.253 kg. Similarly, an increase of one kg of potato mixture would bring down the yield gap by 14.412 kg.

Table 13.5. Estimated regression coefficients of yield gap function (progressive farmers)

Particulars	Coefficient	't' statistic
Intercept	618.82	-
Seed rate (kg/ha)	13.253	2.827**
Number of irrigations	10.112	1.719
Farm yard manure (kg/ha)	0.7827	0.947
Potato mixture (kg/ha)	14.412	2.976*
Plant protection chemicals (kg/ha)	891.59	2.719**
Education (years of schooling)	-0.6896	-0.5247
R^2	0.60	
F	0.425	

Note: * and ** indicate significance at 1 and 5 per cent probability levels, respectively

Constraints

The constraints faced by the farmers in the study area were classified into two groups, viz. technical constraints and socio-economic constraints. The former included lack of suitable varieties, water problems, poor quality inputs and pest and disease problems, while the latter included lack of funds, high cost of inputs, non-availability of inputs, unfavourable marketing facilities and lack of storage facilities. The constraints faced by the farms in the study area in potato cultivation were analysed by using Garrett Ranking technique.

Lack of suitable varieties of potato was identified as the major problem by the sample farms followed by pests and diseases and water problem during the first season (Table 13.6). *Kufri Jyothi* was the only variety of potato available to the farmers. Though it is a high-yielder, it has 25-30 per cent susceptibility to late blight disease. The problem of golden yellow

Table 13.6. Farmers' ranking to technical constraints in potato cultivation

Reasons	Small farms		Large farms		All farms (small+large)		Progressive farms	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Lack of suitable varieties	III	47.1	I	53.9	I	50.5	III	47.5
Water problem in the first season	II	50.5	III	43.7	III	46.0	I	58.9
Pests and diseases problem	I	50.6	II	50.2	II	50.4	II	48.1

nematode was also prevalent in the study area. Besides, late wild boar was becoming an increasing menace, causing extensive damage to potato crop.

Progressive farmers indicated water problem in the first season as the major constraint, followed by the problem of pests and diseases and lack of suitable varieties. Since wells were the only source of irrigation in the study area, when they dried out in the summer season, this crop became entirely rainfed during the second and third seasons.

The socio-economic constraints faced by the farmers are presented in Table 13.7. For all the farms, the major problem was the high cost of inputs. The problems like poor quality of inputs, unfavourable marketing facilities, non-availability of inputs, lack of storage facilities, and lack of funds were major constraints expressed by small farms. Large farms opined that high cost of inputs was one of the main constraints, followed by lack of own funds.

Table 13.7. Farmers' ranking to socio-economic constraints in potato cultivation

Reasons	Small farms		Large farms		All farms (small+large)		Progressive farms	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Lack of owned funds	VI	27.0	II	58.0	III	42.5	-	-
Poor quality inputs	II	43.3	III	47.5	II	45.0	II	50.0
High cost of inputs	I	66.1	I	66.9	I	66.4	I	64.9
Non-availability of inputs	IV	40.0	V	31.0	V	35.5	V	31.7
Unfavourable marketing facilities	III	41.1	IV	42.6	IV	41.7	III	41.6
Lack of storage facilities	V	33.3	VI	29.7	VI	31.6	IV	34.6

Among the progressive farms also, high cost of inputs was the major constraint (mean score 64.9). They ranked poor quality inputs, unfavourable marketing facilities, and lack of storage facilities and non-availability of inputs as other major problems in that order.

Policy Options

The following policy options are suggested for increasing potato production in the Niligiris area of Tamil Nadu:

- Adequate and timely supply of inputs at affordable prices as well as training of farmers to upgrade their skills to use new technology.
- Research on potato has to be focused on developing high-yielding cultivars, which are acceptable in quality with resistance to nematodes. Hence, scientific seed programme has to be taken up.
- Provision of remunerative price is important for increasing the productivity. A majority of the farmers suggested that procurement prices should be fixed for this tuber crop also in line with the procurement price of cereal crops.

To sum up, keeping in view the short- and long-term benefits of the farming community, there should be a comprehensive policy of production in the entire district to arrest the decline in the area under potato and bridge the yield gap.

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Part IV.

Marketing, Demand and Nutrition Security

14. Vegetable Demand and Production in India: Long-term Perspective

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Abstract

The changes in consumption pattern of vegetables at different levels of rural and urban by income groups and geographical regions of India have been examined. The elasticities of vegetables demand in rural and urban areas across income groups and regions have been computed. Long-term perspectives of vegetable demand and production have been presented. The study is based on the National Sample Survey (NSS) data of 38th, 43rd, 50th and 55th rounds pertaining to the periods 1983-84, 1988, 1993-94, and 1999-00, respectively.

The per capita annual consumption of vegetables has increased from 47 kg in 1983-84 to 76 kg in 1999-00 with 2.9 per cent annual growth rate. A widespread increase in consumption of vegetables has been observed across income groups, regions and areas (both rural and urban). The vegetable consumption has been found to accelerate at a higher rate among the poor. Potato has been reported to be the dominant vegetable contributing maximum in total consumption (24 per cent) followed by onion (12.4 per cent), and cauliflower (3.6 per cent). The gap in vegetable prices between rural and urban has shown a declining trend. It may be inferred that market integration has taken place in vegetable. The income elasticity of demand for vegetables (0.3) is reported to be not as high as it is in other non-cereals. The demand elasticity has been found to be high among poor (0.4-0.5) as compared to non-poor (0.1-0.2) households. Its implications on future demand for vegetables in the country have been discussed. The demand for vegetables has been projected for 2006, 2011 and 2016. The required production and yield targets have also been suggested.

Introduction

Vegetables occupy a significant place in human diet and provide vitamins and minerals, essential for human health and growth. Their production being labour-intensive, and undertaken largely by the small farmers, vegetables play an important role in the household nutritional-security, employment generation and alleviation of hunger. At present, India is producing nearly 91 million tonnes of vegetables on 3 per cent of the total cultivated area. These account for about 12 per cent of their world production. With the increasing availability, a shift in the consumption

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patterns in favour of vegetables is being observed in all the socio-economic groups of people living in either rural or urban areas (Kumar and Mathur 1996b; Kumar 1998). It is hypothesized that the factors like urbanization, shift in dietary patterns, economic and population growth would enhance the vegetable consumption further in the country in future. In this paper, a study has been made on the changes in the consumption patterns of major vegetables and their groups at the disaggregated level in the rural and urban areas by several income groups in different geographical regions of the country. The demand elasticities of vegetables in rural and urban areas across income groups and regions have also been estimated. A long-term perspective of vegetables demand and production has been provided.

Data and Analytical Procedure

In India, the National Sample Survey Organization (NSSO) collects the data on household consumption expenditure at the national level by adopting sample survey techniques. In this study, the household data collected during the 38th, 43rd, 50th and 55th rounds of the National Sample Survey on consumption expenditure were used. These corresponded to July 1983 to June 1984, January 1987 to December 1987, July 1993 to June 1994 and July 1999 to June 2000, respectively. The sample size of the survey was quite large and ranged from 69 to 82 thousand households in the rural and 40 to 48 thousand households in the urban areas. The household data were classified into four income groups, namely Very Poor (persons below 75 per cent of the poverty line), Poor (persons between 75 and 100 per cent poverty line), Non-poor low (persons between poverty line and 150 per cent of poverty line), Non-poor high (above 150 per cent of poverty line); and six geographical regions, viz. Eastern (comprising Assam, Bihar, Orissa, and West Bengal), Western (Gujarat, Maharashtra, Madhya Pradesh, and Rajasthan), Northern (Punjab, Haryana, and Uttar Pradesh), Southern (Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala), Hills (Himachal Pradesh and Jammu & Kashmir), and North-east (the north-eastern states).

The data were analyzed for major vegetables as well as three broad groups of vegetables, namely root vegetables (comprising potato, onion, raddish, carrot, turnip, beet, sweet potato, arum), cucurbits (pumpkin, gourd, bitter gourd, cucumber, parwal/patal, jhinga/torai, snake gourd) and other vegetables [papaya (green), cauliflower, cabbage, brinjal, okra, palak/other leafy vegetables, French beans and barbate, tomato, peas, chillies (green), capsicum, plantain (green), jackfruit (green), lemon and others].

The prices of vegetables were derived from the available household data on quantity of vegetables consumed and their value.

Following Bouis (1990), the Food Characteristics Demand System (FCDS) were used for estimating the expenditure elasticities of vegetables for the sub-groups of consumers and those were used to project the demand for vegetables, using formula (1):

$$D_{ijkt} = d_{ijko} * N_{ijkt} (1 + y * e_{ijk})^{t} \quad \ldots\ldots(1)$$

$$Dt = \Sigma \; \Sigma \; \Sigma \; Dijkt$$

where, D_{ijkt} is the demand for a commodity for the sub-group of *'i'* lifestyle (rural, urban), *'j'* is region (Eastern, Western, Northern, Southern, Hills, North-eastern regions of India), *'k'* is income group (very poor, poor, non-poor low, non-poor high) and *'t'* is the period; d_{ijko} is per capita consumption demand for *'i'* lifestyle, *'j'* region, *'k'* income group in the base year (1983-84); N_{ijkt} is population in *'t'* year belonging to *'i'* lifestyle, *'j'* region, and *'k'* income group; y is growth in per capita expenditure (income), and e_{ijk} is the expenditure elasticities for the sub-group of population belonging to *'i'* lifestyle, *'j'* region, and '*k*' income group; D_t is the aggregate demand in year *t* which is the sum over *i, j, k* for D_{ijkt}. D_t captures the income and population distribution effects on dietary pattern, which is taking place across income groups within region and across regions within the rural/urban groups. In this paper, the demand projections have been made for each sub-group and then aggregated to arrive at the figures of national demand for vegetables. Vegetable demand has been forecast for the years 2006, 2011 and 2016 under the scenarios of 3.5 per cent and 5.5 per cent growth in the per capita gross domestic product (GDP) at constant prices.

Results and Discussions

Consumption Pattern of Vegetables

The annual consumption of vegetables has increased from 47 kg per capita in 1983-84 to 76 kg per capita in the year 1999-00 with 2.9 per cent annual growth rate (Table 14.1). A widespread increase in consumption of vegetables was observed across income groups, regions and in both rural and urban areas. Among the poorest of the poor households, per capita annual consumption has reached to a level of 48 kg in the year 1999-00 and was just half of the per capita consumption of non-poor high. The vegetables consumption had accelerated at a higher rate among the poor. The annual growth rate of consumption was higher in the rural area (3.0 per cent) than in the urban area (2.6 per cent). In the year 1999, the consumption of vegetables in rural pockets was found higher in all the income groups over the respective income groups in urban pockets, except in the non-poor high income group. This widespread increase in consumption may be a reflection of changed production patterns.

Table 14.1. Vegetable consumption by socio-economic groups

(kg/capita/ year)

Income group	Rural		Urban		All India		Annual growth (%)		
	1983	1999	1983	1999	1983	1999	Rural	Urban	All-India
Very poor	33	51	29	44	31	48	3.0	2.5	2.7
Poor	40	58	40	54	40	57	2.4	1.9	2.2
Non-poor (low)	47	71	49	69	47	70	2.6	2.0	2.4
Non-poor (high)	60	86	70	92	64	89	2.2	1.6	2.0
All groups	45	74	50	78	47	76	3.0	2.6	2.9

Wide regional variations were observed in the consumption of vegetables. The per capita consumption was higher in the Northeast (101.4 kg), Eastern (90.9 kg) and Northern (83.1 kg) regions and lowest in the Southern region (52.7 kg) (Table 14.2). A similar trend was observed in both rural and urban India. Marked low consumption in the Southern region was due partly to the food habit practised by the people of the region and partly was the result of low production and resultant higher prices of vegetables. Quite surprisingly, the consumption of vegetables in the North-eastern region was not only higher in the rural area (102.4 kg) than that in urban area (99.6 kg) but was also growing at a faster rate. In the Northeast India, poor access to distant markets was forcing the

Table 14.2. Vegetable consumption by regions in India

(kg/capita /year)

Region	Rural		Urban		Annual growth (%)	
	1983	1999	1983	1999	Rural	Urban
Eastern	61	88	71	100	2.2	2.1
Western	32	52	43	64	3.1	2.3
Northern	54	80	56	88	2.6	2.5
Southern	33	49	36	58	2.2	2.8
Hills	45	60	53	77	1.4	2.0
North-east	44	102	59	100	3.8	2.4

produce to be sold in the region at cheaper rates, leading to their higher consumption. Moreover, relatively higher literacy rate in Northeast India might have had an influence on the consumption patterns. The climatic condition and smallholding size also favoured vegetable production and hence had an influence on high proportion of vegetable in their food basket.

Consumption Pattern of Various Vegetables

Among the three broad groups of vegetables, cucurbits constituted a small proportion (11.8 per cent) of the total vegetables consumed. The annual per capita consumption of all the three broad groups of vegetables was higher in the urban pockets in the year 1999-00 (Table 14.3). The consumption of other vegetables was significantly higher in the urban India (37.3 kg) than in the rural India (33.6 kg). Potato was the most dominant vegetable contributing 24 per cent to the total consumption followed by onion (12.4 per cent), leafy vegetables (8.4 per cent), tomato (6.8 per cent), brinjal (6.1 per cent), cabbage (3.7 per cent), and cauliflower (3.6 per cent). Potato is a rich source of carbohydrate and is consumed mainly to supplement the calorie requirement of the body. The consumption of onion, carrot, cucumber, cauliflower, cabbage and tomato was relatively higher in the urban areas than in the rural areas. Potato, also called the poor man's sugar, along with pumpkin and brinjal was consumed relatively more by the rural people. The consumption patterns of different vegetables reflected that the consumption was higher of those vegetables, which had longer shelf-life, spread-over production and storage ability. These facts revealed that it was the availability that influenced the consumption of a particular vegetable. There were certain pockets in the country, especially in the hilly areas, which were suitable for vegetable production round the year and these regions deserved priority for the same. It was also the development of high-yielding varieties of vegetables with longer shelf-life, as in the case of tomatoes, that had increased their consumption considerably.

A considerable regional variation was observed in the annual per capita consumption level of different vegetables in the year 1999-00 (Table 14.4). It was higher in the North-eastern (101.43 kg), Eastern (90.98 kg) and Northern (83.13 kg) regions, reflecting the importance of vegetables in the diet of the people of these regions. The annual per capita consumption of potato was found significantly higher in the Eastern (30.79 kg) and Northern (28.56 kg) regions and was considerably lower in the Southern region (4.23 kg). The reason being that the consumption pattern in the

Table 14.3. Annual per capita consumption of different vegetables in India, 1999-00

Vegetables	Rural		Urban		India	
	Quantity (kg)	Share in total (%)	Quantity (kg)	Share in total (%)	Quantity (kg)	Share in total (%)
Root vegetables						
Potato	18.87	25.5	15.98	20.4	17.79	23.5
Onion	8.58	11.5	10.69	13.7	9.37	12.4
Radish	2.04	2.8	1.88	2.4	1.98	2.6
Carrot	0.68	0.9	2.24	2.9	1.26	1.7
Turnip	0.10	0.1	0.13	0.2	0.11	0.2
Beet	0.07	0.1	0.17	0.2	0.11	0.1
Sweet potato	0.26	0.4	0.12	0.1	0.21	0.3
Arum	0.98	1.3	0.50	0.6	0.80	1.1
Sub-total	**31.58**	**42.7**	**31.71**	**40.6**	**31.63**	**41.9**
Cucurbits vegetables						
Pumpkin	2.54	3.4	1.75	2.2	2.24	3.0
Gourd	2.22	3.0	2.19	2.8	2.21	2.9
Bitter gourd	0.63	0.9	0.97	1.2	0.76	1.0
Cucumber	0.90	1.2	1.49	1.9	1.13	1.5
Parwal /Patal	0.63	0.9	0.89	1.1	0.73	1.0
Jhinga / Torai	1.67	2.3	1.46	1.9	1.59	2.1
Snake gourd	0.23	0.32	0.34	0.4	0.27	0.4
Sub-total	**8.83**	**11.9**	**9.10**	**11.7**	**8.93**	**11.8**
Other vegetables						
Papaya (green)	0.75	1.0	0.48	0.6	0.65	0.9
Cauliflower	2.38	3.2	3.20	4.1	2.69	3.6
Cabbage	2.48	3.4	3.35	4.3	2.81	3.7
Brinjal	4.73	6.4	4.48	5.7	4.63	6.1
Ladyfinger	1.75	2.4	2.47	3.2	2.02	2.7
Palak/other leafy vegetables	6.56	8.9	5.50	7.0	6.16	8.2
French beans and barbate	0.58	0.8	0.86	1.1	0.68	0.9
Tomato	4.27	5.8	6.59	8.4	5.14	6.8
Peas	0.57	0.8	1.02	1.3	0.74	1.0
Chillies (green)	4.71	6.4	3.99	5.1	4.44	5.9
Capsicum	0.02	0.0	0.12	0.2	0.06	0.1
Plantain (green)	0.04	0.5	0.38	0.5	0.39	0.5
Jackfruit (green)	0.24	0.3	0.14	0.2	0.20	0.3
Lemon	0.22	0.3	0.50	0.6	0.32	0.4
Others	3.95	5.3	4.25	5.4	4.06	5.4
Sub-total	**33.59**	**45.4**	**37.33**	**47.8**	**34.99**	**46.3**
All vegetables	**74.01**	**100**	**78.14**	**100**	**75.56**	**100**

Note: The average weight of a lemon was taken as 30 grams

Table 14.4. Annual per capita consumption of vegetables in different regions of India, 1999-00

(quantity in kg)

Vegetables	Eastern	Western	Northern	Southern	Hills	North-eastern
Root vegetables						
Potato	30.79	10.82	28.56	4.23	11.58	14.27
Onion	6.18	8.02	7.91	8.05	8.84	12.34
Radish	2.31	1.36	3.14	0.71	2.93	3.04
Carrot	0.26	0.75	1.64	2.72	1.74	0.52
Turnip	0.06	0.01	0.23	0.04	0.97	0.04
Beet	0.05	0.03	0.01	0.40	0.01	0.04
Sweet potato	0.18	0.12	0.18	0.11	0.02	1.10
Arum	1.04	0.17	0.69	0.40	0.21	4.09
Subtotal	**40.88**	**21.28**	**42.35**	**16.65**	**26.30**	**35.44**
Cucurbits vegetables						
Pumpkin	4.37	1.05	1.96	0.41	1.12	6.62
Gourd	2.45	2.11	3.29	1.08	1.79	2.25
Bitter gourd	1.00	0.58	0.55	0.91	0.37	1.01
Cucumber	1.07	0.63	0.94	1.70	1.11	1.86
Parwal /Patal	2.24	0.30	0.59	0.06	0.00	0.03
Jhinga / Torai	3.33	0.88	1.85	0.91	0.11	0.83
Snake gourd	0.25	0.12	0.07	0.64	0.04	0.49
Subtotal	**14.70**	**5.68**	**9.25**	**5.72**	**4.54**	**13.37**
Other vegetables						
Papaya (green)	2.11	0.08	0.03	0.91	0.01	1.55
Cauliflower	3.20	2.60	4.24	0.50	4.67	2.28
Cabbage	3.48	2.56	1.98	2.29	3.07	5.33
Brinjal	5.84	4.85	3.69	4.41	2.08	4.94
Ladyfinger	2.35	1.77	1.83	2.58	1.52	0.95
Palak/other leafy vegetables	7.60	4.34	4.32	4.50	9.82	16.07
French beans and barbate	0.58	0.68	0.27	0.88	0.53	1.73
Tomato	2.58	5.78	5.59	7.05	6.29	3.31
Peas	0.28	0.61	1.87	0.19	1.38	0.63
Chillis (green)	2.06	3.26	3.94	2.93	1.58	3.45
Capsicum	0.05	0.07	0.08	0.02	0.08	0.08
Plantain (green)	0.60	0.02	0.05	0.93	0.01	0.59
Jackfruit (green)	0.33	0.08	0.28	0.21	0.01	0.09
Lemon	0.28	0.42	0.37	0.29	0.25	0.12
Others	4.05	3.48	3.00	3.33	3.80	11.49
Subtotal	**35.40**	**30.61**	**31.54**	**30.30**	**35.10**	**52.62**
All vegetables	**90.98**	**57.57**	**83.13**	**52.67**	**65.94**	**101.43**

* The average weight of a lemon was taken as 30 grams

southern states did not favour vegetables to a large extent. Pumpkin was consumed mainly in the North-eastern (6.62 kg) and Eastern (4.37 kg) regions and to a lesser extent in other regions of the country. Parwal (2.24 kg) and Jhinga/Torai (3.33 kg) were consumed mostly in the Eastern region and to a smaller extent in the northern states. Parwal is a vegetable cultivated exclusively on riverbeds and hence its production is concentrated in the Eastern region. The consumption of leafy vegetables was substantially high in the Northeastern states (16.07 kg) followed by Hills (9.82 kg) and the Eastern region (7.6 kg). The per capita consumption of tomato was the highest in the Southern region (7.05 kg) followed by the Western (5.78 kg) and the Northern (5.59 kg) regions. Its per capita consumption was observed lowest in the Eastern states (2.58 kg). The reason for higher consumption of tomato in the Southern region was due to the food habits of the people of the region, with their traditional preference for sour items (tamarind, tomato, etc.). Higher consumption was also due to higher production resulting from adoption of high-yielding varieties of tomato with longer shelf-life.

The poor consumers also had easy access to all kinds of vegetables but were found using low quality of vegetables as was evident from the lower prices paid by them for vegetables. The annual per capita consumption of vegetables increased with increase in income, from 48.34 kg for the very poor group of consumers to 88.86 kg for the non-poor high group of consumers. A similar trend was observed in all groups of vegetables (Table 14.5). All the vegetables were present in the consumption basket of people in all the income groups. This revealed that the people of all the income groups had access to all the vegetables.

Prices of Vegetables

The prices paid for one kilogram of vegetables, presented in Table 14.6, varied from Rs 4.70 (very poor) to Rs 6.80 (non-poor high). It revealed that apart from other factors, the quality consideration also existed in the purchase of vegetables by the non-poor high income group of consumers. Potato (Rs 4.60), an important source of carbohydrate, having the highest consumption, was one of the cheapest vegetables consumed.

As expected, the prices of vegetables were higher in the urban than rural areas (Table 14.7). In the year 1999, the average prices of vegetables in urban India were higher in the Southern region (Rs 8.57), followed by Western region (Rs 8.43) and Hills (Rs 8.18). The average prices of

Table 14.5. Annual per capita consumption of vegetables by different income groups in India, 1999-2000

(kg)

Vegetables	Very poor	Poor	Non-poor low	Non-poor high
Root vegetables	21.72	25.67	30.72	35.53
Gourd vegetables	5.52	6.82	8.31	10.48
Other vegetables	21.09	24.43	31.09	42.85
All vegetables	**48.34**	**56.92**	**70.13**	**88.86**

Table 14.6. Average price of vegetables paid by different income groups in India, 1999-2000

(Rs per kg)

Vegetables	Very poor	Poor	Non-poor (Low)	Non-poor (High)	All groups
Potato	3.90	4.10	4.40	5.00	4.60
Onion	5.90	6.50	5.00	5.60	5.50
Tomato	6.40	6.80	7.40	9.10	8.40
Peas	5.80	6.20	7.40	9.30	8.50
Cauliflower	5.50	5.40	6.20	7.90	7.10
Cabbage	3.60	5.20	6.00	7.50	6.70
All vegetables	**4.70**	**5.10**	**5.40**	**6.80**	**6.10**

Table 14.7. Temporal and regional variations in retail prices of vegetables in India

(Rs per kg)

Region	Location	1983	1988	1993	1999	Annual growth (%)
Eastern	Rural	1.30	1.84	3.13	4.90	8.5
	Urban	1.68	2.32	3.95	6.05	8.2
Western	Rural	1.84	2.70	4.39	6.44	8.0
	Urban	2.42	3.67	5.91	8.43	7.9
Northern	Rural	1.31	1.78	3.15	4.66	8.2
	Urban	1.83	2.52	4.25	6.21	7.9
Southern	Rural	1.76	2.79	4.86	7.41	9.2
	Urban	2.17	3.30	5.17	8.57	8.6
Hills	Rural	1.57	2.27	4.44	7.29	9.9
	Urban	1.84	2.78	5.60	8.18	9.7
North-eastern	Rural	1.90	2.65	4.29	4.55	5.8
	Urban	2.37	3.84	5.62	6.07	5.9
India	**Rural**	**1.51**	**2.22**	**3.72**	**5.43**	**8.2**
	Urban	**2.03**	**3.01**	**4.94**	**6.12**	**7.1**

Note: Average price of all the vegetables.

vegetables in rural India were again higher in the Southern region (Rs 7.41), followed by the Hills (Rs 7.29) and Western region (Rs 6.44). The prices of vegetables had increased with time in both urban and rural India. However, the annual growth was found higher in rural (8.2 per cent) than urban India (7.1per cent). The growth rate in prices of vegetable was highest in both the urban (9.9 per cent) and rural (9.7 per cent) areas of Hill region. This growth rate was lowest in both the urban (5.9 per cent) and rural (5.8 per cent) areas of the Northeast region. The gap in vegetable prices between rural and urban depicted a declining trend, from 34 per cent in 1983 to 32 per cent in 1993 and a sharp decline to a level of 12 per cent in 1999. It appeared that integration of vegetable market had taken place as a result of adoption of trade liberalization policies in the country.

Demand Elasticity

The income elasticity of demand for vegetables was not as high (0.3) as was found in the case of other non-cereal foods. Vegetables have emerged as the necessary food items in the Indian diet. The expenditure elasticity of vegetables was recorded higher in urban pockets than in rural pockets (Table 14.8).

The expenditure elasticity of vegetables, presented in Table 14.9, was found very high for the very poor consumers of both urban (0.44) and rural areas (0.44). With economic growth, the vegetable demand among poor would increase at a faster rate. It has wide implications on future

Table 14.8. Expenditure elasticity of food in rural and urban India

Food items	Rural	Urban
Rice	0.33	0.30
Wheat	0.14	0.17
Coarse cereals	0.02	0.06
Pulses	0.52	0.46
Milk	0.57	0.53
Edible oils	0.53	0.45
Vegetables	0.28	0.30
Fruits	0.47	0.49
Meat, fish and eggs	0.72	0.63
Sugar	0.40	0.33
Other food items	0.75	0.61

Source: Kumar and Antiporta (2001)

Table 14.9.Expenditure elasticity of demand for vegetables in rural and urban India

Region	Very poor	Poor	Non-poor (low)	Non-poor (high)	All groups
Rural					
Eastern	0.42	0.31	0.22	0.13	0.24
Western	0.51	0.41	0.34	0.25	0.35
Northern	0.42	0.31	0.25	0.16	0.25
Southern	0.52	0.43	0.37	0.24	0.36
Hills	0.54	0.46	0.38	0.25	0.37
North-eastern	0.38	0.28	0.20	0.13	0.23
Rural India	0.44	0.34	0.27	0.18	0.28
Urban					
Eastern	0.43	0.34	0.19	0.06	0.18
Western	0.47	0.40	0.28	0.14	0.32
Northern	0.42	0.36	0.24	0.12	0.28
Southern	0.50	0.44	0.31	0.17	0.35
Hills	0.54	0.47	0.32	0.17	0.34
North-eastern	0.49	0.33	0.21	0.13	0.28
Urban India	0.44	0.37	0.24	0.12	0.30

Source: Kumar and Antiporta (2001)

demand for vegetables as we move from the very poor group to the non-poor high income group. The higher expenditure elasticity for the very poor reflected that the vegetables had remained a luxury item for them.

On the contrary, very low expenditure elasticity in the case of the non-poor (high) revealed that the vegetables were an important and essential component of their food basket. There existed a considerable regional variation in the expenditure elasticity. It was high in the Hills (0.37), Southern (0.36) and Western (0.35) regions and was relatively low in other three regions in the rural areas. In urban areas, it was high in the Southern (0.35), Hills (0.34) and Western (0.32) regions. Thus, a general pattern was that where the total consumption was high, the expenditure elasticity was low; and where the consumption was low, the expenditure elasticity was high.

Projected Demand for Vegetables

Rural and urban population of the country has been projected by regions and income groups (Table 14.10) and was used for predicting the vegetable demand at the household level with low-income growth (3.5

per cent per capita GDP) and high-income growth (5.5 per cent per capita GDP). The demand for vegetables would be 86-88 Mt in the year 2006 which will further grow to 98-103 Mt by the year 2011 and 111-119 Mt by the year 2016. The demand for root vegetables would be 47-50 Mt and for cucurbits, 15 Mt by the year 2016 (Table 14.11). The demand for potato has been projected as 28-30 Mt; for onion, 12-13 Mt; for tomato, 8-9 Mt; for brinjal, 7-8 Mt; and for cauliflower and cabbage, 4 Mt each by the end of the year 2016.

Table 14.10. Projected population in rural and urban India by different income groups

(in million)

Region	Year	Very poor	Poor	Non-poor low	Non-poor high	All groups
Rural India	2006	31.9	103.0	264.6	365.3	764.8
	2011	20.9	91.1	270.5	421.7	804.2
	2016	14.7	82.0	273.7	470.2	840.6
Urban India	2006	16.9	34.6	76.7	206.7	334.9
	2011	12.7	31.1	78.2	258.2	380.2
	2016	10.1	28.5	79.9	310.5	429.0

Table 14.11. Projected consumer demand for different vegetables in India

(million tonnes)

Vegetable groups	Low income growth (3.5 % per capita GDP)			High income growth (5.5% per capita GDP)		
	2006	2011	2016	2006	2011	2016
Root	36	42	47	37	44	50
Potato	22	25	28	23	26	30
Onion	9	11	12	10	11	13
Cucurbits	11	12	14	11	13	15
Others	39	45	50	40	47	54
Tomato	6	7	8	6	8	9
Brinjal	6	6	7	6	7	8
Cauliflower	3	4	4	3	4	5
Cabbage	3	4	4	3	4	4
All vegetables	86	98	111	88	103	119

Post-harvest Losses

It was estimated that the total losses in vegetables and fruits in India due to inadequate post-harvest management, transportation and storage were at least 20-25 per cent (Singh 1981). Improper harvesting, handling, transporting and distribution result in significant losses. Factors influencing post-harvest losses in vegetables are physical, physiological, mechanical and hygiene. Owing to their high moisture-content and tender nature, vegetables pose considerable post-harvest problems. High moisture-content makes it difficult and expensive to conserve vegetables as dry products. They bruise easily and are metabolically active than the durables. These characteristics significantly limit the storage-life of vegetables and post-harvest life may, therefore, be only of a few days. Experts with wide experience in the field have estimated 20-30 per cent losses in fruits and vegetables under Indian conditions (Anonymous 1977). The considerable losses have been reported for onion (16-35 per cent), tomato (20-50 per cent), cabbage (37 per cent), cauliflower (49 per cent), and lettuce (62 per cent) in developing countries (Anonymous 1976).

Atteri (1995) has estimated the post-harvest losses in tomato (31.8 per cent), onion (26.2 per cent) and potato (13.8 per cent) as presented in Figure 12.1. In tomato, the maximum loss was estimated at the wholesale market (13.8 per cent), followed by farm level (9.3 per cent), retail market (5.7 per cent) and storage level (3.0 per cent). In onion, the maximum loss was estimated at storage level (9.0 per cent), while the lowest losses were seen at the wholesale market (4.2 per cent). Potato recorded the maximum post-harvest losses at the retail market (5.75 per cent) and storage level (4.0 per cent).

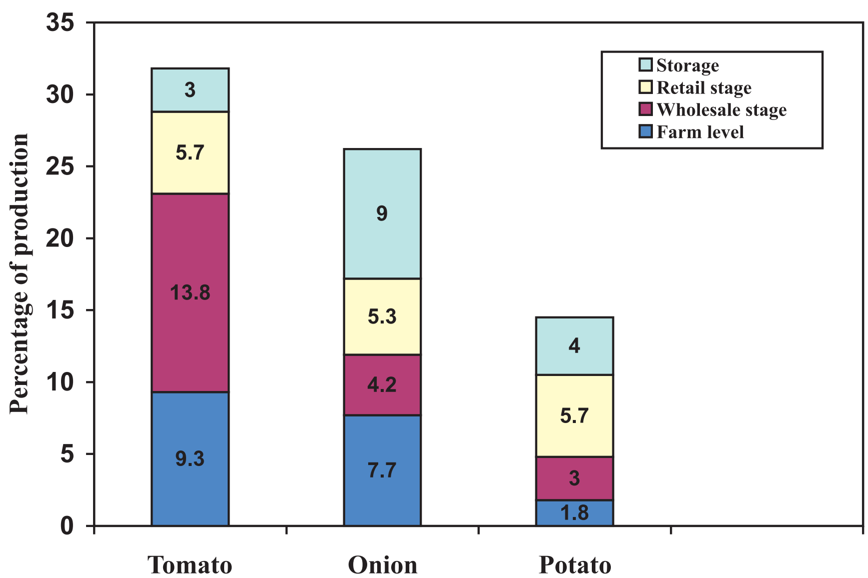

Figure 14.1. Post-harvest losses of major vegetables in India

The personal discussions of authors with the scientists of the Indian Agricultural Research Institute, New Delhi, revealed that the post-harvest losses of other root vegetables were about 9.8 per cent; and that for root vegetables (Group 1), 16.9 per cent; for cucurbits (Group 2), 20.0 per cent; and for others 20.0 per cent. Thus, the post-harvest losses of all vegetables were arrived at 19.5 per cent of the total production (Table 14.12).

Table 14.12. Estimated post-harvest losses of vegetables in India

Vegetables	Per cent share in total vegetable consumption	Post-harvest losses (per cent of production)
Onion	12.4	26.2
Potato	23.5	13.8
Other root vegetables	6.0	9.8*
Root vegetables (Group 1)	41.9	16.9
Cucurbits (Group 2)	11.8	20.0*
Tomato	6.8	31.8
Others	39.5	20.0*
Other vegetables (Group 3)	46.3	21.7
All vegetables	100	19.5

Source: Atteri, B.R. (1995)
* Information was obtained through personal discussions with scientists of IARI, New Delhi.

Demand for Vegetables

The demand for vegetables was computed after accounting for the post-harvest losses of 19.5 per cent and keeping 1.5 Mt for industrial processing and export. The required production was estimated to be 108-111 Mt by the year 2001, 123-129 Mt by 2011 and 139 -149 Mt by 2016 (Table 14.13). This increase has to be achieved by enhancing the productivity only as the scope of area expansion was limited. The average yield of vegetables has to be increased from the present level of 15.2 t/ha (in 1999) to 18.9 t/ha by 2006 and 25.4 t/ha by 2016.

It was observed from Table 14.14 that in the short-run there would be a surplus production of brinjal (0.7 Mt), cabbage (1.8 Mt) and cauliflower (0.5 Mt). Therefore to clear the market, the policy makers could promote processing of these vegetables for value-addition and also encourage exports. But in the long-run, production of all the vegetables need to be increased. The yield of potato should increase to 26 t/ha; brinjal to 19.6 t/ha; cabbage to 21.4 t/ha; cauliflower to 23.4 t/ha; tomato to 27.9 t/ha and okra to 12.8 t/ha by the year 2016.

Table 14.13. Projected demand for vegetables in India

Year	Consumer demand, Mt		Required production*, Mt		Yield target (t/ha)	
	Low growth	High growth	Low growth	High growth	Low growth	High growth
2006	85.5	88.1	107.7	111.0	18.36	18.92
2011	98.0	103.0	123.3	129.2	21.01	22.08
2016	110.8	118.7	139.2	149.0	23.73	25.40

Low growth: 3.5 per cent per capita GDP growth.
High growth: 5.5 per cent per capita GDP growth.
* Required production was computed assuming 19.5 % post-harvest losses and keeping 1.5 Mt for industrial processing and exports.

Table 14.14. Production targets of major vegetables in India

Vegetables	1999*	2006	2011	2016
Production targets				
Potato	25.0	26.2	30.4	34.9
Brinjal	8.1	7.4	8.6	9.8
Cabbage	5.9	4.1	4.8	5.5
Cauliflower	4.7	4.2	5.0	5.8
Tomato	7.4	9.3	11.0	12.7
Okra	3.4	3.2	3.8	4.4
Yield targets				
Potato	18.6	19.5	22.6	26.0
Brinjal	16.2	14.5	17.1	19.6
Cabbage	22.9	15.7	18.5	21.4
Cauliflower	19.0	16.9	20.0	23.4
Tomato	16.3	20.4	24.0	27.9
Okra	9.8	10.4	11.0	12.8

* Indicates actual production and yield during the year

Conclusions and Policy Implications

The area and production of the vegetables in the country have been increasing. A widespread increase in the consumption of vegetables has been observed across the income groups, in both the rural and urban areas. Wide regional variations in consumption of vegetables have been observed. Among various vegetables, potato is the most dominant vegetable. The high expenditure elasticity of vegetables reveals that the future demand for them would increase with economic growth. The demand for vegetables is expected to be 85-88 Mt by the year 2006, 98 – 103 Mt by the year 2011 and 111-119 Mt by 2016. After accounting for the post-harvest losses and also the requirement for exports, the vegetable production should be 108-111 Mt by the year 2006, 123-129 Mt by 2011 and 139-149 Mt by 2016. As there is very limited scope for bringing more area under vegetable cultivation, productivity enhancement is the only way out to meet the production targets. To achieve the production target, the productivity of vegetables should be 18.36 t/ha by the year 2006, 21 t/ha by 2011 and 23.73 t/ha by year 2016. This calls for a greater role on the part of researchers to develop high-yielding varieties and better crop management practices, and strengthening of extension agencies to disseminate these technologies. Efficient post-harvest management of the produce avoiding spoilage and bringing in value-addition through promotion of infrastructure are other ways to increase the availability of vegetables in India.

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15. Marketing Strategies for Vegetables in the Context of the Changing Policy Environment

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Abstract

The marketing system of vegetables has been studied and strategies to overcome the problems during their post-harvest handling have been suggested. These include co-operative marketing of vegetables, integrating production with marketing through processing and establishing backward linkages with producers through contract farming. It has been reported that the brinjal growers in Karnataka could get a higher price (Rs 51.50/q) by selling through cooperatives than other agencies. Feasibility study has shown that with an average area of 0.45 ha under tomato crop per grower, hardly 10-20 growers can supply the required materials to a small-scale processing unit. The benefit-cost ratio has been found to be higher for processed tomato (2.23), as compared to fresh tomato (1.72). It has been argued that there is a good scope in export of new and processed vegetable products.

Introduction

The importance of horticultural crops, especially of fruits and vegetables, in improving the nutritional status and economy needs no elaboration. The varied agro-climatic conditions prevailing in India are conducive for the cultivation of different types of fruits and vegetables. However, the importance of this sector has been realized by the planners and policy makers only recently. Establishment of National Horticulture Board (NHB) in 1984, creation of Agricultural and Processed Food Export Development Authority (APEDA) in 1986 for encouraging exports, formation of a separate Ministry of Food Processing Industries (MFPI) in 1988 for improving the processing of horticultural crops, and adoption of liberalized seed import policy in 1988 to overcome the constraints of non-availability of quality planting material are some of the important steps taken by the Government of India (GOI) for encouraging the horticulture sector. A major boost to horticultural development was given during the VIII Plan by allocation of Rs 10,000 million, which coincided with the initiation of liberalization in policies by the GOI. A special provision of Rs 975 million was also made for the export of horticultural crops. Some of the policies initiated for the overall development of the horticultural sector were: according 100 per cent EOU status to vegetable and fruit processing units, 'Extreme Focus Area' for fruit and vegetable processing industries like abolition of excise duty on processed food, subsidy on export of vegetables by APEDA, etc.

The steps taken and policies initiated by the GOI have started showing results in terms of increased production. The introduction of hybrids in vegetables like tomato and cabbage during the late-1980s has increased their productivity. However, concurrent improvements have not been made in vegetable marketing which has resulted in frequent market gluts and a wide fluctuation in their daily prices. Against this background, the paper analyses the present status and trend in vegetable production in the context of changed policy environment and strategies for post-harvest handling of vegetables

Present Status

India is now the second largest producer of vegetables, contributing about 12.3 per cent to the world vegetable production. The country is the largest producer of cauliflower (33.2 per cent) and green peas (33.58 per cent) and second largest producer of brinjal (44.63 per cent) and onion (8.23 per cent). India ranks third in the production of cabbage and fourth in tomato and potato production. In India, vegetables are grown on an area of 6.25 million hectares; the important ones are: potato, brinjal, tomato, onion, okra, cauliflower, cabbage, potato and green peas.

Growth in Vegetable Production

The production of vegetables has been increasing in India over the years (Table 15.1). Between 1991-92 (when liberalization policies were introduced) and 2000-01, the production of vegetables increased from 58.5 to 93.2 million tonnes, registering an annual compound growth rate of 5.32 per cent. It is evident from Table 15.1 that the bulk of increase in vegetable production has come through the increased productivity which could be regarded as an impact of liberalized seed/planting material import policy of the government initiated during the late-1980s.

Cabbage, cauliflower and chilli were the important vegetables registering a significant growth in production due to increased productivity. Area-led growth was witnessed in the case of peas, tomato, eggplant (brinjal) and onion.

Table 15.1. Annual compound growth rates in area, production and yield of vegetables, 1991-2001

Vegetable crops	Annual compound growth rate (%)		
	Area	Production	Yield
All vegetables	2.12*	5.32*	3.13*
Cabbage	3.33*	8.64*	5.14*
Cauliflower	2.84*	6.15*	3.22*
Potato	2.94*	4.97*	1.97*
Tomato	5.63*	7.16*	1.45*
Onion	4.51*	3.69*	-0.80^{NS}
Okra	2.81^{NS}	3.91^{NS}	1.07^{NS}
Brinjal	10.61*	10.15*	0.31^{NS}
Chilli	0.05^{NS}	4.33*	4.28*
Green peas	6.67*	9.36*	2.52*

* Significant at 5 per cent level of probability
NS: Non-significant

Post-harvest Losses and Their Impact on Per Capita Availability

Despite the phenomenal increase in production, the per capita availability of vegetables (174 g per person per day) is far less than the recommended dose (300 g per person per day) as per ICMR recommendations. The per capita availability of vegetables is not only low but is further reduced due to the losses in handling after harvest. Thus, the low per capita availability of vegetables may be attributed largely to the huge post-harvest losses (Table 15.2) including those in transportation and marketing. This suggested that there was a need to increase marketing of vegetables through technological innovations, and improving marketing efficiency.

Table 15.2. Post-harvest losses in vegetables

Vegetables	Post-harvest losses (%)
Onion	13-30[1], 13.75[3]
Tomato	22-27[1], 32[2], 17-23[4]
Potato	2-15[1], 20[2]
Okra	11.71[2]
Radish	9.80[2]
Bottlegaurd	5.48[2]

Source: [1]Madan et al. (1993); [2]Gauraha (1997); [3]Atibudhi (1997); and [4]Gajanana et al. (2002)

Present Marketing System for Vegetables

The presence of many intermediaries and concentration of vegetable trade in a few hands have resulted in exploitation of the growers and sellers; the producer's share in consumer rupee being low. To motivate cultivators for producing more, it is imperative that growers get a reasonably good price for their produce. It is also essential to identify the best channel of marketing the vegetables. In this context, the present marketing system was examined; the most important channels being followed were:

- Producer→ Commission Agent/Wholesaler → Retailer→ Consumer
- Producer→ Agent of the distant market/wholesaler → Retailer → Consumer
- Producer→ Cooperative Society → Consumer
- Producer→ Processor → Consumer

The studies in the past have shown the predominance of commission agents (CA) in vegetable marketing. The analysis of costs and returns associated with this channel indicated that commission charges constituted a major component of marketing costs (Subrahmanyam and Gajanana 2000; Gajanana *et al.* 2002).

Marketing Strategies for Vegetables

Cooperative Marketing of Vegetables

In the system of marketing of vegetables, the limited literature on cooperative marketing of vegetables indicated that it was beneficial to sell through cooperatives, since the producer's share was substantially high and there were some other benefits also from such a sale. In general, where the cooperatives were functioning well, the producers were getting higher benefits through them (Gajanana and Subrahmanyam 1993; Subrahmanyam and Gajanana 2000). The producer's share was found highest for carrot and cabbage (66-72 per cent and 51-55 per cent, respectively) when these vegetables were sold through cooperatives rather than other agencies like PHCs and CAs (Table 15.3). The brinjal cultivators in Karnataka could get a higher price (Rs 51.45/q) by selling through cooperatives than other agencies. Even the variability in prices was found less in cooperatives than other agencies (Hugar *et al.* 1983). It was also observed (Narasimhan and Ravindran 1989) that HOPCOMS in Karnataka helped the vegetable growers by offering higher prices as compared to other intermediaries. All these suggested that it was beneficial to sell through cooperatives which would not only reduce the number of intermediaries but also help the producers in getting better prices.

Table 15.3. Producer's share in marketing of vegetables

(per cent)

Marketing channels	Cabbage	Carrot
Producer → Co-operative societies → Wholesalers → Retailer → Consumer	51.44	68.09
Producer → (Mandies) Wholesaler → Consumer	48.67	66.36
Producer → Co-operative societies → Wholesalers → Retailer → Consumer	55.42	72.01
Production → PHC → Wholesalers → Retailers → Consumer	30.46	56.62

Source: Selvaraj and Krishnamoorthy (1990)

However, in general, there have been more failures than successes in the cooperative sector due to excessive dependence on the government, proportionately higher overheads, lack of participation on the part of the members and improper linking of credit with marketing.

Distant Market Sale

It is often considered prudent to sell the produce in the distant markets, generally close to the town or city, which helps the producers in taking advantage of the higher price prevailing in these markets. The tomato produced in Kolar district being sold in Chennai was the case in point. Although the farmers had to incur additional marketing cost of around Rs 12/box of 15 kg towards transport, commission and packing, the price realized by them was much higher (Rs 57/box) than what they could have got (Rs 36.37 per box) in the local market (Gajanana *et al.* 2002). However, due to the problems of storage, packing and poor transportation, coupled with high commission charges, the producers were depending on the local market.

Integrating Production with Marketing through Processing

One of the main problems faced by the vegetable cultivators was the price risks. For example, one important vegetable, tomato, was found subject to violent fluctuations in prices; the wholesale price varied from Rs 273/q in September to Rs 1382/q in June 1998, similarly from Rs 224/q in August to Rs 952/q in October 2000. In such cases, a linkage of producer with the processor becomes important to reduce the price fluctuations and avoid distress sale by the cultivators (Sudha and Gajanana 2003). This type of arrangements would also help in reducing the post-harvest losses. The feasibility studies (Sudha and Subrahmanyam 1994; Subrahmanyam 2000) have shown that small-scale intermediate processing units can be established even in rural (production) areas. In case of tomato, it was observed that hardly 5-10 hectares under tomato were required for supplying raw material to produce 33 tonnes of tomato paste, which a small–scale unit should produce to achieve the break even point. Based on the average area of 0.45 hectare under tomato crop per cultivator, hardly 10-20 cultivators can supply the required raw material. This suggested that the small-scale processing units could be started on cooperative basis.

It was also observed that despite high investment, tomato processing fetches higher returns than fresh sales in the wholesale market (Table 15.4) as the benefit-cost ratio (BCR) was more in the case of processed tomato than fresh tomato.

Incentives have been announced by the MFPI for providing financial assistance to establish cooperative processing units, infrastructure parks and also for establishing backward linkages with producers (Anonymous

Table 15.4. Economic feasibility of processing of tomato in Karnataka

(quantity in 100 Mt)

Particulars	Costs and returns (Rs)	
	Fresh tomato	Processed tomato
Total cost	84,000	3,69,500
Gross returns	2,00,000	6,69,700
Net returns	1,16,000	3,00,200
BCR	1.72	2.23

Source: Sudha and Subrahmanyam (1994)

1998). In view of the rapid changes in the policy environment, new types of linkages would have to be worked out.

Contract Farming

Contract farming has been found to be successful in vegetables like gherkins (pickling cucumber), with large processing demand. Haque (2000) has observed that VST Natural Products Limited in Andhra Pradesh was able to have contracts with the gherkin farmers by providing seeds, credit and other technical inputs for supplying gherkins which were processed and exported. The contract farming in the case of tomato farmers practised by the Hindustan Lever Limited in Punjab, however, was not so successful.

The results of the two case studies on contract farming (Haque 2000), one in Punjab for tomato and another in Andhra Pradesh for cucumber, indicated that the contract farming helped in increasing the yield and income of the farmers because of the availability of high quality seeds and assured market for the produce (Table 15.5). It helped the company in getting adequate and assured supply of quality raw material for the processing unit at a pre-determined price. However, as far as equity dimension was concerned, the small farmers could participate in contract farming only when there was a backward linkage in the farm of assured supply of inputs of all kinds.

Table 15.5. Contract farming and its impact

Company	Crop	State	Districts	Net income, Rs per acre	
				Contract farmers	Non-contract farmers
Hindustan Lever Ltd (HLL)	Tomato	Punjab	Amritsar	20,000	10,200
			Hoshiyarpur	9,940	6,440
			Jullandhar	13,000	6,885
			Kapurthala	14,535	8,075
			Ludhiana	8,125	5,600
VST Natural Products Ltd (VST NPL)	Cucumber	Andhra Pradesh	Karimnagar	4,500	3,200
			Mehboobnagar	5,200	4,500
			Medak	4,100	3,400
			Nalgonda	4,800	4,200
			Ranga Reddy	4,800	5,000

Source: Haque (2000)

Further, it was observed that contract farming in Punjab with HLL, which sold only hybrid seeds to the tomato (contract) farmers and provided no other inputs, was of help only to the large and medium farmers. As against this, in case of VST NPL in Andhra Pradesh, the contract with the cucumber (gherkin) cultivators was found to benefit small and marginal farmers also, as the company provided not only seeds but also other inputs on credit basis.

In Karnataka, Subrahmanyam (2000) also observed that gherkin marketing on contract basis followed by Sterling Agro-Processing Pvt. Ltd was more successful than the tomato marketing followed by Hindustan Level Ltd. The main reason for this was that in the case of gherkin, there was no demand for fresh vegetabes and the company deputed its Field Officer to arrange for the contracts, whereas in the case of tomato, the channel included an agent, who was not the employee of the company, thereby preventing the direct contract between the producer of the raw material and the supplier of the inputs (seeds).

To encourage contract farming, the Government of India has announced an incentive of Rs 25 lakhs for private processing units which have contractual arrangements with at least 25 farmers. The recently announced schemes of MFPI also provide incentives for such linkages (Anonymous 1998; Sudha and Gajanana 2003). Apart from gherkins and tomato, there is a need to develop contractual arrangements for other vegetables also.

Export of Vegetables

The analysis of data on fresh and processed vegetables during 1993-2001, indicated that exports of processed vegetables have been growing at the rate of more than 20 per cent per annum, both in quantity and value terms. Among the processed vegetables exported, gherkin registered a growth of 43-45 per cent, and onion grew by 26-29 per cent. The export of mushroom though has registered a negative growth in quantity; in value-terms the exports have grown at a rate of around 13 per cent. Thus, it suggested that there was a considerable scope in export of processed vegetables. In the case of exports of fresh vegetables, there had been stagnation and only in case of vegetables other than onion, there was some growth (Table 15.6). This means that instead of depending on onion alone, it was necessary to diversify our exports to other vegetables and vegetable products.

Table 15.6. Growth of vegetable export, 1993-2001

S. No.		Vegetables	Compound growth rate (%)	
			Quantity	Value
A.	All processed vegetables		20.47*	20.26*
	1	Tomato	7.13^{NS}	5.78^{NS}
	2	Mushroom	-4.61^{NS}	12.85*
	3	Garlic	2.32^{NS}	10.25^{NS}
	4	Onion	29.19*	26.42*
	5	Gherkin	43.01*	45.03*
	6	Peas	17.41^{NS}	15.00^{NS}
	7	Chilli	8.29^{NS}	20.72^{NS}
B.	All fresh vegetables		-079^{NS}	6.74^{NS}
	1	Fresh onions	-3.81^{NS}	4.05*
	2	Other fresh vegetables	14.97*	27.29*

* Significant at 5 per cent level of probability

It was heartening to note that to improve the level of processing and reduce the wastage, APEDA has developed the concept of Agri-export zones (AEZs). It takes a comprehensive look at a particular produce/ product located in a contiguous area for the purpose of developing and sourcing raw materials, their processing/packaging, leading finally to exports.

The cluster approach is followed to address marketing problems of certain produce/products in a specified area. In fact, there are 45 AEZs for horticultural produce/products. AEZs have been set up in Jharkhand, Uttar Pradesh, Andhra Pradesh, West Bengal and Gujarat. AEZs have been established for rose onion (type of a onion group mainly used for export purposes) and gherkins in Karnataka; for onions, garlic and potatoes in Madhya Pradesh and Maharashtra; and for potatoes, cabbages, broccoli, baby corn, carrot, green beans, chillies and tomatoes in Punjab.

These AEZs are expected to enhance the export of vegetables in the years to come. Further, in the context of changing global policy environment due to WTO and to make the vegetable products competitive in the international markets, it is necessary to adhere to the international quality standards by either following the hazard analysis and critical control point (HACCP) guidelines, Codex standards, or modifying the Indian standards under Prevention of Food Adulteration (PFA) Act, AGMARK grades and Bureau of Indian Standards to comply with the international standards.

Conclusions and Suggestions

It may be concluded that the new policy environment has made a definite impact on the production of vegetables in the country. However, it has also brought with it a set of marketing problems. In this context, the strategies like cooperative marketing of vegetables, distant market sale, integration of production with marketing through processing, preferably on cooperative basis and contract farming to establish backward linkage with the producers by providing all the inputs would help to overcome the problems of post-harvest handling of vegetables. The incentives provided by Government of India in the form of subsidy for establishment of infrastructure parks for processing and contract farming should be utilized for effective post-harvest management of vegetables. Further, there is a good scope to export vegetables, both in fresh and processed forms. There is a need to tap the international markets for new and diversified processed vegetable products.

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16. Strengthening Economic and Nutrition Security: Role of Vegetables

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Abstract

Vegetables have excellent nutritive values and are regarded as one of the potential options for improving the economic situation of resource-poor farmers. This study has explored the possibility of increasing vegetable production and consumption to address the problem of malnutrition and improve the economic security of farmers. To highlight these issues, relevant evidences based on literature studies have been presented. Vegetable production system has been reported to highly favor the increased intake of iron, vitamin A and vitamin C as compared to the rice and sugarcane systems. Further, vegetables are reported to have higher benefit-cost ratio (vegetables: 0.76; field crops: 0.15) and generate higher man-days (vegetables: 330; field crops: 188). The increasing export demand for high-value vegetables, and the possibility of usage of underutilized and indigenous vegetables as well as bio-diversity have been projected to provide excellent opportunity for the growth of vegetable sector. The data on processing show that hardly 1 per cent of the total vegetable production is processed in the country at present and there is a tremendous scope for its improvement. It has been suggested that creating technological options and favorable policy environment for venturing into biotechnology research, post-harvest processing, strengthening cold-chain, and greater access to international market intelligence would help in a faster expansion of the vegetable sector.

Introduction

Indian farmers are predominantly small landholders and resource-poor. Their mainstay of income is the cereals-based production systems, but these are not sufficient enough to improve their living standards. Further, depletion of natural resource-base like soil and water and introduction of World Trade Organization (WTO) regime are leading them to the challenging situations. This typical scenario demands a production system capable of saving their interest and improving their economic condition.

Vegetables are regarded as one of the potential options for improving the economic situation of resource-poor farmers through diversifying

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the existing production system. These can be grown in a relatively shorter period, provide good yields and generate higher income as compared to those from cereals. In India, vegetables have enormous potential in providing nutritional and economic security, as our bio-diversity in vegetables is very wide and supportive. In this paper, the significance and opportunities of the vegetable sector in India have been highlighted to strengthen the nutritional and economic security in the country.

Vegetables and Nutritional Security

Vegetables are rich in vitamins, minerals, plant fibres and other health-promoting identities. Though they contain less than 3% protein, these proteins are of high biological value. In addition, vegetables possess medicinal properties also. As for example, juices of carrot, cucumber, cabbage, lettuce, spinach, and other green leafy vegetables are highly useful for treating bronchial asthma, arthritis, skin diseases, cough, common cold, congestion of lungs, oedma (swelling-puffiness), rheumatism, dysentery, leucorrhoea, anaemia, etc. (Bhat and Shah 1999).

In spite of the spectacular progress made in vegetable production, their per capita consumption in India is only about 176 g/day/person, which is far below the minimum dietary requirement of 280 g/day/person. Forty per cent of the world's malnourished children are in India and 60 per cent of Indian women are anaemic (World Bank 1998). Direct feeding and pharmaceutical-based nutritional intervention programs involve huge costs. Because the vegetables possess tremendous medicinal and nutritive values, there exists an enormous potentiality in vegetable technologies in India to address the micronutrient malnutrition, often called "hidden hunger".

Food systems addressing the human nutrition needs are one of the causes for global food-insecurity. Empirical evidence has suggested that local food systems having micronutrient-rich vegetables favor nutritional security (Adhiguru and Ramasamy 2003). In a study conducted in Tamil Nadu on comparing crop production systems and nutritional security, the food intake deficit was found comparatively lower in the vegetable production system than in the rice and sugarcane production systems, especially in terms of green leafy and other vegetables. It was observed that vegetable production system had highly favoured the increased intake of iron, vitamin A and vitamin

C (Table 16.1). The nutrient deficiency was found considerably lower in the vegetable system. The enhanced food and nutrients intake in vegetable system indicated the potentiality of vegetable system in supplying healthy food to the weaker sections. Studies have indicated that the income control by the women did influence the pattern of food consumption in the household. In this context, the wages received in kinds had better chances of directly benefiting the food intake, particularly by the labour households.

The diversified kind wages in vegetable production system helped the poor directly in improving their nutritional-security (Figure 16.1).

Table 16.1. Adult nutrients intake by agricultural production systems

(shortage to RDI in %)

	Crop systems nutrients intakes					
	Protein	**Energy**	**Calcium**	**Iron**	**Vitamin A**	**Vitamin C**
Men						
Rice	23	13	-50	21	60	42
Vegetables	22	15	-125	14	40	5
Sugarcane	25	14	-63	26	65	45
Women						
Rice	24	14	-38	33	64	50
Vegetables	22	13	-113	23	43	13
Sugarcane	26	14	-50	37	67	50

Note: The negative sign indicates more than the Recommended Dietary Intake (RDI)

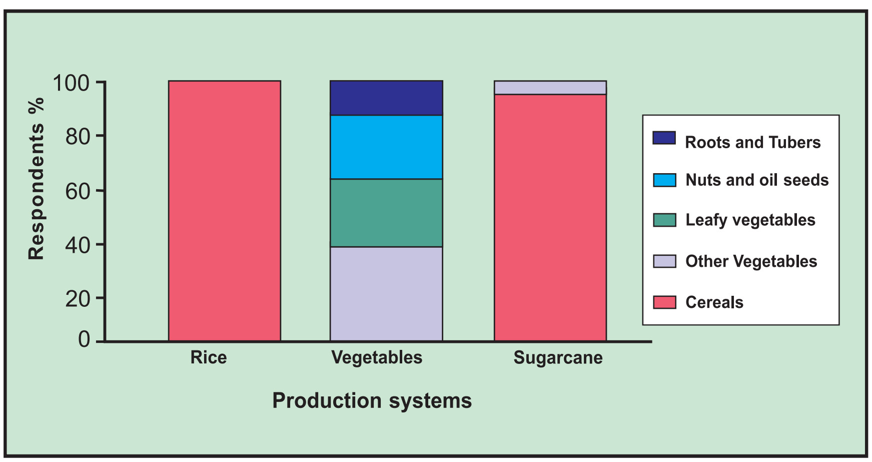

Figure 16.1. Kind wages in different production systems

Income and Employment Potential

The returns from vegetable production are high and could be much higher if the recommended packages of practices were adopted. Vegetables are highly remunerative, quick income generating and more profitable than cereals. The comparative economics of vegetables and other crops are provided in Table 16.2. Apart from yield and income, vegetables generate high employment opportunities, since their production requires more labour. It is clear from the table that labor requirement in vegetable production on an average was about 330 man-days, as against about 188 man-days per hectare in field crops (Rao 1997). It was postulated that increase in vegetable acreage on small and marginal farms would not only provide gainful employment to them, but would also reduce the disparity among different farm categories.

Table 16.2. Economics of vegetables and other crops

Vegetables	Yield, t/ha	Net income, Rs/ha	Employment, man-days/ha	Benefit-cost ratio
Tomato	15.2	9,737	236	0.45
Bhendi	14.2	12,999	314	0.60
Brinjal	29.4	34,641	439	1.13
Paddy	4.5	2,248	175	0.15
Sugarcane	10	4,626	285	0.13
Groundnut	2.2	2,289	105	0.16

Source: Rao (1997)

Export Potential

Export Trend

The technological innovations in vegetable production enhance their export potential. The export of vegetable products has the capacity to earn 20 to 30-times more foreign exchange per unit area than cereals. India exports onion in a sizeable quantity and okra, brinjal, tomato and chilli in limited quantities. Onion accounts for 60 per cent of the total foreign exchange earnings from fresh vegetables. India exports onions, fresh or chilled tomatoes, cauliflower, and broccoli to different countries including Bangladesh, Germany, the Netherlands, UAE, and Nepal. In the past, the Indian vegetable exports were restricted to potatoes and fresh onions only. Recently, the Government of India has shown interests in expanding the exports of vegetables, which include lettuce, fresh peppers, tomatoes, squash and gherkins. It is to be noted that less than one per cent of India's total vegetable production only is being exported which implies that there is considerable scope in improving our vegetable export (Table 16.3).

Table 16.3. Trends in vegetable exports of India

Year	Vegetable quantity		Export value (US $ million)
	Production (Mt)	Export ('000 tonnes)	
1991	61.66	394.54	66.70
1992	63.47	292.64	45.94
1993	66.61	378.42	62.50
1994	69.16	446.15	75.28
1995	73.38	420.27	85.81
1996	79.67	488.30	92.73
1997	81.65	425.11	82.93
1998	86.73	491.89	106.18
1999	88.99	362.54	76.73
2000	92.01	442.83	93.23

Source: Economic Survey (2002-03)

Export of High-value Vegetables

The high-value vegetables have a good demand in the international markets. The diversified agro-climatic conditions and availability of cheap labour put India at an advantageous position in fixing prices for vegetables as compared to the developed countries. Some vegetables having export potentialities are:

- *French bean, Lima bean*: Fresh for the domestic and gulf markets, and processed and frozen for European markets.
- *Sweet corn and Asparagus*: Fresh for the domestic and gulf markets, and processed for the other world markets.
- *Bell Pepper*: Fresh for domestic and gulf markets.
- *Brussels sprouts and Broccoli*: Fresh for the European markets

In recent years, India has taken up the production of gherkins, babycorns, asparagus, silverskin onions and broccoli for domestic as well as export markets. At present, there are about 20 units in India which are producing and exporting gherkins. In 1998-99, the production of gherkins in India was about 40,000 tonnes. India's exports of fresh chilled gherkins rose from 33 tonnes valued at Rs 3.6 lakhs in 1992-93 to 9,609 tonnes valued at Rs 1,449 lakhs. These vegetables have potential to earn foreign exchange and enhance national economic security.

Opportunities in Vegetables Sector

Diversity in Vegetables

The global diversity of vegetable crops comprises about 400 species. The tropical Asian region (India and China) holds the maximum diversity. India is a primary centre of diversity for crops such as brinjal, smooth gourd, ridge gourd and cucumber and a secondary centre for cowpea, okra, chillies, pumpkin and several *Brassica* species. More than 40 vegetables are cultivated in India. Its diversity encompasses solanceous, cucurbitaceous, root, bulb, cole, legume and leafy vegetable categories (Table 16.4).

Around 20-25 vegetable crops are commercially important, but around 80 species of major and minor vegetables, apart from several wild kinds,

Table 16.4. Diversified vegetables grown in India

Vegetable groups	Name of vegetables
Solanaeceous vegetables	Brinjal, tomato, chillies, sweet pepper (capsicum)
Cole crops	Cabbage, cauliflower, knoll-khol
Bulbous vegetables	Onion, garlic
Okra	Okra
Cucurbits	Muskmelon, snapmelon, watermelon, cucumber, pumpkin, summer squash, bitter gourd, bottle gourd, pointed gourd (parwal), ridge gourd, round gourd, snake gourd, sponge gourd, wax gourd (ash gourd)
Root vegetables	Carrot, radish, turnip
Leguminous vegetables	Broad bean, cluster bean, cowpea, dolichos bean, French bean, peas
Leafy vegetables	Amaranths, beet leaf, fenugreek, spinach
Salad vegetables	Lettuce
Perennial vegetables	Drumstick, curry leaf, agathi

Source: Sidhu (2002)

are found in India. These broad-based germplasm pools have potential for high productivity as well as production of new varieties of superior quality.

Underutilized and Indigenous Vegetables

In India, there are several lesser-known plant species, which have tremendous potential to be used as vegetables. The important species are faba bean (*Vicia faba*), rice bean (*Vigna umbellata*), hyacinth bean (*Lab lab purpureus*), amaranthus (*Amaranthus* spp.) and chenopods (*Chenopodium* spp.). These species do not require high input technology and can thrive well even on marginal and sub-marginal lands. In India, there are about 158 Mha of wastelands of different kinds. Such lands can easily be put to use for growing these low-input demanding underutilized crops (Bhag Mal and Joshi 1995). Moreover, vegetables like amaranthus and chenopods possess very high protein contents along with higher contents of lysine and other essential amino acids. Some indigenous vegetables have been identified as a good source of beta-carotene (Table 16.5). Use of these vegetables having high nutritive value could be of great help in solving the problem of malnutrition to some extent. Further, they could be complemented with other regular vegetables to augment their supply during the lean season/ off-season and help sustain nutritional security. These indigenous vegetables could be conserved as well as utilized in research programs for evolving new varieties.

Table 16.5. Indigenous vegetables with their beta-carotene content

Vegetables		Beta-carotene content (mg/100g)
Dark green		
1.	Spinach	2513±130
2.	Water convelvolus	2111±120
Light Green		
1.	Asparagus	361±71
2.	Garlic	69±35
Others		
1.	Asparagus bean	324±57
2.	Carrot	10940±530
3.	Pumpkin	5770±1632

Source: Engle and Altoveros (1999)

Vegetable Germplasm and Crop Improvement

A good number of germplasm resources of different vegetables are available in India (Table 16.6). Many promising lines have emerged during the screening and evaluation of these germplasms. Augmentation of genetic resources of endemic species is desirable for conservation of resources, safeguarding of variability, utilization of germplasm and special breeding for specific adaptability.

Table 16.6. Potential germplasm accession of vegetables in India

Vegetable crops	Number of germplasm accessions
Okra	531
Tomato	493
Brinjal	383
Chillies	250
Bittergourd	219
French bean	182
Cauliflower	153
Cow pea	138
Pea	134
Other vegetables	525

Source: Kalloo (1998)

Biotechnological research can contribute to the developing of such varieties which possess useful traits like resistance against pests and diseases, high-yield and long shelf-life (Table 16.7).

Research efforts have been made to improve the bio-available micronutrient contents of a few vegetable crops. For instance, nutritionally improved transgenic potatoes have been obtained in India, by transferring the amaranth seed albumin gene (AmA1) from *Amaranthus hypochondriacus* into potato (Chaudhury 2000). These transgenic potatoes have shown significant increase in the content of all the essential amino acids, including lysine, tyrosine; and of sulphur-containing amino acids such as cysteine and methionine. The introduction of this gene has resulted in a significant increase in all the essential amino acids and these are well balanced. Interestingly, the transgenic plants have also shown enhanced content of total proteins in tubers as compared to that in the control plants. Identification of apomictic genes and their incorporation in the hybrids would increase hybrid vigour in self-pollinated vegetable crops. Tissue culture techniques can be exploited

Table 16.7. Application of biotechnology in improving the quality of vegetables

Genetic modification	Crop type	Benefit
Controlled ripening	Tomato	Will permit the shipping of vine ripened tomatoes; improved quality and longer shelf-life; improved food processing quality
High solids content	Tomato, potato	Improved processing quality
Insect resistance	Potato, tomato	Reduction in insecticide-use
Fungal resistance	Tomato	Reduction in fungicide-use
Viral resistance	Potato, tomato, cantaloupe, squash, cucumber, alfalfa	Reduction in production losses
Herbicide tolerance	Tomato	Environmentally safe herbicides
Freezing tolerance	Tomato, vegetables	Improving textural properties
Improved nutrition	Potato	Increase in all essential amino acids and total proteins

Source: The Hindu, 1996

for *in vitro* preservation of germplasm and in culture and fusion of protoplasts for somatic hybridization of vegetables (Ghosh, 1996). Biotechnology research can also be focused on developing varieties having longer shelf-life, better shape, aroma, etc. which can make the marketability of the produce better.

Processing and Value-addition

In India, a staggering 50 per cent production of fruits and vegetables is lost due to wastage and value destruction, according to a joint study conducted by Mc Kinsey & Co and Confederation of Indian Industry (CII). In monetary terms, the loss is estimated at Rs 23,000 crore per year. On the other side, value-addition by way of processing is done only on 2 per cent of total agri-production in India. A big gap exists between the actual capacity of processing units and their utilized capacity. It is mainly due to the low domestic consumption of the processed items. Hardly 1 per cent of total vegetable production is processed in India (Verma *et al.* 2002) as compared to 70 % in the countries like Brazil and the U.S.

Vegetable processing and value-addition are very important for minimization of post-harvest losses and effective utilization of vegetables. It enlarges the potential for foreign exchange earning and generates additional employment. Realizing its importance, a few new varieties have been developed which are suitable for processing. For example, Kufri Chipsona 1 and 2 for potato and Pusa Ruby for tomato are ideal varieties for processing. But, still more is needed in this direction which would be helpful in the export of vegetables.

Conclusions and Policy Implications

Vegetable research in India has contributed many improved varieties and efficient input management techniques, which, in turn, have improved their productivity and exports. But there still exists a scope for further improvement to achieve higher nutritional security and enhanced contribution for economic security. The advantageous position India has in terms of diversified agro-climatic conditions and cheap labour should be exploited by readjusting vegetable research agenda and utilization of technologies. A balanced production system needs to be promoted in vegetable cultivation. Technological options are to be explored to improve production efficiency of vegetable crops so that the vegetable sector becomes more lucrative in terms of employment and income generations. The reasons for low uptake of both production and processing technologies need to be assessed and bottlenecks be removed. Appropriate institutional linkages should be developed for the improvement of post-harvest processing of vegetables. Conducive policy environment for streamlining post-harvest processing, strengthening cold chain, and greater access to international market intelligence would help in exploitation of export potential. Research and extension system should evolve strategies for cultivation of indigenous crops appropriate to diversified climatic regions, which also would help expansion of area under vegetables. Scope of biotechnology in terms of bio-fortification and enhanced shelf-life needs to be assessed for different vegetables, which would facilitate prioritization of research in Indian horticulture.

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Part V.

Abstracts of Other Selected Papers

I. VEGETABLE RESEARCH IN INDIA

Vegetable Production in Temperate Regions of Jammu & Kashmir: Present Status and Future Prospects

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The climate and topography of the temperate region of Jammu and Kashmir is ideal for growing many off-season vegetables. Due to its cool climate, this region has monopoly in the seed production and contributes about 50 per cent seeds of temperate vegetables to the national seed pool. Besides, it is the region where exotic vegetables such as lettuce, celery, asparagus, Chinese cabbage, Brussels sprout, sprouting broccoli, etc. are grown successfully. Their cultivation is expected to bring high returns to the vegetable growers.

The intensive research and development in vegetable improvement, agro-techniques and seed production technologies have contributed much to vegetable cultivation. The productivity of vegetables has increased from 19.62 t/ha during 1980-85 to 24.02 t/ha during 1996-2000, with an annual growth rate of 1.1 per cent. The increased productivity in the region has been the result of introduction of hybrids and release of high-yielding and disease-resistant varieties adapted to temperate conditions. As a result, the vegetable growers of this region have become much better-off socio-economically and are getting higher returns. However, there is a gap between potential yields and farmer's yields mainly due to non-adoption of improved vegetable technologies. This yield gap would be reduced if constraints in production and marketing could be removed.

It has been argued that the congenial agro-climatic conditions and adequate irrigation facilities in the area can transform this region into one of the most potential vegetable-growing, export-earning and quality seed-producing areas at rates cheaper than imported seeds. To accomplish this, there is a need of a wider dissemination of improved technologies and establishment of strong input-output markets.

Varietal Specificity of Plant Growth Regulators in Bottle Gourd

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In India, in almost all the studies related to plant growth regulators' effect on yield and its attributing traits in bottle gourd, the researchers have used only one variety, *Pusa Summer Prolific Long,* in their experiments. No scientific investigation has been made to ascertain the differential response of various PGRs on varying genotypes of bottle gourd. The present investigation, therefore, was designed to study the effect of four plant growth regulators, viz. maleic hydrazide (MH), gibberellic acid (GA3), ethanol and naphthalene acetic acid (NAA) with two concentrations each on the three diverse bottle gourd genotypes, viz. NDBG-208, NDBG-129 and *Pusa Naveen*. The study comprised assessment of the (i) efficacy of the four PGRs on yield and yield attributes on the three bottle gourd genotypes, (ii) differential response of the genotypes to different PGRs at their varying concentrations, and (iii) economic feasibility of the use of PGRs. The experiment was conducted at Students' Instructional Farm of ND University of Agriculture and Technology, Kumarganj, Faizabad, during the summer of 2000.

The study has revealed a differential response to different PGRs, even to different concentrations of the same PGR. MH 100 ppm has produced the best results in NDBG-129 with increase in yield of 28.62%, MH 150 ppm has given the best performance in NDBG-208 with an increase in yield of 27.36%, while ethanol 50 ppm has shown the best results in *Pusa Naveen* with an increase of 27.37% in yield, over the respective controls. The three best PGR treatments, viz. MH 100 ppm, MH 150 ppm and Ethrel 50 ppm have been found to give the highest net return per rupee invested in the case of NDBG-129 (Rs 1.55), NDBG-208 (Rs 0.05) and *Pusa Naveen* (Rs 1.91), respectively. It has, therefore, been concluded that the recommendations for the use of PGR applications should specifically be made for a specific PGR at a specific concentration on a specific variety, at least in the case of bottle gourd.

An Innovative Scheme to Produce CMS-based Chilli Hybrid Seeds at Farmers' Fields

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The outcome of a study conducted at the farmers' fields near IIVR, Varanasi and experimental plot of IIVR during winter seasons of 2000-01 and 2001-02, with the aim of finding the extent of natural cross-pollination in chilli (*Capsicum annuum* L.) is reported. A feasible scheme has been suggested to produce hybrid seeds using cytoplasmic-nuclear male sterile (CMS) line. The amount of fruit and seed set on the plants of cytoplasmic-nuclear and nuclear male sterile lines (CCA-4261 and MS-12, respectively) have been utilized to study the extent of natural out-crossing at the experimental plots. The extent of variability at the farmers' field and farmers' views on retaining the seeds of local cultivars and their performances in next cropping season have been recorded. The development of normal amount of fruits with considerable number of seeds on male sterile plants during the months of October-November has revealed very high rate of natural cross-pollination at the Varanasi location. The progenies (natural hybrids with unknown pollen parents) derived from the single fruit (harvested from male sterile plants) have been found unexpectedly less variable in terms of plant height, fruit size, shape and number. The less variability observed in the random hybrid plants has been explained on the basis of collection of sufficient amount of pollen from the flower of one plant and its release on flower of male sterile plant by the honey bees in a single visit. The amount of variability among the local cultivars in terms of fruit size, shape and number at the farmers' field has although been consistent over the years, it has been more than the natural hybrids developed at the experimental plot. Hence, it has been concluded that in the farmers' fields, the occurrence of natural hybrids derived from unknown male parent(s) is a common phenomenon and unknowingly farmers are exploiting heterosis from the mixture of F_1 and selfed seeds. This study has not only provided a basis for proposing an innovative scheme to produce non-conventional hybrid seeds at the chilli grower fields utilizing cytoplasmic-nuclear male sterile line, but has also provided a method of avoiding monopolistic cultivation of hybrid varieties to the small and marginal farmers.

Effect of Date of Sowing, Varieties and Topping on Growth and Seed Yield of Coriander

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The effect of date of sowing, type of cultivars and topping operation on the growth and seed yield of coriander is reported based on an experiment conducted during the rabi season of 1998-99, at ND University of Agriculture and Technology, Faizabad. It comprised a set of three treatments, i.e. three sowing dates (3rd October, 15th October, and 14th November); three cultivars (*Rajendra Swati, Pant Haritima* and *Kumarganj local*) and topping and without topping at 65 days after sowing. Altogether eighteen treatment combinations have been evaluated jointly adopting randomized block design with factorial concept, in three replications. Biometrical observations with regard to the growth and seed yield of coriander have been recorded. The texture of the soil was sandy loam and fertility status was poor with respect to nitrogen availability and medium in phosphorus and high in potassium contents. All package of practices were adopted as and when required. The results have shown that the sowing of coriander on the 15th October responded well and had maximum yield. Delaying of sowing by a margin of 15 days interval has resulted in a gradual decrease in yield.

The three cultivars of coriander used in the experiment have also shown difference with respect to yield potential and maximum yield (17.87 q per ha) has been obtained with cv. *Pant Haritima* followed by *Rajendra Swati*. Topping operation has shown a conspicuous response on branching and yield of coriander. The conjunctive use of V_2 T_2 (*Pant Hartima* x topping operation) has produced maximum yield, i.e. 20.20 q/ha, which is significantly superior over other interactions.

Vegetable Research at MPKV—
An Impact Analysis

T. A. More
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Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, is one of the important centres in vegetable research pertaining to the development of varieties/ hybrids including disease-resistant varieties , standardization of agro-techniques, plant protection measures, seed production technologies, post-harvest management, etc. MPKV has released 36 varieties/F_1 hybrids in vegetables including 4 each of brinjal and bitter gourd, 6 each of chilli and onion, 3 each of cucumber and tomato, 2 of garlic, 1 each of French bean, okra, sponge gourd, ridge gourd, snake gourd, radish, dolichos bean and bottle gourd. Of these 36 varieties, 12 have been notified and released by the Central Sub-Committee on Varietal Standardization, Notification and Release. These include *Baswant-780* and *Phule Suvama* of onion; *Rajashree* (F_1) of tomato; *Phule Priyanka* (F_1); *Phule Green Gold, Phule Ujwala* of bitter gourd; *Phule Shubhangi* of cucumber; *Phule Prajakta* of sponge gourd; *Musalwadi, Agnirekha* of chilli; *Phule Surekha* of French bean and *Krishna* (F_1) of brinjal.

Efforts have also been made to standardize the production technologies such as seed rate, spacing, fertilizer, irrigation, and control of pests and diseases of 25 vegetable crops. As many as 177 technologies (66 agro-techniques, 77 plant protection measures, and 34 post-harvest technologies) have been standardized and transferred to the farmers at the state level. Besides, a number of pipeline technologies have been transferred to the farmers which have helped them in achieving production of better quality vegetables, safeguarding the crops from the diseases and pests and reduction in the post-harvest losses significantly. The classic examples mentioned are of the onion storage and onion dehydration, the bottle gourd production, and some packaging and transport technologies. It is reported that the farmers of Maharashtra are practically utilizing these technologies. Some varieties resistant to diseases and pests have also been developed. For example, the variety *Phule Mukta* of chilli is resistant to powdery mildew; *Phule Jyoti* and *Phule Suryamukhi* of chilli are tolerant to leaf curl virus; *Phule Kirti* of okra is tolerant to yellow vein mosaic virus, *Phule Sureksha* of French bean is resistant to anthracnose, leaf crincle, bean yellow mosaic and wilt; and *Dhanashree* of tomato is tolerant to leaf curl virus and spotted wilt virus. By virtue of these resistant and tolerant varieties, the expenditure on the plant protection measures has been reduced considerably and in turn has benefited the farmers. The area occupied by the varieties released by MPKV, Rahuri, is about 20-25% of the total area in Maharashtra. This University is the main source of breeder's seed for the public and private sectors in Maharashtra and many other states of the country.

Storage Studies of Improved Tomato Varieties at Ambient and Cool Chamber Conditions

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The effect of storage environment on shelf-life of some improved tomato varieties, viz. *HY-2, Rajashree, M-1-1, HY-2* and *Dhanashree* has been studied. Freshly harvested fully matured to turning stage tomatoes were subjected to cleaning, grading and stored in plastic crates. The effect has been studied by keeping one at room temperature (20.18 to 29.16^{0}C and 31.20 to 76.17% relative humidity) and the other in cool chamber (20.15 to 24.97^{0}C and 80.11 to 86.16% relative humidity). The shelf-life of each of *HY-1, Rajshree, M-1-1, HY-2* and *Dhanashree* has been found longer, i.e. 19, 17, 15, 14 and 12 days, respectively in cool chamber and lower (i. e. 9, 7, 6, 6 and 5 days, respectively) at room temperature. In general, all the fruits have been found to have good consumer acceptance at the end of shelf-life under both the storage conditions; but the fruits stored in cool chamber have been found more fresh, firm, glossy in appearance and attractive. The physiological losses in weight of the cool chamber varieties has been less, i. e. 6.24%, 7.63%, 8.05%, 8.89% and 9.20%, respectively in cool chamber and more at room temperature (i. e. 9.66%, 10.11%, 10.98%, 11.40% and 12.50%, respectively). It has also been noted that the fruits kept in cool chamber recorded lower rotting as compared to those stored at room temperature; the latter have been found to be infected with *Rhizoctonia solani* and *Fusarium semitectum* also.

Assessment of Improved Technologies for the Management of Pests and Diseases in Tomato and Ginger Crops in Mid-hills of Himachal Pradesh

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Tomato and ginger are the two major vegetable cash crops of the mid-hills of Himachal Pradesh. The benchmark survey conducted before initiating this study revealed high incidence of fruit borer (10.83%), leaf spot (16.09%), buckeye rot (2.68%), and late blight (6.36%) in tomato crop, and in ginger, the incidence of rhizome rot was up to 70%. The results of two years data of on-farm trails conducted on 145 farmers' fields have indicated that the use of improved technology of spraying Ridomil (0.25%, one spray after onset of monsoon and than in the second week of September), Dithane M-45 (0.25%, spray after 7 days of first spray of Ridomil), and Blitox (0.3%, 2-3 sprays) on tomato crop could reduce the disease incidence of leaf spot (10.08%), buckeye rot (0.95%) and late blight (2.91%) and has provided an additional food-security of 50.2 q/ha with a cost-benefit ratio of 1:7.2. The fruit borer incidence has been reduced by 5%, resulting in an additional food security of 35.6 q/ha with a cost-benefit ratio of 1:1.4. Rhizome rot incidence in ginger has been reduced to 2.62% through seed treatment with Dithane M-45 (0.25%) and Bavistin (0.1%). The improved technology has provided an additional food security of 5.72 q/ha with a cost-benefit ratio of 1:1.14. The technological needs of the farmers have been determined by adopting the participatory rural appraisal (PRA) tools and the field trials have been conducted with active farmers' participation. Therefore, the farmers themselves have evaluated the technologies related to their own practices and, in fact have adopted the improved technologies.

Effect of Organic and Inorganic Fertilizers on Production of Tomato

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The results are reported of an experiment conducted during 1998-99 and 1999-00 at the Vegetable Research Farm of ND University of Agriculture and Technology, Faizabad, with the objective of finding the best combination and doses of manures and fertilizers for obtaining maximum production and net return from the tomato variety *Narendra Tomato-2*. Nine treatments have been given comprising two doses of N:P:K (120:60:60 kg/ha), green manuring and their different combinations. The experiment has been laid out in a randomized block design with three replications. The tomato seedlings have been transplanted on ridges at 60 x 45 cm spacing during the last week of October in both the years. The data on yield and yield attributing parameters, i.e. average number of fruits/ plant, fruit yield/plant and average weight of fruit have been reported. Maximum fruit yield (354 q/ha) and net income (Rs 49770/ha) have beeen obtained with 20 tonnes FYM/ha + full recommended doses of NPK (120:60:60 kg/ha) followed by green manuring + ½ dose of NPK, which could produce 332 q/ha fruit yield and have given the net income of Rs 47, 200/ha. Highest cost-benefit ratio (1: 3.45) has been found with the treatment of green manuring + ½ dose of NPK. The Farm Yard Manure applied alone at 20 and 40 t/ha could produce 145 q/ha and 166 q/ha fruit yields, respectively. On an average, dhaincha green manuring has been found superior to both the doses of FYM by producing a fruit yield of 183 q/ha.

Evaluation of Onion Varieties for Processing

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The evaluation of onion varieties for processing has been done under the All India Coordinated Research Project on Post-harvest Technology of Horticultural Crops. In this study, 12 varieties of onions have been assessed for parameters like total soluble solids, dry matter contents and processing qualities. For this purpose, bulbs were harvested at 50% topfall, field-cured by windrow method for 5 days, followed by top cutting with keeping 4-cm long intact bulb neck and shade-cured for 21 days. The marketable bulbs were kept for storage at room temperature for recording the total losses. The study has revealed that the storage loss has beeen maximum in *Phule Safed* (67.55%) and minimum in N-2-4-1 (11.11%) at the end of three-month storage under ambient conditions. The total soluble solids and dry matter content of the variety *Phule Suvarna* are found as 13.90% and 14.51%, followed by *Phule Safed* with 13.33% and 13.80% contents, respectively. Looking to the processing quality requirements and shorter storage-life, the variety *Phule Safed* has been found to be the best for dehydration.

Micro-site Adaptability of High-Yielding Vegetable Varieties in the Farmers' Fields

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The performance of released vegetable varieties of cowpea, okra, bittergourd and snakegourd has been evaluated in the farmers' fields of the pilot project areas of southern Kerala under the Kerala Horticultural Development Programme. The variety, *Sharika* in cowpea has recorded the highest yield. The okra variety, *Arka Anamika* has been observed to be superior to the local variety in yield and resistance to yellow vein mosaic. *Preethi* and *Priyanka* of bittergourd which have given mixed response, are found acceptable to the farmers. In snakegourd, *Kaumudi* is found well accepted by the farmers due to high-yield and fruit length. It has been recommended that periodical survey may be conducted for identification of better genotypes with high-yield and resistance.

Heterosis in Brinjal

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The results of a study on the extent of standard heterosis for yield and yield contributing characters of brinjal during autumn-winter season of year 2000 are reported. The material consisted of 22 F_1-hybrids raised from straight crosses between ten parents and two standard parents of brinjal. In order of merit, F_1-hybrids DBL- II x PB-33, *Pant Samrat* x KS.331, PB-33 x PB-30 and PB-30 x KS-331 have depicted a better performance over the standard parents (*Pant Samrat*) for yield as they have recorded significant heterosis of 51.3%, 50.1%, 45.9% and 34.6%, respectively. It is observed that these hybrids could be recommended for commercial cultivation after confirmation of their potential by testing for one more year.

Impact of Population Density and Trailing Systems in Gherkin

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The impact of trailing systems and population density on the growth and yield of gherkin has been reported in this study conducted during January-March 2000, at the College of Agriculture, Thiruvananthapuram. Three trailing systems and six population densities have been tried to understand their direct and interaction effects on morphological and yield attributes. A majority of the yield and yield attributes were found significantly influenced by the systems of trailing, population densities and their interaction effects. Among the population densities, plants trailed on twigs have been found to have the highest yield/plot. Among the trailing systems, plants trailed on twigs have depicted maximum yield/ plot. The highest benefit-cost ratio of 1:2.18 has been observed in plants trailed on twigs with the highest population density of 53,333 plants/ha.

Effect of Potash Levels and Season on Physio-chemical Composition of White Onion cv. *Phule Safed*

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The study on the effect of potash levels and season on physio-chemical composition of white onion cv. *Phule Safed* undertaken at the University Farms has revealed that the thickness of scale and neck get decreased with successive increase in the levels of potash in both the seasons. The bulb weight has also increased significantly with higher levels of potash but only during the rabi season. The bulb diameter has significantly increased with increase in potash levels up to 150 kg K_2O/ha; however, the shape index and total marketable bulb yield have not altered significantly by potash levels. The biochemical constituents like total soluble solids, total and reducing sugars, pyrubic acid and protein content have been found to increase up to the level of 200 kg K_2O/ha during the kharif season and up to 150 kg K_2O/ha during the rabi season. The bulbs obtained during the rabi season have been far superior in quality than those obtained during the kharif season.

Yield Determinants in the New Hybrids of Brinjal

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Evaluation of twenty-four genotypes of brinjal including twenty-two F_1-hybrids and two standard parents, during 2000-01 has been reported. Nine economic characters, namely days to first flowering, days to first picking, early yield/plant, number of fruits/plant, fruit length, fruit diameter, number of primary branches/plant, plant height, and yield/plant have been observed. The analysis of correlation coefficients has shown that the yield is positively and significantly correlated with early yield/plant, number of fruit/plant, length of fruit and number of primary branches/ plant.

Biological Control of Clubroot Disease of Cole Vegetables Using Bait Crops

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Clubroot disease of cole vegetables, caused by the obligate bio-trophic soil-borne pathogen *Plasmodiophora brassicae* (woronin), is a serious threat to cole vegetable growers in the Darjeeling hills. The conventional methods used for controlling this disease include growing of resistant cultivars, raising of soil pH by liming, crop rotation, and chemical treatment. An attempt made to develop biological control by means of bait/trap cropping is reported. The method involves growing of bait or trap crop in advance of the main cole vegetables in order to induce resting spore germination and infection of bait species. The bait crop is then removed and main crop is planted, as a result inoculum pressure, i.e. resting spore population is reduced in soil before cultivation of main crop. This has helped in managing the crop against the clubroot disease.

Line x Tester Analysis of Combining Ability in Okra

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The results of a study undertaken to estimate the combining ability in okra through line x tester analysis involving 6 lines (females) and 3 testers (males) have been reported. The combining ability analysis has revealed that the variance components due to line x tester interactions has been significant for all the characters, except the edibility period of fruits and number of branches per plant. The dominant component (σ^2 D) has been found higher than the additive (σ^2A) component for all the characters, except the edibility period of fruits and fruit yield per plant, indicating the role of non-additive gene action. The lines *Punjab Padmini* and tester *Pusa A-4* have proved to be the good general combiners for fruit yield and components. The per cent distribution of lines, testers and their interactions have indicated that the variability among the crosses has been mainly due the contribution of line x testers.

Status of Vegetable Research in the Humid Tropics

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Vegetable crops play an important role in the farming system of Kerala. The humid tropical weather favours cultivation of a wide range of summer season vegetables. Cucurbits, solanaceous vegetables, amaranth, okra and tuber vegetables deserve priority. The medium and mild temperatures coupled with evenly distributed rainfall in the state are congenial for growing three crops in a year. Tuber vegetables and the underexploited perennial vegetables like drumsticks and coccinia are unique vegetables in this tract. As most of the vegetable cultivation is practised in either homesteads or leased rice fallows, special care and intensive management practices are the necessary requirements. The cultivation of export-oriented vegetables is receiving special consideration from the educated unemployed youth in Kerala. Location-specific varietal assessment, landrace characterization and utilization are the strategies receiving current research attention in the state.

Feasibility of Chilli Genotypes in Homesteads

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In this study conducted in 1997-98, identification of superior genotypes of chilli under shade for cultivation in the homesteads of Kerala is reported. For this, seventy genotypes of chilli belonging to *Capsicum annuum, C. frutescens* and *C. chinense* have been evaluated for shade tolerance and yield under four levels of shade. *CA 38* of *C. annuum, CF* 51 of *C. frutescens and C C 63 of C. chinense* have been identified as shade-tolerant which could be recommended for cultivation in homesteads of Kerala.

Studies on the Effect of Bio-fertilizer for Increasing Nitrogen Use Efficiency in Sweet Potato under New Alluvial Soils of West Bengal

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This study reports the response of bio-fertilizers in increasing nitrogen use-efficiency in sweet potato conducted during rabi season of 2000-01. The experiment comprised 9 treatments following randomized block design with 3 replications. A perusal of results has revealed that application of 2/3rd of the recommended dose of Nitrogen + Azospirillum as vine dipping (@ 2 kg/ha) could produce the maximum tuber yield (17.83 t per ha) followed by 1/3rd of the recommended dose (16.79 t/ha). Between the two bio-fertilizers, azospirillum has been found to be more responsive than azotobacter. Both inoculation with bio-fertilizer and higher rate of nitrogen have increased the starch concentration and decreased the total sugar content of tubers. Economic analysis has revealed that the net return and benefit-cost ratio are higher for the treatment receiving 2/3rd of the recommended dose of Nitrogen + Azospirillum as vine dippings (@ 2 kg/ha), which has fetched an additional income of Rs 16508 /ha over that from control.

Storage Studies of Leafy Vegetables at Ambient and Cool Chamber Conditions

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The effect of packaging and storage environments has been studied on the shelf-life of green leafy vegetables, viz. palak, methi and coriander. Sympo-33 has been subjected to cleaning, trimming, washing, draining and packing in polyethylene bags (300 gauze and 2% vents). The effect has been studied by keeping the packed and unpacked lots under two storage environments, viz. at room temperature (18.68 to 31.13^{0}C and 27.36 to 74.23% relative humidity) and in cool chamber (16.24 to 20.46^{0}C

and 80.12 to 85.23% relative humidity). The shelf-life of plalak, methi and coriander packed in polythylene bags and stored in cool chamber are found to be the highest (7 and 5 days, respectively than of those kept at room temperature (4 and 2 days, respectively). The physiological loss in weight (PLW) has been found to be lowest in leafy vegetables packed in polyethylene bags than in unpacked ones, irrespective of storage environment. The PLW of packed palak, methi and coriander has been found lowest (5.50, 5,90 and 6.33%, respectively) in cool chamber than at room temperature (9.25, 10.31 and 12.36%, respectively). The packed green leafy vegetables are reported to appear more fresh, firm, attractive and marketable than the unpacked ones in cool chamber or stored at room temperature.

Effect of Spacing, Fertility and Crop Duration on Production of Seed Size Tubers in Potato

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The results of an experiment consisting of the combinations of two fertility levels (100:80:80 and 150:120:80, N: P: K kg/ha), two plant spacings (60 x l5 cm and 60 x l0 cm) along with two-crop durations (70 and 80 days) conducted to get maximum yields of seed size tuber in potato variety *Kufri Jawahar* have been reported. None of the treatments has been found to influences emergence and the number of tubers per unit area. The number of stems /hill and per unit area have been found higher at closer spacings. The closer spacing has been found to increase significantly the total number of small tubers per unit area but has no significant effect in number of medium and large size tubers per unit area. Fertility levels have not influenced the total number of tubers per unit area of small and big tubers, but have been found to differ significantly in respect of medium size tubers. With increase in duration from 70 to 80 days, the number of medium size tubers has been found to increase at lower fertility level. Yields of small size tuber differ significantly, whereas the yields of medium size tuber have been observed to rise with increase in closer spacing along with move in crop duration.

II. ADOPTION AND IMPACT OF VEGETABLE RESEARCH

Constraints in Adoption of Improved Vegetable Technologies in Western Maharashtra

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Vegetable research in India has generated various production technologies but their adoption has been limited. This study has examined some of the constraints in adoption of improved vegetable technologies generated by the Mahatma Phule Krishi Vidyapeeth, Rahuri, in the western Maharashtra. This region occupies more than 66% area under vegetables in the state. The area under vegetables in the state has risen by 90% during 1980-81 to 1999-2000. The research efforts being made at MPKV, Rahuri, have increased the productivity of vegetables to a significant extent. Nearly 35% area has been occupied by the varieties released by this University.

The production technologies relating to the use of improved seed, sowing, spacing, fertilizer and plant protection application for various vegetable crops have been adopted. However, there is a partial adoption or non-adoption of seed treatment and rouging. Technology is available for rouging but the farmers feel that there is a loss of crop resulting into a decreased yield. As such, there exists an extension gap. Farmers need to be convinced about the use of rouging. Lack of awareness has been found a major constraint for non-adoption of production technologies. The research is needed for varietal improvement, including virus resistant types through hybridization in the case of chilli, brinjal, tomato, okra, peas, beans, potato, cole and cucurbits vegetables. Cole vegetables need research on seed production; garlic and onion on storage ability of bulbs on grain and fodder separately. It has been argued that most of the vegetable crops need research on low cost production technologies.

Proven Technologies and Other Issues of Vegetables in West Bengal—A Case Study

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The proven technologies and other issues in the production of vegetables in West Bengal have been investigated. It has been observed that (i) pace of increase in area, production and productivity of summer, rainy and winter vegetables in the state are not static, and (ii) there have been fluctuations in area, production and productivity of vegetables, probably due to lack of marketing facilities. The cultivation of vegetables by adoption of proven technologies has been found to be highly remunerative. Similarly, land productivity is considerably higher resulting from the better performance of vegetables in almost all farms. At the same time, high yield performance of vegetables has been observed in most of the farms. However, the income from vegetables has been found to differ widely across different categories of farms. On dividing the estimated cost of production into various cost components, it has been found that the NIVF, NIB and NIC are highest in smaller size of farms, except in tomato. Accordingly, the net income even in the case of higher production is comparatively low in large farms which is due to higher production costs and the unorganized nature of marketing.

The wide fluctuations in daily prices and large margins between the wholesale and retail prices are the common features in almost all the markets of the state. The large margins are meant to cover risks of loss due to perishability of the produce. Due to these constraints and drawbacks, over – production creates glut in the domestic markets, resulting in low price to the producers. The defective methods of handling and marketing and even intentional moves by the middlemen lead to the waste of a substantial percentage of vegetables. The value of Gini Coefficients in vegetables has been found higher than that in other crops. Based on these results, it has been suggested that involvement of corporate form of organizations may be encouraged to help improve the vegetable sector and facilitate access to international market. Also, the Land Ceiling Act may be amended suitably allowing the corporate sector to invest capital on the development of large-sized captive gardens. Finally, it has been proposed that thrust be laid on production of value-added products for reducing transportation costs and generating more rural employment.

Economic Viability and Constraints in Production and Marketing of Vegetables in Western Maharashtra

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The share of Maharashtra state in country's vegetable area and production is about 4%, with a productivity (13.67 tonnes/ha) higher than the national average (13.42 tonnes /ha). Among the four regions of Maharashtra, the western Maharashtra alone occupies more than 66% area under vegetables concentrated in four districts of Pune, Nasik, Ahmednagar and Satara. Increased production resulting into a higher increase in marketable surpluses, accompanied by the increase in demand by urban population, call for a rapid improvement in the existing vegetable marketing pattern. In this study, the production and marketing of vegetables in the western Maharashtra have been reported considering the major vegetables, viz. tomato, okra, and green chillies.

The study has revealed that the per hectare cost of cultivation is relatively more for tomato and green chillies during the kharif while for okra, it is higher during the rabi season. The per ha gross and net returns have been found relatively more for tomato in kharif season, for green chillies in rabi season, and for okra in summer season. The average per quintal cost of marketing in primary and terminal markets has been noticed highest during the summer season for all the selected vegetables. The producers could get better returns in terminal markets in spite of high marketing cost, because of better prices. The major constraints faced by the sample cultivators in cultivation are non-availability and high prices of inputs like seeds, agro-chemicals, etc. In marketing of vegetables, the major problems faced are high cost of packing material, high commission charges, high cost of transportation, non-payment on time, and malpractices. It has been suggested that farmers should cultivate tomato during kharif, and okra and green chillies during the rabi season to maximize profits. A need has been emphasized for establishing a co-operative marketing society for vegetables so that the crucial inputs could be supplied on reasonable costs and marketing could be done on a collective basis.

Constraint in Adoption of Improved Vegetable Technology in Maharashtra

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Mahrashtra has ample scope to grow various vegetable and fruit crops. This study has analyzed constraints in the adoption of improved vegetable technologies. The study is based on the primary data collected from 120 farmers, 60 each from Pune and Akola districts of the state during the period 1996-97. It is reported that the sample households have devoted about 34% of the irrigated area for growing vegetables, fruits and flowers. Marginal and small farmers are reported to be more attentive towards growing of vegetables than medium and large farmers. Onion and tomato being the most important vegetable crops are reported to be grown by 72% and 28% of the sample household, having about 14% and 3% total cropped area, respectively. Among the vegetables, onion has been found to be grown by 63% farmers on about 5% of the cropped area; other vegetables, i.e. tomato, okra, brinjal and chilli have covered about 5% of the total cropped area.

For studying the constraints being faced by the vegetable growers, only six controllable factors have been selected to find their impact on vegetable production. It has been revealed that price fluctuations, lack of proper storage facilities and non-availability of credits are the major constraints in production of onion, tomato, okra and chilli in the Pune district. The scarcity of water, price fluctuations, non-availability of credit, lack of proper storage facilities are the major constraints in onion, tomato, okra, brinjal and chilli in the Akola district. It is suggested that farmers having no land under fruits and vegetable crops, redistribution of land may be helpful. Secondly, collective action such as group farming or cooperative farming is to be encouraged so that soil testing, irrigation, storage, transportation, standardization and grading, quality control, other marketing problems, yields and price risks could be handled on a collective basis. Small and marginal farmers may be assured of their food requirement so that they could go in for vegetable cultivation. The crop insurance scheme should be extended to cover vegetable crops also. These measures would finally lead to improve the economic position of the farmers, and the economic growth of the nation.

Analysis of Farmers' Indigenous Method of Storage of Small Onion to Hedge against Price Fluctuations in Dindigul District of Tamil Nadu

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In Tamil Nadu, Dindigul district is the second largest small onion-producing district. A study has been conducted on the use of small onion storage structure developed indigenously by the local farmers to hedge against price fluctuations in the district. The primary data have been collected from 90 farmers selected randomly by following the three-stage random sampling. The information has been collected for two consecutive years 1997-98 (the year in which the prices of onion were high at Rs 40/kg) and 1998-99 (the year in which prices of onion were very low at Rs 3/kg). In the Dindigul district, small onion is cultivated during rabi (October- December) and kharif (May- July) seasons. Normally, onion storage is followed by farmers for family consumption and as seed for the next season so as to reduce the price risk. Onion-storage structure is prepared by using coconut leaves and bamboo sticks. The dimensions of the storage structure are: width, 0.90 metre, height 1.2 metre, and the length depends upon the quantity of the onion to be stored. The cost of preparation of this storage structure is about Rs 500 per tonne of onion. During the second season of 1997-98, the stored onion fetched a maximum of Rs 30 per kg. In 1998-99, because of high production and poor quality of onion at the time of storage, the price of the stored onion declined to Rs 3.0 per kg during the rabi season and Rs 2.94 per kg during the kharif season, causing heavy losses to farmers. The factors influencing the prices of stored onion have been studied applying the regression model separately for both years — one of high (1997-98) and the other of low (1998-99). The results have indicated that in 1997-98, the number of months of storage, variety and rabi season of cultivation had a significant influence on prices while the storage losses significantly reduced the price. In 1998-99, the number of months of the storage significantly reduced the small onion price. This has been due to the poor quality of the produce stored at the time of storage and indigenous storage method as a hedge against price.

Proven Technologies in the Vegetable Sector in India: Some Issues and Concerns

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The changing dietary patterns of consumers and emerging environment under globalization have put forth a challenge for improving the production and productivity of vegetable crops. The changes in food consumption, diversification in production, value-addition and export, have made the role of vegetables very prominent.

The study has shown that output-input ratio over cost C is lowest in cauliflower and highest in brinjal. It has been observed that the net income due to cultivation of vegetables in marginal, small, medium and large farms is Rs 5252, Rs 7360, Rs 9954 and Rs 7985 per acre, respectively. Thus, the net income even in case of higher production is comparatively low in large farms, which is due to higher production costs and unorganized nature of marketing. It has been observed that the generation of human-labour employment is comparatively higher in most of the vegetables in comparison to field crops. To quantify the impact of vegetables on environment, the input-use pattern for traditional and vegetable crops has been assessed. It has been observed that the practice of growing high-value crops is more eco-friendly than that of traditional crops. The use of irrigation, especially in the case of summer paddy, is very high than vegetables and is causing havoc to the ecosystem. On the other hand, use of FYM is comparatively high in vegetable and potato production than that in cereals. However, indiscriminate use of pesticides in vegetables has become a common phenomenon, probably due to unawareness of the growers campaigns of pesticide dealers and fear of losing the crop yield.

The constraints as per their importance have been spelt out as non-availability of marketing facilities, lack of capital, unsuitable land situation, total failure due to natural calamities, lack of information about improved farm technologies, high wages of labour and non-availability of cold chain facilities.

The elasticity of demand for vegetables with respect to consumer expenditure is close to one. With faster growth in per capita income, the demand for vegetables is supposed to rise. The vegetable sector has great potential for export of processed and fresh vegetables. Moreover, efforts are also being made by various organizations including the National Horticultural Board (NHB), to adopt such policy measures that would not only help in creation of post-harvest infrastructure but also provide sound footing to boosting of horticulture exports, and would have positive impact on vegetable production and productivity.

Energy Consumption Scenario for Tomato Cultivation in Tamil Nadu

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Tomato is one of the important vegetables, grown in 25,000 hectares in Tamil Nadu. Its average yield is 9.8 tonnes per ha. In 1997-98, tomato crop was grown in 18,278 hectares in Coimbatore, Salem, Dharmapuri and Dindigul districts. It has been observed that the area under tomato cultivation is increasing due to its demand and better infrastructural facilities. To assess the impact of energy consumption in tomato cultivation, an energy audit has been done of 100 tomato growing farmers of the four major tomato–growing villages and results are reported in this study.

The energy requirements for cultivation of one hectare of tomato have been estimated as 18218 MJ. Human energy used for frequent harvesting and transportation, electricity for irrigation and fertilizer energy are the main contributors (around 59%) to the total energy consumption. Amongst various operations, irrigation and harvesting have been found to utilize a major portion of the total energy. To have control over the energy use and spurt in tomato cultivation, adoption of improved practices has been suggested. Cultivation of improved and hybrid varieties would result in increased yield and thereby reducing input-output energy ratio.

Impact of Off-season Vegetables in Himachal Pradesh: Economics, Constraints and Policies

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Himachal Pradesh has vast potential for vegetable production because of its cold climate and other favourable conditions. The vegetables produced in the hills do not face any competition from the local produce when supplied to the markets in the plains, because it being off-season there. The state thus, has a specific advantage in vegetable production compared to other crops. The main vegetables grown in Himachal Pradesh are potato, tomato, cauliflower, cabbage, peas, capsicum and French bean.

Several studies have been undertaken to examine the costs and returns of off-season vegetables in the state. These studies have revealed that the cost of cultivation, gross returns as well as net returns are higher in most of the vegetables in Solan district of Himachal Pradesh. In the case of tomato, highest input-output ratio has been found on large farms (1:5.30), followed by small farms (1:3.04) in the Solan district.

The analysis has also revealed that use of human labour in production of vegetables is an important parameter. In the production of vegetables, all the farmers have reported facing the problems of irrigation, besides non-availability of quality seeds, insecticides and pesticides in time. Lack of technical know-how and credit are the other main problems. A urgent need has been pressed to start the integrated vegetable development programme focused on distribution of all critical inputs with development of infrastructure, marketing and technology, etc. to motivate vegetable growers. It would help in minimizing the margin of the intermediaries and would ensure a higher producer share in the consumer rupee.

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Energy Management for Potato Cultivation in the Nilgiris District

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Potato is primarily a crop of temperate region, and grown best at an elevation of above 1000 metres with evenly distributed moderate rainfall in the Nilgiris district. It was grown in 5571 hectares in Tamil Nadu in 1997-98, and average yield obtained per ha was 16.2 tonnes. In this study, the energy management in the cultivation of potato is reported in the Nilgiris district through its (i) source-wise, and (ii) operation-wise estimation. Some rational management practices have also been suggested. The study has been conducted in the district of Nilgiris where the crop was cultivated in an area of 2331 hectares which is nearly 42% of the total area cultivated of tomato in Tamil Nadu during 1997-98.

The energy consumption in the production of crop has been observed as 49969 MJ/ha. Among different sources, fertilizers have consumed more energy (about 46%) followed by seeds (29.4%) in the total energy consumption. The energy consumption in operations like sowing, fertilizer application and spraying has been found less than that in other operations such as tillage, irrigation and transport. The farmers are not found practising the recommended package of practices. It has been observed that if the farmers adopt the scientific method of cultivation, not only energy consumption would be reduced but productivity would also be increased, and thereby the income levels of potato growing farmers would rise.

Constraints in Vegetable Production

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Realization of yield potential depends primarily on several factors, cumulative effect of which is reflected in the field level yield gap. It is mentioned that factors like lack of knowledge, poor availability of resources and capital are the major constraints in adoption of any modern agricultural practice by the growers. Vegetable crops, which are 4 to 8-times more remunerative than cereals, and other field crops, can also contribute significantly in solving the food and malnutrition problems of the country. These are still not in a position to achieve the desired levels of production. In the study conducted in the Varanasi district of Uttar Pradesh, it has been observed that major constraints faced by the vegetable growers are crop loss from wild animals, non-existence of market, and unstable market prices. Therefore there is an urgent need for micro-level planning to overcome these constraints and help the vegetable growers in achieving the targeted vegetable production.

Economics of Hybrid Seed Production in Tomato

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A field experiment conducted to study the hybrid seed production in tomato *(Lycopersicon esculentum.* Mill) at the University Research Farm during the kharif season has revealed that spraying of 10 ppm NAA followed by pollination on initial truss sequences (up to six flower trusses) during early days of flowering is the most ideal time to result in the highest percentage of fruit set and highest number of seeds per fruit. It requires the minimum number of female flower buds to be pollinated, reducing ultimately the time required for the production of one kilogram of hybrid seeds. The net returns per kilogram of hybrid seeds are higher in NAA treatment with pollination on initial truss sequences than the PCPA treatment and control.

Assessment of Energy Use Pattern for Carrot Cultivation in the Nilgiris District

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Carrot is a root crop, grown in hilly regions and plains. During 1997-98, it was cultivated in 2731 hectares in Tamil Nadu, with productivity of 26.6 tonnes per ha. In the Nilgiris district alone, it was cultivated in 1914 hectares, which constituted around 70% of its total area in Tamil Nadu. In this study, the energy consumption pattern is reported in the cultivation of carrot in the Nilgiris district of Tamil Nadu, with specific objectives of (i) assessing the source-wise energy consumption, (ii) estimating the operation-wise energy consumption, and (iii) suggesting management practices to improve the productivity.

The study has been conducted using the whole village approach in two villages (Kokkal and Thoddani) of the Nilgiris district. The total energy consumption has been found as 35592 MJ/ha for cultivating carrot crop. Fertilizer and diesel energy consumption has been reported to be around 72% of the total energy used. Field preparation (26.5%) and irrigation (46%) have consumed more energy operation-wise than other operations. It is also observed that the present level of fertilizer use (217:185:210 kg per ha) can be reduced to the recommended N:P:K levels (135:135:135 kg per ha) without affecting the current yield levels. However, energy consumption on account of irrigation could be reduced by the adoption of modern water-harvesting technologies.

Post-harvest Management of Major Vegetables: Problems and Prospects

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India is the second largest producer of vegetables. However, gap between production and demand is very wide. Vegetables have great export potential and can earn 20 to 30-times more foreign exchange per unit area than cereals. But shorter shelf-life and higher post-harvest losses in vegetables are critical constraints in vegetable demand-supply scenario. Post-harvest losses of perishables are more serious in the developing countries like India because of lack of elaborate harvesting equipment, collection centres in major producing areas and poor marketing and transportation facilities. In this paper various factors responsible for post-harvest losses in vegetable crops have been identified and measures to minimize them have been suggested. It has been recommended that harvesting, canning, sorting, grading, transportation, storage under refrigerated/ controlled atmospheric/ modified atmosphere and timely marketing need be thoroughly standardized and proper technology may be adopted/ developed for each stage of chain to improve the entire post-harvest management.

Economic Analysis of Constraints to Onion Production on Small Farmers in Nasik District

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Onion is important not only in the domestic vegetable market but in the export basket of the country also. It constitutes 26% of the total vegetable export. The country exported about 9% of the total onion production with export value of Rs 3.30 crores in 1998-99. The onion production though is spread over a large number of states, but Maharashtra, Karnataka and Gujarat contribute more than 80% of the total onion production in the country. The state of Maharashtra has the highest area under onion cultivation, and its important onion-growing districts are Nasik, Pune, and Ahmednagar. Nasik is a major onion-growing district, which contributes around 50% of the total production of the state. In this study, the cost of production and productivity of onion on small farms have been examined and the constraints being faced by the producers in its cultivation have been identified. The study is based on the primary data collected on a sample of farms located in the Nasik district. Various cost types of production, viz. C-1, B-2, C-2 and C-3 have been computed.

III. MARKETING, DEMAND AND NUTRITION SECURITY

Marketing Strategies of Vegetables for Small and Marginal Farmers

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India is the second largest producer of vegetables (94 million tonnes) in the world but the development of vegetable production among states is uneven. Nearly, 78% of farmers in India are small and marginal; they have sufficient availability of labour and grow more vegetables than other farmers. However, these farmers are being exploited in various ways by the middlemen and get low share in consumers' rupees. They have been facing several problems that need to be addressed so as to increase their income. The increased income of these farmers who are large in number will enlarge the market for industrial goods and thus will add to a faster rate of development. In this paper, the growth of vegetables in different states, distribution of area under vegetables by small and marginal farmers and the problems and probable solutions of these problems have been studied. West Bengal among major states in India has highest area and production of vegetables. The increase in the area under vegetables and its production have been found more in West Bengal than in any other state in India during the 1990s. However, productivity growth was highest in Tamil Nadu during this period. The small and marginal farmers cultivate significant area under vegetables, about 56%, of the total area in India and get employment and income through vegetable cultivation and its marketing. The additional marketable surplus of vegetables in future will come from these categories in view of the increasing number of such holdings and their resource availability of labour. However, they have several pre- and post-harvest problems, especially related to marketing. The co-operative marketing institutions of small and marginal farmers can help them in vegetable marketing and mitigating of their sufferings. In fact, co-operatives can help these categories of farmers a lot besides the public sector marketing organisations. The future research on vegetables should concentrate on small and marginal farmers, particularly problems related to marketing of vegetables. Linkage with the processors would further help them in getting assured market for vegetables.

WTO and Its Implications on Potato Trade in India

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The market-oriented economic policies of WTO have brought into focus many new issues, which were not very important or relevant in the past. It is argued that the liberalized trade regime has created a favourable climate for agricultural commodities to achieve large increases in exports. Export opportunities have emerged for new enterprises and horticultural crops have substantial export potential to tap the foreign exchange. At the same time, the economy is now more prone to global changes and developments which may effect smooth flow of trade of any commodity.

India is the fifth largest producer of potato in the world and production and productivity of potato have increased significantly over time. However, India's share in world potato trade is negligible and highly fluctuating (0.04 to 0.50 %). The export trends of potato from India, examined in this study have revealed that the policy of trade liberalization seems to have provided impetus to potato trade in recent years. It has been interesting to note that the destinations of Indian potato exports are to six countries in which Sri Lanka ranked first, importing nearly 80% of India's total potato exports. The analysis has indicated that the Indian potato is, by and large, moderately competitive in the world market and India stands a fair chance in expanding its potato exports. But, about three-quarters of total imports and exports are traded among the 12 European Commission (EC) member countries and the trade opportunities outside EC are limited. However, rapid urbanization in the developing countries and the emerging importance of potato processing are expected to generate additional demand and could result in a considerable expansion in world trade. It is expected to be further stimulated by growth in requirements for fast foods and snacks. Study has shown that if the full effects of WTO are considered, world net trade could expand at an annual rate of almost 6% per year. These suggest that for enhancing sustained potato exports from India, favourable policy initiatives have to be taken. Infrastructural facilities in terms of cold storage, indigenous storage system, transportation and shipping, market intelligence etc. have to be strengthened.

Vegetable Marketing in Uttaranchal: Constraints and Opportunities

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Uttaranchal holds a vast potential for supplying a variety of vegetables throughout the year. But, due to the prevailing deficiencies in the marketing system for inputs and outputs, losses are enormously high and producers are unable to realize the benefits. The vast potential of the region for production, marketing and export of vegetables is yet to be harnessed for the economic security of vegetable producers. In this paper, the constraints faced by vegetable producers on input and output fronts have been studied. The study has comprised a cluster of six villages from both the divisions of Kumaon and Garhwal of the state. From each division, 75 vegetable growers, spread equally across the sample villages have been included in the sample to make a sample size of 150. Personal interview method has been used to collect the information from them.

It has been found that the problems on the input front are related to key inputs, viz. seeds, irrigation, fertilizers and plant protection chemicals. The constraints related to their non-availability at right time, in required quantity and of good quality, besides high costs have been noticed. Labour is not a constraint on small farm holdings. Only large farmers face the problem of labour, that also during the peak season. The severe constraints noticed on output front have been high cost of packaging material, unnecessary deductions and high transportation costs. The other problem related to the prevailing marketing system is the high marketing cost.

For increasing the interests of the vegetable growers, the input delivery system, particularly for seeds, fertilizers and agro-chemicals, should be made more efficient and farmer-friendly; transportation and marketing should be improved; and various provisions of the *Agricultural Produce Market Act*, 1964, be implemented faithfully. Some other befitting issues have also been mentioned which need to be looked into by the policy makers and officials of the mandi committees, so that this bowl of off-season vegetables receives its due from its unique potential, particularly in the emerging economic scenario in the country.

Vegetable Production and Research in India

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Vegetables are important in our daily diet not only for providing requisite quantities of vitamins and minerals, but for providing fibre and flavonoids also. The medical research has proved that that vegetables are essential for digestion of food, lowering of cholesterol level in the blood vessels and increasing resistance to diseases. Our country ranks second in vegetable production and contributes about 14% of global produce. The vegetable production has increased after independence from 15 million tonnes to 94 million tonnes at present. This can mainly be attributed to vegetable research by NARS during the post-independence era by developing superior high-yielding varieties and hybrids resistant to various biotic and abiotic stresses.

At the national level, the development of several groups of thermo-insensitive varieties of cauliflower has made it possible to cultivate off-season crops and seeds of different vegetables even in plains. It is pointed out that area, production and productivity of several vegetables have increased during the past three decades. These included cabbage, tomato, brinjal peas, okra and potato. Even export of seeds of vegetables and fruits has increased.

For achieving number one position at the global level, the country will have to improve the productivity levels and find solution to several problems like leaf curl, early and late blight and spotted virus in tomato hybrids; little leaf, bacterial wilt, fusarium wilt, fruit and shoot borer in brinjal; black rot in cauliflower, etc. Future thrust should be on development of hybrids with multiple disease and pest resistance, tolerance to abiotic stresses and development of cost-effective hybrid seeds production technology. It has been pointed out that measures like organic farming for production of hybrid vegetables, biological control for efficient post-harvest management, modern packaging techniques, high-tech processing and storage technology are needed. Besides, thrust on development of human resource and appropriate training programmes for hybrid seed production are also needed.

Analysis of Variability in Tomato Production

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Tomato production is being confronted with problems of erratic monsoons, and infestation by insects, diseases, weeds, storms, etc. Due to the perishable nature of tomato fruit, its marketing suffers widely. In the present study, the variability in area, production and productivity; yield and price uncertainty in tomato have been examined. The study was conducted in the district of Panipat in the Haryana state, using the multi-stage sampling technique. The secondary data on area, productivity and production of major vegetable crops for the years 1990-91 to 2000-01 have been collected from the Directorate of Horticulture, Haryana state. The coefficient of variation has been estimated to measure the relative stability. The yield and price uncertainty ratios have also been calculated.

The coefficient of variation (C.V.) for tomato productivity has been found highest among the vegetable crops, whereas, C.V. of area is quite low, indicating unstable yields. The production losses have been noted due to fruit borer (38.95 %), whitefly (11.85 %), mosaic (11.35 %), and decay (10.51 %), late picking (10.01%), cracking (7.61%) and others (10.01 %). The marketing risk embodied price risk due to excess arrival during peak harvest. The price and yield uncertainty ratios have been revealed as 0.97 and 0.90, respectively. Farmers' views have also been ascertained on relative prevalence of production and marketing risks. A majority of farmers (46.33 %) have shown concern for marketing risks and narrated that sometimes, price becomes so low that it was difficult to cover even the variable costs. In contrary, 16.84% of the farmers have perceived more emphasis on production risks. However, 36.63% respondents have rated both risks equal. Thus, efforts are required to minimize production and marketing risks simultaneously. It has been suggested that production risks can be minimized through improved insect-pest management, use of resistant varieties and cost-effective technology. The establishment of processing units and cooperative marketing may help the farmers in overcoming the marketing risks. Infrastructure with sufficient forward linkages can also reduce price uncertainty.

Production and Export Potentials of Onion in Tamil Nadu

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The cultivation of onion is important not only for domestic consumption in India but for export also. The country produces 44 lakh tonnes of onion, but the export is below 10% of the total production. In Tamil Nadu, onion is produced in both kharif and rabi seasons, mostly in five central and southern districts, viz. Nammakal, Dindugul, Perambadur, Trichy and Coimbatore. These districts contribute around two-thirds of area and production of the state. Seed cost is the major expenditure, around 41% of the operational expenses, in onion cultivation. The next major cost is on human labour followed by fertilizer and machine power, each around 5% of cost C3. The net income over cost C3 has been found as Rs 8574 /ha, with cost of production as Rs 431/q, and realized market price as Rs 532/q. The benefit-cost ratio has been estimated as more than unity (1:1.23), indicating good profitability in onion cultivation in the state.

It has been argued that productivity of onion could be increased by minimizing post-harvest losses during handling, storage and curing, which would provide more onion for domestic consumption and for export. Hence, proper storage technology and facilities must be developed through the regulated market and National Agricultural Cooperative Marketing Federation (NAFED). Market intervention by NAFED and other cooperatives, and government agencies be strengthened to meet the requirements at domestic and international markets. The value-addition in onion through dehydration and processing for paste making needs to be encouraged. Onion may be brought under Essential Commodity Act of India on an ad-hoc basis. Other suggestions included in the study are maintenance of sufficient buffer stock, fixing of procurement prices, and development of a strong infrastructure to manage gluts and shortages in the market.

Commercial Production, Seasonality and Economic and Nutritional Status of Vegetable Growers in Lower Brahmaputra Valley Zone of Assam

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The results of the study conducted in the Barpeta district of the Lower Brahmputra Valley Zone of Assam during 1996-97, using multistage stratified random sampling technique have been reported. The sample growers (136) selected from 12 villages have been classified into three groups of commercialization based on input used with appropriate scores. This study has examined (i) the economics of commercial cultivation of vegetables, (ii) marketed and marketable surpluses of vegetables, and (iii) nutritional status of vegetable growers in the zone at different levels of commercialization. It has been observed that the farmers cultivated 11 different types of vegetables in winter and summer seasons; sharing 65.37% of total area under vegetables and 22.50% of total gross cropped area in the district. The winter vegetables like cabbage, cauliflower, knolkhol, brinjal, tomato and potato and the summer vegetables like ridge gourd, pointed gourd, okra and cucumber dominate the cropping pattern. The average cropping intensity has been found as 202.49%. The net income has been noted higher for early and late cultivation of vegetables. The benefit-cost ratios have been found higher for tomato, brinjal and cabbage from winter vegetables and okra, ridge gourd and pointed gourd from summer vegetables cultivated in early season. In all the vegetables selected, higher benefit-cost ratios in both winter and summer vegetables have been exhibited by group II category of commercial farms, followed by group III category. Cultivation of these vegetable crops has been reported economically feasible. The highest area has been put by all groups of farmers in cabbage and potato under winter vegetables; and ridge gourd and okra under summer vegetables. As commercial group of farms, marketed surplus of winter vegetables has been found to vary from 73.81% for potato to 91.14% for cabbage in group I farmers; and 76.53% for potato to 92.23% for cabbage in group III of farms. The sale has been found highest for cabbage and the lowest for potato. Cabbage, brinjal and tomato have been noted to share a higher percentage in total sales. In

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case of summer vegetables, the highest marketed surplus has been in okra followed by ridge gourd and pointed gourd, and the lowest in cucumber. A wide gap between recommended dietary allowance and actual consumption of nutrients has been observed amongst the growers; the lowest gap being for consumption of calcium, iron and folic acid, and the highest in consumption of fat and beta-carotene. Except ascorbic acid, all the nutrients have been found deficit in consumption from the selected vegetables. The study has concluded that the commercial growers could earn more income in early and late cultivation of vegetables. Tomato, brinjal and cabbage and okra, ridge gourd and pointed gourd in summer are more remunerative. The farmers can cultivate cabbage, potato, okra and ridge gorud more intensively.

Production, Processing, Marketing and Exports of Fresh and Processed Vegetables

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India is the second largest producer of vegetables, but the capacity of India's fruit and vegetables processing industry remains largely unutilized. Due to lack of pre-cooling treatment and cold chain coupled with rough handling by intermediaries at different stages, there is a tremendous loss of vegetables. The export of fresh fruits and vegetables was valued at Rs 762.80 crore in 1997-98, and in this, the share of vegetables was 40%. Among the vegetables, onion constituted the major share with 26% in the total export. India has been able to capture some neighboring as well as gulf markets. However, there is a scope for increasing exports to these in distant markets. In spite of the potentialities in production base, India's export of fresh and processed fruits and vegetables is not getting encouraged due to higher taxation, poor quality, lack of infrastructure, and export promotion activities and research and development. There is a need to link production with trade in this sector. There is also a need to promote the cultivation of off-season vegetables to augment their supply. Direct contracts between producers and processing industries should be encouraged. Efforts should be made to establish public and co-operative management for production, collection, processing and distribution of vegetables.

Economic Analysis of Production and Marketing of Vegetables in Thiruvananthapuram District (Kerala)

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Problems encountered in production and marketing of vegetables have been studied with a view to examine the costs and returns of vegetable cultivation, technical efficiency, employment generation, and marketing efficiency. A comparative study of vegetable growers of Kerala Horticulture Development Programme (KHDP) funded through EEC and Intensive Vegetable Development Programme (IVDP) (government-funded) has been attempted during 1999. The cost of cultivation (Cost C per 3) has been found to vary from Rs 64,314 /ha in amaranths to Rs 1,34,135 /ha in bitter gourd. The highest return of Rs 2,06,065/ha has been noticed in bitter gourd under KHDP, and the benefit-cost ratio has been found as 1:1.53. Bitter gourd has been found as the most remunerative crop in the area. Cost on manure occupied the highest share among the inputs applied for all the crops.

Frontier Production Function has been attempted to analyse and compare the technical efficiency of vegetable farms included in the two schemes. The estimated mean technical efficiency has been found highest (80%) for KHDP bitter gourd growers; it was 71% for IVDP growers. The marketing efficiency has been found highest for bitter gourd (1.99), followed by snake gourd (1.31) and amaranths (0.83). The major constraints experienced in cultivation were incidence of pests and diseases, unavailability of quality seeds at reasonable costs, and lack of credit availability and marketing facilities.

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Emerging Trends in Export of Processed Products

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The emerging trends in export of processed agri-products have been reported in this study. The export of processed products has maintained an increasing trend and achieved 206% increase during the period 1996-97 to 2000-01. However, the contribution of dried and preserved vegetables has remained more than 80% during the previous five years. It has exhibited 223% increase during 1996-97 to 2000-01. Egypt, Sri Lanka, Sudan, the USA, the UAE and Bangladesh together have accounted for a predominant share of 70% of the total export of dried and preserved vegetables in recent years. The processed fruits and vegetables are exported to Indonesia, the USA, Philippines, Netherlands and Malaysia, etc. These countries accounted for 63% of the total export. The domestic consumption of processed items is quite low because of economic reasons and food habits. The domestic consumers, by and large, prefer fresh vegetables and fruits. The high cost of packaging pushes up the cost of processed items, however, with the rise in per capita income particularly of the middle class, a positive change towards the processed foods has been anticipated. It has been pointed out that the production base is being enlarged, and modern methods of cultivation are being adopted to improve the productivity and reduce per unit cost. To some extent, cold chain is being provided which would help in maintaining quality, and freshness and would reduce the post-harvest losses.

Developing Seed Villages in Eastern Uttar Pradesh: A Preliminary Appraisal

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The availability of good quality vegetable seeds at the right time in adequate quantities is still a goal to be achieved. The objective of this study has been to educate and orient the small farmers of the eastern Uttar Pradesh, so that they could establish the organized seed production units. It is assumed that without active participation of farmers in an organized way, scarcity for good quality seeds would not be removed. The study has outlined the need of bringing the scientists and development workers together for identifying suitable superior varieties for the agro-climatic conditions, training the farmers, and facilitating institutional, financial, input supply, quality control and marketing supports. High assurance to seed quality has been made possible with multiplication of seeds by following the community-based systems, wherein proper crop husbandry, isolation, inspections, crop protection, harvesting and post-harvest handling of seeds have been securely adopted. Good quality seeds have been multiplied and made available to the producers. This has resulted in a greater crop productivity and socio-economic development of farmers in the eastern Uttar Pradesh.

Economic Analysis of Vegetable Production and Export in India

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The production and export of vegetables in the country during 1980-2000 have been analysed using the secondary data. India's vegetables in global production have been found to contribute about 14%. The annual growth rate of production has been estimated as 3.09% during 1980-90 and 2.32% during 1990-00. However the overall production growth rate during 1980-00 has been recorded as 2.49%. The annual compound growth rate of export has been noted as 5.23 % during the 1980-90 and 3.14% during 1991-00. The export growth during 1980-2000 was found to be 5.21% per annum. However, there is a need to increase vegetable

production to meet the demand of vegetables in both domestic and foreign markets. This is mainly because of the improving income status of household and rapid urbanization in the developing countries. The higher growth in export of vegetables may be attributed to both considerable growth and export promotion measures. There are problems like incidence of pests and diseases, lack of quality seeds, cold chain storage facilities, and sanitary and phyto-sanitary measures, etc. These problems are hindering the growth of both production and export of vegetables. Popularization of high-yielding cultivars, cold chain transport facility, and other infrastructure facilities would be required for improving the performance of both production and export of vegetables.

Prospects and Problems of Vegetables Production in North-Eastern Region in India

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In the North-Eastern Hill (NEH) region, commercialized farming or mixed cropping of vegetables has been found to be limited. This region has also lagged behind in adoption of HYVs of crops including vegetables. Topographical features of high hilly terrains, deep valleys, slopes and river systems, etc. have restricted the cultivation of many species. No reliable estimates are available about the area under inter-cropping or mixed cropping in this region. This study has been carried out to: (i) assess the prospects of vegetable crops in NEH region from the available data, and (ii) examine the factors affecting the large scale adoption of vegetable crops in this region.

To a considerable extent, in Jantia and Khasi hills of Meghalaya certain crops like turmeric and ginger are grown as inter crops with mandarin orange. The productivity of vegetable crops is much below its potential, except in a few crops like potato, tomato and cassava. The low productivity is mainly because of poor quality of planting material, and poor management practices. Major bottlenecks in achieving the desired yield levels in vegetable crops in this region are susceptibility of crops to pests and diseases and stresses like shortage of water, and lack of key micro and macro nutrients. Though better management techniques of these stresses are known, their adoption is low due to lack of information to the farmers.