ADVANCES IN QUALITY POTATO PRODUCTION AND POST-HARVEST MANAGEMENT

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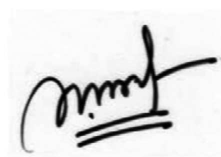
FOREWORD

Though potato is a household name today in India, it came to this ancient land only about 400 years ago during *Mughal* dynasty. After its introduction from Europe in the beginning of 17th century, it remained an insignificant crop till independence, largely because of poor productivity of introduced European varieties that were adapted to temperate agro-climate and were suitable for cultivation in hills of India as summer crop. The Government of India established the ICAR-Central Potato Research Institute in the year 1949 to harness the potential of this promising crop for food security. The institute developed indigenous varieties and technologies that virtually transformed the temperate potato crop to sub-tropical one enabling its spread from cooler hill regions to the vast Indo-Gangetic plains as a *rabi* crop. It triggered a revolution in potato production causing very fast growth in area, production and productivity during next five decades, thus making India the second largest potato producer in the world after China.

During the last 67 years of its existence, ICAR-Central Potato Research Institute has developed 52 high yielding, disease resistant and trait specific varieties; besides developing several path breaking technologies which include seed plot technique, package of practices, disease management schedules, forecasting models for late blight and crop production, aeroponics and tissue culture techniques for seed production, on-farm and elevated temperature storage technologies, processing technologies, etc. However, there are numerous challenges before the Institute to sustain the growth rate of potato production and to provide food and nutritional security to ever growing population of the country. As per

Vision 2050 of ICAR-CPRI, India would require 125 million metric tonnes of potato from 3.6 million hectare area at an average productivity of 34.5 t/ha by the year 20150. On the contrary, all the natural resources including soil, water, and energy are under severe constraint in India. Inputs for agricultural production will also become scarcer and dearer with time. It is also imperative that future food production technologies should be carbon neutral and sustainable. Under this background, we have to strike a balance between cutting edge technologies and their environmental cost for sustainable production enhancement of potato. Therefore, strategic planning to face the above challenges is the need of the hour. The Institute has a well-conceived plan to address the above challenges through appropriate R&D activities and development of climate-smart technologies. The weakest link in this strategy, however, would be technology dissemination and capacity building of all the stakeholders associated with potato sector in the country.

The present book focusses on "Advances in Quality Potato Production and Post-Harvest Management" and contains the updated information on the available tools and technologies for the best crop management practices for production of quality potatoes for seed, ware and processing and their post-harvest management; in fact it has the "Farm to Fork" essence. I am happy that the authors largely succeeded in keeping the book in a popular reading format. I hope it will be appreciated by students, researchers, teachers, policy planners, industry personnel and all other people interested in agricultural situation of the country.



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ABOUT THE BOOK

Potato is considered world's number one non- grain food commodity. It holds promise for food and nutritional security in the scenario of ever growing human population, due to its inherent efficiency in producing high dry matter, energy and edible protein per unit area per unit time. It provides carbohydrates, minerals, vitamin C, a number of B group vitamins, high quality proteins and dietary fibre. People of several European and Latin American countries consume potato as a staple food. Thinkers and planners in developing countries like India recognize potato as the potential food crop for ensuring food and nutritional security to fight hunger and malnutrition. A wealth of information on different technical aspects of potato crop and its cultivation under sub-tropical climate has been generated from the concerted research efforts, which made India, a leader in sub-tropical potato production.

This book is organized under 33 distinct chapters, covering almost all aspects of potato technologies that includes The past, present, and future of potato; organic potato production; potato based cropping system; micro irrigation system in seed potato production; nutrient management; crop modelling, remote sensing and GIS (Geographical Information System); farm mechanization; decision support system for potato production; diseases and pests management; breeding for biotic and abiotic stresses; physiology, storage, processing; hi-tech seed potato production including aeroponics; potato seed certification; frontier areas like biotechnology, economics of seed potato production, marketing and export of potato and diffusion & adoption of potato technologies in India etc. We hope that this book will evoke interest among people in all areas of agriculture and even those outside the field and would further give an ascent to potato in our country. We have tried our best to make this book error- proof, however, we hold ourselves fully responsible for any un-intended errors that might have crept in during its compilation and / or printing. We are grateful to Dr. S Ayyappan, Director General, ICAR and Secretary, DARE and Dr. NK Krishna Kumar Deputy Director General (Horticultural Science) for their valuable suggestions and motivation to bring out the book on "**Advances in Quality potato production and post –harvest management"**. We are confident that this document will act as a rich source of information and excellent textbook for the undergraduate and postgraduate student in potato research in the country.

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Dhiraj K. Singh

Born on 13th February ,1981, he obtained his Bachelor degree in Agriculture from Dr BS KKV, Dapoli (Maharashtra), Master and Doctoral Degree (Agril. Extension) from ICAR-Indian Agricultural Research Institute, new Delhi. He joined ICAR-Central Potato Research Institute, Shimla in the year 2010 and presently working as Scientist in Division of Social Sciences. He has more than 5 years of research experiences in the field of Agricultural Extension and Transfer of Technology. He has been associated in assessment of potato production technologies and organization of several training programmes for farmers as well as Officers of Agri./Hort. Deptt. He has published more than 30 research papers/book chapters/Technical/Extension bulletin.

Bir Pal Singh

Born on 1st july,1953, he obtained his Bachelor, Master and Doctoral degree from Aligarh Muslim University, Aligarh. He joined ICAR-Central Potato Research Institute campus, Modipuram in the year 1977 and has retired as Director, Central Potato Research Institute Shimla. He is widely travelled eminent Fungal Plant pathologist and has over 38 years of research experiences in potato crop . He has also been member of Board of trustee of International Potato Centre, Lima-Peru and has guided several Ph.D students, organised/coordinated International/National conferences/ seminars and contributed more than 280 research article/reviews/book chapters/technical bulletins etc. He is recipient of several award and Honour like Hari Om Ashram Trust award, ICAR Award for outstanding interdisciplinary team research in Agriculture and allied sciences and Late LC Sikka Endowment award.

Jeevalatha A

Born on 27th October, 1979, she obtained her Bachelor degree from Tamil Nadu Agricultural University, Coimbatore; Master from Acharya N. G. Ranga Agricultural University, Hyderabad and Doctoral from Tamil Nadu Agricultural University, Coimbatore with CSIR-JRF fellwoship. She joined the Central Potato Research Institute in the year 2009 and presently working as a scientist (ss) in the Division of Plant Protection at CPRI, Shimla. She has above 6 years of research experiences, especially in the field of potato virology. She was involved in development of lateral flow immune assay kits, PCR/RT-PCR and qRT-PCR assay protocols. She also worked on recombinant coat protein based antibody production, transgenics, whole genome analysis and transcriptomics of potato pathogens. She guided four M.Sc students for their thesis work, published papers in reputed journals and visited Asia Pacific Centre, Shanghai for training on micro array system and Next Generation Sequencing. She has also received the IPA-Kaushalya Sikka Memorial Award (2009-2013) for her team research in potato virology.

Baswaraj Raigond

Born on 25th January, 1980, he obtained his Bachelor degree (B.Sc. Agri.)

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Bir Pal Singh

Contents

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops after wheat, maize and rice, contributing to food and nutritional security in the world. This tuber crop of the family solanaceae has about 200 wild species. It originated in the high Andean hills of South America, from where it was first introduced into Europe towards the end of 16th

century through Spanish conquerors. There the potato developed as a temperate crop and was later distributed throughout the world largely as a consequence of the colonial expansion of European countries. It was introduced to India by early 17th century probably through British missionaries or Portuguese traders.

Potato: The Crop and the Food

Potato is an annual, herbaceous, dicotyledonous and vegetatively propagated plant. It can also be propagated through botanical seed known as True Potato Seed (TPS). The potato tuber is a modified stem developed underground on a specialized structure called stolon. It contains all the characteristics of a normal stem like dormant bud (eye) and scaly leaf (eyebrow). Potato tuber is a bulky commodity which responds strongly to its prevailing environment thus needs proper storage.

Potato is a highly nutritious, easily digestible, wholesome food containing carbohydrates, proteins, minerals, vitamins and high quality dietary fibre. A potato tuber contains 80 per cent water and 20 per cent dry matter consisting of 14 per cent starch, 2 per cent sugar, 2 per cent protein, 1 per cent minerals, 0.6 per cent fibre, 0.1 per cent fat, and vitamins B and C in adequate amount. Thus, potato provides more nutrition than cereals and vegetables. Keeping in view the shrinking cultivable land and burgeoning population in India, potato is a better alternative to deal with the situation.

Potato in India

In Europe the potato crop is grown in summer having long photoperiod of up to 14 hours and the crop duration of 140-180 days. The potato in Indian plains is, however, grown in completely contrasting situations. Nearly 85 per cent of the crop is grown during winters having short photoperiod (with about 10-11 hours sunshine) and the crop duration is also limited to 90-100 days because of short and mild winter. The mornings usually have fog, which further reduces the sunshine hours posing severe constraints on photosynthetic activity. Besides, the post-harvest period consists of long hot summer, which creates storage problems.

All these problems called for suitable varieties and technologies for growing potatoes under the sub-tropical conditions of India. This necessitated to initiate indigenous potato research and development programmes, and accordingly the Central Potato Research Institute (CPRI) came up in 1949 at Patna. The headquarters was later on shifted to Shimla in order to facilitate hybridization and maintenance of seed health. In 1971 the All India Coordinated Research Project (AICRP) on potato was initiated under the aegis of the Indian Council of Agricultural Research (ICAR) at the CPRI with an objective to coordinate potato research and development in the country across diverse agro-ecological regions. The success story of over five decades of potato research in India is phenomenal. Compared to the area, production and productivity in 1949-50, the increase over this period is 832 per cent, 2963 per cent and 345 per cent, respectively (Table 1). India now ranks third in potato area (1.99 million ha) and second in production (45.34 million tonnes) in the world with an average yield of 222.7 q/ha.

Table 1: Area, Production & Yield of Potato in India

Year	*Area (million ha)*	*Production (million tones)*	*Yield (q/ha)*
1949-50	0.239	1.543	65.9
1959-60	0.362	2.733	75.5
1969-70	0.496	3.913	78.9
1979-80	0.685	8.327	121.5
1989-90	0.940	14.771	157.1
1999-00	1.340	24.713	184.4
2003-04	1.270	23.123	182.0
2005-06	1.400	23.90	170.6
2006-07	1.482	22.09	149.0
2007-08	1.553	28.47	183.3
2008-09	1.810	28.58	157.8
2009-10	1.84	36.58	199.2
2010-11	1.86	42.34	227.0
2011-12	1.90	41.48	217.5
2012-13	1.99	45.34	222.7

It was only because of indigenously developed technologies that potato in India has shown spectacular growth in area, production and productivity during the last five decades. The major achievements of potato research in India are as under:

Varietal Improvement

So far 50 potato varieties have been bred for different agro-climatic regions of the country with 28 varieties alone for north Indian plains. Varieties have also been developed for north Indian hills and other special problem areas viz. Sikkim, north Bengal hills and south Indian hills. Of the 50 varieties developed, 19 possess multiple resistance to different biotic and abiotic stresses. Besides, nine varieties are suitable for processing purposes. These are Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Himsona, Kufri Frysona, Kufri Jyoti, Kufri Chandramukhi, Kufri Lauvkar and Kufri Surya. All these varieties fall in three maturity groups, i.e. early (70-80 days), medium (90-100 days) and late (110-120 days).

The potato varieties developed by CPRI are grown not only in India but also in several neighbouring countries. The variety Kufri Chandramukhi is grown in Afghanistan, Kufri Jyoti in Nepal and Bhutan, and Kufri Sindhuri in Bangladesh and Nepal. Besides, five Indian hybrids are also commercially grown in Sri Lanka, Madagascar, Mexico and Philippines.

Seed Plot Technique

This technique was developed in 1970s to enable healthy seed potato production in the sub-tropical Indian plains under low aphid period. This technique aided by bio-technological approaches for virus elimination, micro-propagation and effective viral diagnostics has sustained the National Potato Seed Production Programme by producing about 2600 tonnes of breeder's seed annually. This breeder's seed is further multiplied to about 4,32,000 tonnes of certified seed by the State Departments of Agriculture/ Horticulture. Thus, the country saves about 484 million US dollars because most Asian countries like Pakistan, Bangladesh and even China continue to import seed potatoes from Europe.

The decentralization of potato breeding from hills to plains in India through the seed plot technique enabled the development of varieties suited to different agro-climatic regions of the country. The area under seed potato production also increased by 12 times and enabled the availability of seed potato throughout the country in proper physiological state.

Tissue Culture

Efforts are being made to improve seed health standards and reduce the time required for production of breeder's seed by employing *in vitro* techniques of meristem culture and micro-propagation. Presently, about 5 per cent of Breeder's seed production programme is fed annually by microtubers produced through tissue culture. It is proposed to produce 100 per cent of breeder's seed through tissue culture propagated material in the years to come.

Agro-techniques

The development of package of practices for potato production in different agro-climatic zones has helped in improving potato productivity in these zones. The potato crop is input intensive and requires optimum cultural practices for achieving higher productivity. Optimum cultural practices depend on delineated phenological phases of crop growth and development viz. pre-emergence, emergence to tuber initiation, tuber initiation to tuber bulking and tuber bulking to termination of bulking.

The cultural practices are adjusted in the Indian plains in a way so that tuber initiation and development coincide with the period when night temperature is less than 20°C and day temperature is below 30°C. The phenological phase of tuber initiation to tuber bulking is mainly conditioned by nutrition and moisture. For this purpose, fertilizer and irrigation requirement in different agro-climatic zones have been worked out through multi-locational trials under AICRP (Potato). Termination of tuber bulking coincides with onset of foliage senescence. By manipulating the nutrition and moisture, the foliage senescence is delayed for ensuring continuation of linear tuber bulking phase resulting in higher yield.

Several profitable potato-based inter-cropping and crop rotations have also been identified for different regions of the country. Potato can be profitably intercropped with wheat, mustard and sugarcane. These cropping systems have helped in the maintenance of soil fertility and have improved the fertilizer economy, crop yield and gross returns. Besides, potato cultivation has also been mechanized in selected regions through the fabrication and development of cost-effective tools and implements.

Plant Protection

Effective management practices have been devised for the major potato diseases and insect-pests in India. Late blight is the most notorious disease of potato which occurs almost every year in the hills and plains. Besides chemical control measures, several late blight resistant varieties have been developed. Potato varieties have also been bred which possess resistance to wart and cyst nematodes. Cultural and biological control measures have also been developed to control the diseases and insect-pests. The development of late blight forecasting systems for hills and plains has enabled the early warning mechanism for the appearance of late blight disease.

Storage

In European countries, the potato crop is grown in summer and the main storage season is the cold winter. However, in India, 85 per cent of potato is produced in winter and stored during long hot summer. This requires storage of potatoes in cold stores at 2-4^{0}C, which involves substantial cost. It also leads to accumulation of reducing sugar in the potato tubers resulting in sweetening of potatoes.

However, there are a number of traditional low-cost and non-refrigerated storage structures (essentially based on evaporative or passive evaporative cooling) in use in India with varying degrees of success. These traditional structures have been studied, validated and popularized for particular regions. In non-refrigerated storages, use of sprout suppressants have also been popularized to prevent excessive weight loss and shrinkage due to sprouting. The CIPC (isopropyl-N-chlorophenyl carbamate) is the most effective sprout inhibitor when applied @ 25 mg a.i. per kg tubers.

Processing and Value Addition

In addition to raw consumption, potatoes can be processed into several products like chips, French fries, cubes, granules and canned products. The primary determinants for potato processing include high dry matter and low reducing sugar content. A dry matter content of more than 20 per cent is desirable for chips, French fries and dehydrated products. Similarly, a reducing sugar content in tubers up to 100 mg/100g fresh weight is considered acceptable for processing. Nine varieties viz. Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Jyoti, Kufri Chandramukhi, Kufri Lauvkar, Kufri Surya and Kufri Himsona, Kufri Frysona have been developed for processing purposes. In India, potato processing in organised sector started about a decade ago, and the recent proliferation of this sector mainly results from the development of three indigenous potato processing varieties, viz. Kufri Chipsona-1 and Kufri Chipsona-3 by CPRI. These two varieties are now being used by the industries for processing into chips and French fries.

Computer Applications

Simulation modelling is now widely used in various disciplines to work out tactical decisions. CPRI has developed INFOCROP-POTATO model to simulate the potato growth and development, to determine the best growing period, to optimise management practices under different agro-ecological regions, and to forecast the accurate yield estimates. An expert system (Potato Pest Manager) has also been developed for decision support with respect to identification and management of diseases and insect-pests.

Transfer of Technology

Research achievements alone are not adequate to gauge the success of an agricultural system. The research information needs to be assessed and refined under various bio-physical and socio-economic situations through adaptive research before it is labelled as a technology. In this regard, the multi-locational trials under AICRP (Potato) and the TOT projects undertaken by CPRI such as Operational Research Project (ORP), Lab-to-Land Programme (LLP), Tribal Area Development (TAD) programme and Institution-Village Linkage Programme (IVLP) proved landmark in getting feedback from the field and development of appropriate technologies.

Transfer of technology to the end users is a complex task which consists of a number of components and dimensions. One of the important components is proper linkage between technology generating system and the client system. In this regard, innovative approaches like need assessment, participatory planning and implementation, and direct scientist-farmer interface facilitated faster dissemination of technologies and consequent adoption by the farmers/clients. The CPRI has build up linkages with farmers through demonstrations, trainings, Kisan Melas, potato school on All India Radio, supply of literatures and other extension activities. Besides, studies have been conducted to measure the socio-economic impact and constraints in transfer of potato technology.

Potato Export

Although India contributes 12% to the total world potato production, its 0.7% share in world's potato export is quite insignificant. Indian potatoes are truly free from the prohibited disease like wart, black scruf, and pests like tuber moth and nematodes, which are the barometer for phytosanitary standards. India has also the natural advantage of exporting fresh table potatoes during January to June when supply from European countries dwindles. It can also supply fresh potatoes round the year because India has diverse agro-climates and potato is grown throughout the year in one or the other part of the country.

Potato has a good future in India under the changed scenario of global economy. Globalisation has resulted in many developing countries becoming much more integrated into the international potato trade. With the phasing out of quantitative restrictions on agricultural commodities, the imports and exports of potato would be based on the differences in price and production cost between the importing and exporting countries involved. Due to low production cost in the country as a result of availability of cheap labour, India will have competitive advantage in the international potato trade.

Potato in the New Millennium

With the improvement in the living standard of people in India, the dietary habits will shift from cereals to vegetables. Under such a situation it is estimated that India will have to produce 49 million tonnes of potato by 2020. This target could be achieved only by improving the productivity level. The productivity of potato in India is quite low (183.3q/ha) as compared to that of Belgium (490q/ha), New zealand (450q/ha), UK (397q/ha) and USA (383q/ha). This is due to shorter crop duration in India. There is a wide ranging variations in the agro-ecological setting of different parts of the country, which results in wide variations in the productivity levels of different states (Table 2). Therefore, all our efforts may be put in to develop location-specific and problem-specific varieties and technologies.

Table 2: Statewise Area, Production & Yield of Potato in India during 2012-13*

States	Area ('000 Hectares)	Production (' 000 Tonnes)	Yield (q/ha)
Assam	99.77	975.27	97.75
Bihar	322.5	6640.5	205.93
Gujarat	81.27	2499.7	307.58
Haryana	29.47	676.0	229.39
Jharkhand	47.21	659.6	139.72
Karnataka	44.40	698.3	157.27
Madhya Pradesh	108.87	2299.0	211.17
Punjab	85.25	2134.3	250.12
Uttar Pradseh	603.76	14430.2	239.01
West Bengal	386.61	11591.3	299.82
Others	183.15	2741.2	149.67
All India (Total)	1992.22	45343.5	227.60

Source: Dept. of Agriculture and Cooperation (Horticulture Division)

Most of the people in India have either no knowledge or wrong notions about the nutritive value of potato. With low fat (0.1 per cent) and calorie contents, it does not cause obesity. Due to misconception the potato consumption, the per capita consumption of potato in India is only about 16 kg/year. On the other hand, the per capita consumption in Europe is 121 kg/year and as high as 136 kg/year in Poland. Hence, there is ample scope for improving the consumption of potatoes in India. For this purpose, a publicity compaign like eggs and milk needs to be launched through mass media such as television, radio and newspapers highlighting its nutritional value. Moreover, the possibility of using surplus potatoes as animal feed also needs to be explored.

The surplus potatoes in a season are stored in cold stores at 2-4°C in the country. This makes stored potatoes just unfit for processing and loses preference for table purposes due to accumulation of sugar content. To avoid sweetening potato are required to be stored at 10-12°C. Only seed potatoes should be cold stored at 2-4°C. This would release atleast 60 per cent of cold storage space that can be converted to store potatoes for processing and table purposes at 10-12°C with CIPC treatment leading to considerable savings on energy and storage costs.

Processing is a fast growing sector in the potato world economy. Due to increased urbanization, rise in per capita income and expanding tourism, the demand for processed potato products in India and international market has risen at a fast pace. However, in India, processing of potatoes constitutes less than 2 per cent of the total annual production as compared to 60 per cent in USA, 47 per cent in the Netherlands and 22 per cent in China. Hence, there is great scope to expand the potato processing industries in India and also to diversify the processing to produce flour, cubes, granules, flakes and starch.

Under the changed global scenario, the potato production and utilisation pattern is changing very fast. These changes harbour many opportunities which could be tapped through effective extension system. The use of modern information and communication technologies (ICT) to create awareness is highly pertinent in the contemporary times. This would enable us to reach directly to the end users by eliminating the intermediate channels which create distortion of information. Efforts are also needed to devise market-based extension strategies in order to promote entrepreneurship among potato growers with regard to potato production and marketing.

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2

POTATO GROWTH IN RELATION TO ABIOTIC FACTORS

P.M. Govindakrishnan

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Phasic growth of potato

Four growth phases have been recognised in potato. These are: establishment phase, growth of autotrophic organs predominantly leaf, overlapping period of leaf growth and induction of storage organs, and lastly the period of predominantly storage organ growth (Kawakami, 1978). The climatic requirements in the different phases vary and depending upon the prevalent conditions, the onset, duration and the growth accrued in the different growth phases is determined. The ecophysiological factors affecting the growth and development in each of these phases is discussed briefly below to serve as a framework to develop agrotechniques.

Establishment Phase

Quick establishment is desirable especially when the duration of the growing season is short so that the plants become autotrophic early and there is sufficient time for the other growth phases to exploit the available resources. Normally non-dormant tubers from the previous season are used as seed in potato. The extent of sprout growth on the seed tubers varies depending upon its physiological age. Physiological age is measured by the accumulated day degrees above a base temperature (normally 4^0C) from the end of dormancy till the end of storage and is a method of manipulating the growth and development of the crop. The process of advancing sprout growth is called pre-sprouting and is achieved by exposing the seed tubers to elevated temperatures for different durations before planting.

Physiologically young tubers take relatively longer time for emergence than the well sprouted ones. Planting of sprouted tubers besides leading to quick emergence also results in a uniform crop with more stems/hill. However, presprouting is beneficial only if seed is planted without damage to its sprouts. For this purpose sprout elongation needs to be retarded so that they become robust. This is achieved by exposing the seed tubers to diffused light. Muthani et al (2014)

Temperature, especially soil temperature also affects the establishment phase. The optimum temperature for emergence has been reported to be between 22-24°C (Sale, 1979) and the emergence rate increases linearly with increase in temperature. Temperatures below 20^0C delayed sprout growth and in such situations plastic mulch can increase the soil temperature which benefits by advancing emergence by 3-5 days. Higher than the optimum temperatures also reduce sprout growth. In such cases treatments that reduce soil temperature are beneficial for fast emergence and early canopy cover.

Autotrophic Organs Growth Phase

As soon as the plants become autotrophic, haulm growth predominates. It has mainly two components *viz.* stems and leaves which together affects the number of leaves, the duration and rate of leaf growth. These factors in turn affect the amount of incident radiation intercepted by the plants which consequently determines the yield. Ground cover duration is positively correlated with yield because yield is a product of intercepted radiation and radiation/light use efficiency. Early establishment of complete canopy cover as well as its continuance for a longer period ensures greater interception of radiation leading to higher yield.

The production of stems is affected mainly by the age and size of the seed tubers and temperature. The relation between stem elongation and temperature is almost linear upto 35^0C (Manrique, 1990) and is stimulated by high day and low night temperatures while high night temperature promotes branching (Moreno, 1985).

Leaf growth is also affected by physiological age as well as size of the seed tubers, day length, temperature, moisture and nutritional status. The leaf area attained is a function of the rate of leaf appearance, their number and individual leaf extension rate. As regards the effect of temperature, leaf growth is affected both by high as well as low temperatures. Low temperatures reduce the overall growth rate of the plants and consequently production of new leaves and the rate of their expansion is slow. The rate of leaf appearance is linearly correlated with temperature in 9-25^0 C range and no further increase occurred beyond 25^0 C (Kirk and Marshall, 1992) while 25^0 C was found to be the optimum for leaf expansion also (Benoit et al., 1983).

At very high temperature the leaves do not expand fully thereby reducing light interception. Prange et al. (1990) observed that though the leaf area was less under warm conditions, the dry weight of the leaves was not affected indicating that the leaf expansion is reduced. Therefore, genotypes grown in hot conditions have lower specific leaf area (Midmore and Prange, 1991). As regards day length, long days also increase leaf area (Lemaga and Caesar, 1990)

Phase of Overlapping Period of Leaf Growth and Induction of Storage Organ

Low temperature especially at night is required for tuber initiation. Night temperatures above 21^{0}C hamper tuber initiation (Pushkarnath, 1976). From studies on exposing different plant parts to differential temperatures, Slater (1968) showed that tuber initiation occurred earlier when shoots were exposed to low night temperature and still earlier when both shoot and root were exposed to low night temperature studies show that the potential for induction of the plants to tuberise is affected principally by air temperature but the expression of the signal can be blocked by high soil temperature. The response to temperature is, however, modified by day length and light intensity (Borah and Milthorpe, 1962; Bodlaendar, 1963) and long days and low light intensity promote haulm growth but delays tuber initiation.

Phase of Tuber Growth

The accumulation of photosynthates in the tubers is determined by the rate of bulking and its duration. Initially bulking is slow but soon it attains a constant rate during which yield increases linearly. During the linear bulking period minor variation in environmental conditions does not affect the bulking rate significantly. However, with the onset of foliage senescence the bulking rate decreases. The rate of translocation of photosynthate into storage organs is determined by temperature. Plants growing under warm conditions are taller with higher stem to leaf and lower tuber to stem dry matter ratios (Ben Khedhar and Ewing, 1985). Only 50 percent of the assimilates produced get translocated into the tubers at 28^0 C, while at 18^0 C more than two thirds of the assimilates get translocated (Randeni and Caesar, 1986). Higher dry matter allocation to the stems under warm conditions was also observed Prange et al., (1990) and Manrique and Bartholomew (1991). Thus at higher temperature, tops get priority over tubers for assimilates leading to increased haulm growth and reduced tuber yield. Pushkarnath (1976) reported night temperature between 12-18^0C to be ideal for high yield.

As regards the effect of radiation in terms of, day length affects the phase growth through its effect on time of tuber inihation which is reported to occor early under short day conditions. The biomass production is a function of amount rediation and the production of biomass per unit of intercepted radiation also ealled radiation use efficiency (RUE). RUE of potato is around 1.25 g/mj and is affected by stressess due to temperature, nitrogen, crop age etc. Daylength also affects the partitioning of biomass which is reported to be higher under short day conditions.

As regards the other climatic elements viz, relative humidity etc, they affect the yield potential and the incidence of pest and disease scenario but their direct effect on growth and development of the crop has not been extensively studied.

Suggested readings

Ben Khedher, M. and E.E. Ewing (1985). Growth analysis of eleven potato cultivars grown in greenhouse under long photoperiods with and without heat stress. *American Potato Journal* 62:537-554

Benoit, G.R., C.D. Stanley, W.J. Grant and D.B. Torry (1983) potato top growth as influenced by temperatures mes. potato. J., 60:489-502

Bodlaender, K.B.A. (1963). Influence of temperature, radiation and photoperiod on development and yield In *The Growth of the Potato*. Eds. Ivins, J.D. and Milthorpe, F.L. Butterworths, London. pp. 328.

Borah, M. N. and Milthorpe, F.L. (1962). Growth of the potato as influenced by temperature. Indian Journal of Plant Physiology. 5:53-72.

Burton W.C. (1981), Challenges by stress physiology in potato. Amar. potato. J., 58:3-14

Kawakami, K. (1978) Physiology of yield of underground storage organs. In U.S. Gupta (ed) *Crop Physiology*. New Delhi. Oxford and IBH pp 269 – 309.

Kirk, W.W., and B. Marshall. (1992). The influence of temperature on leaf development and growth in potatoes in controlled environments. *Annals of Applied Biology* 120: 511-525.

Lemaga, B., and K. Caesar. (1990). Relationships between numbers of main stems and yield components of potato (*Solanum tuberosum* L. cv. *Erntestolz*) as influenced by different day lengths. *Potato Research* 33: 257-267.

Manrique, L.A. (1990). Growth and yield of potato grown in the green house during summer and winter in Hawaii. *Communications in Soil Science and Plant Analysis* 21(3-4): 237-49.

Manrique, L.A. and Bartholomew, D.P. (1991). Growth and yield performance of potato grown at three elevations in Hawaii II Dry matter production and efficiency of partitioning. *Crop Science* 31: 367-372.

Muthari J.J., J.N. Kabira, D. Kipkoech, G.O. Abong and J.H. Nderitu (2014). Yield performance of potato seed tubers after storage in a dittused light store (OLS). J. Agricultural Sciences, (C1):21-28

Midmore, D.J. and R.K. Prange (1991) Sources of heat tolerance amongst potato cultivars, breeding lines and solanum species. *Euphytica* 55: 235-245.

Moreno, U, (1985). Environmental effects on growth and development of potato plants. In P.H. Li (Ed) *Potato Physiology* Academic Press Inc London 481-501.

Prange, R.K., K.B., Mc Rae, D.J Midmore,. and R. Deng. (1990). Reduction in potato growth at high temperature : Role of photosynthesis and dark respiration. *American Potato Journal* 67: 357-370.

Pushkarnath. (1976) Potato in Sub tropics. New Delhi, India, Orient Longman, 289p.

Randeni, G. and K. Caesar, (1986). Effect of soil temperature on the carbohydrate status in the potato plant (*S. tuberosum* L.). *Journal of Agronomy and Crop Science* 156: 217-224.

Sale, P.J.M. (1979). Growth of potatoes (*Solanum tuberosum* L) to the small tuber stage as related to soil temperature. *Australian Journal of Agricultural Research* 30: 667-675.

Slater, J.W. (1968). The effect of night temperature on tuber initiation of the potato. *European Potato Journal* 11: 14-22.

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3

INDIAN TABLE & PROCESSING POTATO VARIETIES FOR DIFFERENT AGRO-CLIMATIC REGIONS

Vinod Kumar, Vinay Bharadwaj and Rajendra Singh

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Introduction

One of the most important factors governing productivity of a crop is the 'variety'. Thus breeding of improved cultivars is of paramount importance. Variety development, however, is a continuous process as new biotic and abiotic stresses continue to arise and the variety previously resistant or tolerant to such stresses may become susceptible due to the evolving of new strains/races of the pathogens or insects and also due to emerging abiotic factors. Performance of a variety depends on the agro-climatic conditions under which it is grown and also the purpose for which it has to be used. Thus the CPRI has been developing potato varieties suitable for cultivation under varying agro climactic zones of the country and also for different purposes i.e. table and processing.

Ecological zones and varietal requirements

India has diverse soil types and agro-climatic conditions. Successful potato cultivation requires night temperatures of 15-20°C with sunny days. Indian sub-tropical plains offer optimum conditions for potato cultivation, where 85-90 per cent of potatoes are grown during short winter days from October to February. The hills account for less than 5 per cent of the total potato production where the crop is grown during long summer days from April to September/October. The plateau regions of South-eastern, central and peninsular India constitutes about 6 per cent area where potato is grown mainly as rainfed or irrigated winter crop. On the basis of the diverse soil, climate and other agronomic features, the potato growing areas in India can be divided into eight zones (Table-1). These zones lay in two major potato growing areas i.e. north Indian hills and north Indian plains, while southern and north Bengal and Sikkim hills and plateaus are three special problem areas. The varietal requirements of these regions are given in Table 1.

Table 1. Potato growing zones in India and its varietal requirements

Zone	Varietal requirements
North-western hills	Long day adapted , highly resistant to late blight
Central hills	Long day adapted, highly resistant to late blight and bacterial wilt.
North-eastern hills	Long day adapted , highly resistant to late blight and bacterial wilt.
North-western plains	Short day adapted, early bulking, heat tolerance and moderate resistant to late blight, slow rate of degeneration. Tolerance to frost is an added advantage.
West-central plains	Short-day adapted, early bulking, moderate resistant to late blight and slow rate of degeneration. Tolerance to frost is an added advantage.

North-eastern plains	Short day adapted, early bulking, moderate resistant to late blight and slow rate of degeneration. Red skin tubers are preferred in some areas.
North Bengal hills and Sikkim	Medium maturity, resistance to late blight and immunity to wart. Red skin potatoes are preferred.
Plateau region	Early bulking, ability to tuberize under high temperatures, resistance to bacterial wilt, mites & potato tuber moth and slow rate of degeneration.
Southern hills	Long day adapted, early bulking, resistant to late blight and cyst nematode.

Quality attributes of potato for table and processing purposes

Marketability of potato produce is a function of its quality. Appearance, colour, size, shape and defects decide the quality for fresh potato. Total solids or dry matter is highly correlated with texture. On the basis of dry matter and texture, potatoes can be used for different purposes. A mealy texture is associated with high solids and a waxy texture with low solids. Mealy textured varieties are usually considered best for baking or French fries. Varieties with waxy texture are more often used for boiling or as salad. In India, mostly white, yellow or red skinned varieties with shallow or medium eyes are the choice of the consumers. Interest now seems to be shifting towards yellow fleshed varieties. More yellow flesh color is indicative of the higher level of vitamin A. Yellow fleshed varieties have a richer flavour than traditional white fleshed varieties and exhibit less darkening after cooking than some red skinned varieties. Specific characteristics of potato varieties for different purposes are listed in Table 2.

The varieties should be widely adaptable, resistant to major diseases and pests, possess good keeping quality and can be used either for table or processing or both. Varieties should produce attractive, medium sized, shallow eyed, white, yellow or red skinned tubers, less physical injuries with good keeping and nutritional quality. For processing purposes varieties should possess high dry matter, low reducing sugars and less tuber defects for producing quality processed potato products. Low glycoalkaloids content and ability to withstand cold induced sweetening are added advantages.

Table 2. Requirement of potato varieties for different purposes

Characters	**Use requirements**			
	Table potatoes		**Processing**	
	Boiled	**Baking**	**French fries**	**Chips**
Tuber shape	Long-oval/round	Long-oval/round	Long-oval (>3 inch)	Round (2.5-3.3 inch)
Skin color	White/yellow/red	White/yellow /red	White/ yellow	White/ yellow
Eye depth	Shallow/ medium	Shallow/ medium	Shallow	Shallow
Flesh color	White/yellow	White/yellow	White/ yellow	White/ yellow
Texture	Waxy	Mealy	Mealy	Mealy
Uniformity	High	High	High	High
Defects	Minimum	Minimum	Minimum	Minimum
Dry matter (%)	18-20	>20	>20	>20
Reducing sugars*	-	-	<200mg	<100mg
Phenols	Less	Less	Less	Less
Glycoalkaloids *	< 15mg	< 15mg	< 15mg	< 15mg
Keeping quality	Good	Good	Good	Good
Damage resistance	High	High	High	High

*mg/100g fresh tuber weight

Potato Improvement

Basics: Cultivated tuber-bearing potato is a clonally propagated crop and maintained over generations through tuber seeds. The plant is tetraploid (2n=4*x*=48) with a complex tetrasomic inheritance combined with high degree of heterozygosity. Pure line breeding is not practiced in potato owing to heterozygosity and high degree of pollen sterility. Selfing of fertile clones results in inbreeding depression. Conventional potato breeding within the ploidy levels involves hybridization between superior clones followed by selection. The vegetative mode of propagation offers distinct advantages. It leads to the perpetuation of a specific gene-combination with precision over generations, thus allowing the breeders to select and maintain, with ease, outstanding segregants in breeding programme and obtain indefinite number of genetically identical individuals. Various hybridization methods like distant crossing, some time followed by back-crossing, bi-parental cross, multiple cross and poly-cross are usually utilized in potato breeding. Besides the above traditional approaches, non-conventional methods are also used in potato breeding and germplasm improvement programmes taking advantages of diversity in reproductive biology like synaptic mutants, unilateral sexual polyploidization, haploidy, stylar barriers, endosperm barriers, endosperm balance number (EBN) etc. Many a times, di-haploids are evolved for production of homozygous lines or for pre-breeding at diploid level for transferring desired traits through transgression.

Early attempts: From its initial status of a garden vegetable in Western India in early 17th century, potato cultivation spread to diverse eco-zones in India over the next two and a half centuries. Early potato introductions in India were *S. tuberosum* ssp. *andigena*. There was enormous confusion regarding the identity and nomenclature of these introductions as these were known by different local names in diverse dialects. As a result, during the initial periods of potato research in India, efforts were directed towards identification of such local "*desi* varieties". Based on the studies on various morphological features, duplicate samples were eliminated, and subsequently a few samples were got identified with the help of Potato Synonym Committee, National Institute of Agricultural Botany, England. These efforts led to the identification and characterization of 16 non-European varieties, which came to be known as *desi* or indigenous samples or varieties. These indigenous samples represent survivors of earlier introductions and chance selections in the Indian agro-climates. A list of these indigenous varieties with their salient attributes is presented in Table 3.

Table 3: Indigenous potato varieties/samples in India

Varieties/samples	Salient features
Agra Red, Chamba Red, Coonoor White, Coonoor Red, Darjeeling Red Round, Desi, Dhantauri, Gola Type A, Gola Type B, Gola Type C, Phulwa, Phulwa Purple Splashed, Sathoo, Red Long Kidney, Shan and Silbilati	Heat and drought tolerant, therefore cultivated predominantly in the Indian plains; tolerant to degenerative viruses; due to physiological advantages can be stored in country stores during hot Indian summers

Source: Pushkarnath (1969). *Potato in India-Varieties,* Indian Council of Agricultural Research, New Delhi, 493pp.

Among these, Phulwa, Darjeeling Red Round and Gola, were found to be the most popular ones. These types though no more the mainstream varieties under cultivation now in our country, yet they enjoy consumer preference in small pockets atleast in Eastern India. Besides the indigenous, 38 European varieties were identified from whatever were under cultivation in India before independence. These are referred to as exotic varieties. Not all exotic varieties, however, were commercially important. Only 16 of these had some commercial value (Table 4). These exotic European varieties were naturally long-day adapted and, therefore, their cultivation was restricted to the hills of the Indian sub-continent.

Table 4: Exotic potato varieties in India

Varieties	Salient features
Ally, Arran Counsal, Ben Cruachan, Craig's Defiance, Dunbar Cavalier, Great Scot, Italian White Round, Late Carman, Magnum Bonum, Majestic, Northern Star, President, Raeburn's Gregor Cups, Red Rock, Royal Kidney and Up-to-Date	Long-day adapted, therefore suitable for the Indian hills only; multiplication was characterized with progressive accumulation of degenerative viral diseases; physiological limitations on tuber storage and utilization in hot Indian summers

Source: Pushkarnath (1969). *Potato in India-Varieties,* Indian Council of Agricultural Research, New Delhi, 493pp.

National breeding Programme

During earlier phase varietal improvement for potato was a challenge to breeders in India because:

i) the introduced European varieties were all long day adapted,

ii) their multiplication in Indian conditions was characterized by progressive accumulation of viral diseases resulting in concomitant decrease in yield, and

iii) limitations in tuber storage and utilization in hot and humid Indian conditions.

The task was further complicated by unique reproductive features of the plant since it flowers only under long days. This condition is available in the higher elevations and hence potato hybridization was initiated at Kufri

(Shimla), Himachal Pradesh. Initial attempts for breeding high yielding potato hybrids for sub-tropical plains and temperate hills was unsuccessful owing to quick degeneration of hill bread progenies in the plains during evaluation and also dormancy of hill potatoes. These bottlenecks did not allow any clonal evaluation in the plains during the appropriate season.

A regular potato breeding programme in India was started in 1949 by Central Potato Research Institute (CPRI). Its headquarters were shifted from Patna, Bihar, to Shimla, Himachal Pradesh in 1956. With perfection of seed plot technique in 1963, it now became possible to raise, maintain and evaluate segregating populations in the plains under disease-free low aphid periods. The hybridization continued to be done in high hills at Kufri. This approach brought in positive results from potato improvement programme and also revolutionized the potato seed production system in the country.

Indian potato varieties

Concerted breeding efforts of potato varietal improvement programmes at Central Potato Research Institute has led to development of 51 improved potato varieties for cultivation under diverse agro-climatic zones of the country. Presently 23 varieties are under cultivation and occupy nearly 95% of the total potato area in India. Prominent among them are Kufri Jyoti in the hills and state of West Bengal, Kufri Badshah in Gujarat, Kufri Bahar in Uttar Pradesh and Kufri Pukhraj in plains of India. Varieties for specific problem areas are Kufri Kanchan for Darjeeling hills where wart is a serious problem and Kufri Swarna for Nilgiri hills where cyst nematodes are serious pests. Varieties specifically suitable for processing are Kufri Chipsona-1, Kufri Chipsona-3, and Kufri Chipsona-4 for making chips and Kufri Frysona for French Fries. The salient features of some important varieties along with their distinguishing morphological features helpful in their identification are described below.

Important Table varieties

Kufri Jyoti : It is a medium maturing widely adapted variety suitable for cultivation in hills, plains as well as plateau regions of India. It is moderately resistant to early and late blight and immune to wart. It has white cream, ovoid tubers with shallow eyes and cream flesh. Its canopy is compact and stem green with red brown pigment highly scattered throughout. Leaflet is ovate, flowers are white and sprouts red-purple. It is an early bulker with slow rate of degeneration.

Kufri Bahar : It is a medium maturing variety suitable for cultivation in north Indian plains. It is immune to wart and tolerant to gemini virus. It has white cream, ovoid tubers with medium-deep eyes and white flesh. Its canopy is semi-compact and stems green. Leaflet is ovate-lanceolate, flowers are white and sprouts green. It is an early bulker.

Kufri Badshah : It is a medium maturing variety suitable for cultivation in north Indian plains as well as plateau regions of India. It is resistant to early blight, late blight and PVX. It has white cream, ovoid tubers with shallow eyes and cream flesh. Its canopy is semi-compact and stem green with red brown pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are white and sprouts red-purple.

Kufri Pukhraj : It is an early to medium maturing variety suitable for cultivation in northern plains as well as plateau regions of India. It is resistant to early blight, moderately resistant to late blight and immune to wart. It has yellow, ovoid tubers with medium-deep eyes and yellow flesh. Its canopy is semi-compact and stem green with purple pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are white and sprouts purple. It is an early bulker and suitable for low-input eco-system.

Kufri Khyati : It is an early maturing variety suitable for cultivation in northern plains of India. It is field resistant to early blight and late blight. It has white cream, ovoid tubers with medium-deep eyes and cream flesh. Its canopy is semi-compact and stem green with purple pigment lightly scattered throughout. Leaflet is ovate-lanceolate, flowers are white and sprouts red-purple. It is an early bulker and suitable for high cropping intensity.

Kufri Sadabahar : It is a medium maturing variety suitable for cultivation in Uttar Pradesh and adjoining areas. It is moderately resistant to late blight. It has white cream, ovoid tubers with shallow eyes and white flesh. Its canopy is compact and stem green with purple pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are white and sprouts red-purple.

Kufri Chandramukhi : It is an early maturing variety suitable for cultivation in northern plains as well as plateau regions of India. It has white cream, ovoid tubers with shallow eyes and white flesh. Its canopy is semi-compact and stem green with red-brown pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are red-violet and sprouts red-purple. It has very good cooking quality.

Kufri Ashoka : It is an early maturing variety suitable for cultivation in northern plains of India. It has white cream, ovoid tubers with medium-deep eyes and white cream flesh. Its canopy is semi-compact and stems green. Leaflet is ovate-lanceolate, flowers are red-violet and sprouts red-purple.

Kufri Jawahar : It is an early maturing variety suitable for cultivation in northern plains as well as plateau regions of India. It is moderately resistant to late blight and immune to wart. It has white cream, round tubers with medium-deep eyes and cream flesh. Its canopy is compact and stem green. Leaflet is ovate, flowers are white and sprouts red-purple. It has slow rate of degeneration and is suitable for inter-cropping.

Kufri Anand : It is a medium maturing variety suitable for cultivation in northern plains of India. It is moderately resistant to late blight and immune to wart. It has white cream, oblong tubers with shallow eyes and white flesh. Its canopy is semi-compact and stem green with purple pigment lightly scattered throughout. Leaflet is ovate, flowers are red-violet and sprouts red-purple.

Kufri Sutlej : It is a medium maturing variety suitable for cultivation in northern plains of India. It is moderately resistant to late blight and immune to wart. It has white cream, ovoid tubers with shallow eyes and white flesh. Its canopy is semi-compact and stem green with purple pigment lightly scattered throughout. Leaflet is ovate-lanceolate, flowers are white and sprouts green.

Kufri Sindhuri : It is a late maturing variety suitable for cultivation in northern plains of India. It is moderately resistant to early blight. It has red with stippled white cream, round tubers with deep eyes and cream flesh. Its canopy is open and stem green with purple pigment highly scattered throughout. Leaflet is lanceolate, flowers are red violet and sprouts purple. It is suitable for low-input system.

Kufri Lalima : It is a medium maturing variety suitable for cultivation in northern plains of India. It is moderately resistant to early blight. It has red, round tubers with deep eyes and white flesh. Its canopy is semi compact and stem red-purple with green pigment lightly scattered throughout. Leaflet is ovate-lanceolate, flowers are red-violet and sprouts red-purple.

Kufri Arun : It is a medium maturing variety suitable for cultivation in north Indian plains. It is moderately resistant to late blight. It has red, ovoid tubers with medium-deep eyes and cream flesh. Its canopy is semi-compact and stem red-purple with green pigment highly scattered throughout. Leaflet is lanceolate, flowers are red-violet and sprouts red-purple.

Kufri Kanchan : It is a medium maturing variety suitable for cultivation in north Bengal hills as well as Sikkim. It is moderately resistant to late blight and immune to wart. It has red, ovoid tubers with shallow eyes and cream flesh. Its canopy is semi-compact and stem red-purple with green pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are blue-violet and sprouts pink.

Kufri Girdhari : It is a medium maturing variety suitable for cultivation in Indian hills. It is highly resistant to late blight. It has white cream, ovoid tubers with shallow eyes and white flesh. Its canopy is open and stem green. Leaflet is ovate-lanceolate, flowers are white and sprouts pink.

Kufri Himalini : It is a medium maturing variety suitable for cultivation in north Indian hills. It is resistant to late blight. It has white cream, ovoid tubers with medium-deep eyes and cream flesh. Its canopy is semi-compact and stem green with red pigment only at base. Leaflet is ovate, flowers are red-violet and sprouts pink.

Kufri Lauvkar : It is an early maturing variety suitable for cultivation in plateau regions of India. It has white cream, round tubers with medium-deep eyes and cream flesh. Its canopy is semi-compact and stem green with purple pigment lightly scattered throughout. Leaflet is ovate, flowers are white and sprouts red-purple. It is heat tolerant.

Kufri Surya : It is an early maturing variety suitable for cultivation in northern plains as well as plateau regions of India. It is immune to wart. It has white cream, oblong tubers with shallow eyes and cream flesh. Its canopy is semi-compact and stem green with purple pigment lightly scattered throughout. Leaflet is ovate-lanceolate, flowers are red-violet and sprouts red-purple. It is heat tolerant.

Kufri Gaurav : It is an early maturing variety suitable for cultivation in north Indian plains. It has white cream, ovoid tubers with medium-deep eyes and white cream flesh. Its canopy is semi-compact and stem green. Leaflet is ovate-lanceolate, flowers are white and sprouts green. It is nutrient–use efficient variety.

Kufri Garima : It is an early maturing variety suitable for cultivation in north Indian plains and plateau regions. It has attractive light yellow, ovoid tubers with shallow eyes and light yellow flesh. Its canopy is compact, stem predominantly green with red-brown pigment only at base. Leaflet flower are ovate-lanceolate is white and sprouts red purple.

Kufri Lalit: It is a medium maturing variety suitable for cultivation across the eastern plain. It is field resistant to late blight. It has light red skinned, round tubers with medium-deep eyes and yellow flesh. Its canopy is compact and stems green with some purple pigment only at base. Leaflet is ovate; flowers are red-violet and sprout pink.

Important Processing varieties

Kufri Chipsona-1 : It is a medium maturing variety suitable for cultivation in north Indian plains. It is resistant to late blight. It has white cream, ovoid tubers with shallow eyes and white cream flesh. Its canopy is semi-compact and stem green. Leaflet is ovate-lanceolate, flowers are white and sprouts green. It has high dry matter and low reducing sugars and produces light colour chips.

Kufri Chipsona-3 : It is a medium maturing variety suitable for cultivation in north Indian plains. It is resistant to late blight. It has white cream, ovoid tubers with shallow eyes and white flesh. Its canopy is semi-compact and stem green with red-brown pigment only at base. Leaflet is ovate-lanceolate, flowers are white and sprouts red-purple. It is suitable for making chips as well as French Fries because it has high dry matter and low reducing sugars.

Kufri Chipsona-4 : It is a medium maturing variety suitable for cultivation in Karnataka, West-Bengal and Madhya Pradesh. It is field resistant to late blight. It has white cream, round tubers with shallow eyes and white flesh. Its canopy is compact and stem green with red-brown pigment lightly scattered throughout. Leaflet is lanceolate, flowers are white and sprouts red-purple. It has high dry matter and low reducing sugars, and thus suitable for making chips.

Kufri Frysona: It is a medium maturing variety suitable for cultivation in north Indian plains. It is field resistant to late blight and immune to wart. It has white cream, long-oblong tubers with shallow eyes and white flesh. Its canopy is open and stem green with purple pigment highly scattered throughout. Leaflet is ovate-lanceolate, flowers are red-violet and sprouts red-purple. It has high dry matter and low reducing sugars and suitable for making French Fries.

Variety improvement programme of CPRI for over 50 years has been instrumental in fourteen-fold increase in total production and three-fold increase in yield per unit area in the country. Many Indian varieties have found favour in foreign countries as well. These are: I 654 as CCM-69.1 in

Mexico, I-822 as cv.Krushi in Sri Lanka, I-1035 as cvs. Montonosa in Philippines and Mailaka in Madagascar, I-1039 as cvs. India in Bolivia and Red Skin in Vietnam and I-1085 as cvs Sita in Sri Lanka and BSUP-04 in Philippines. Further, Indian potato varieties enjoy a high degree of consumer preference in our neighbourhood. There is enormous scope for export of potato for seed and table use to these countries. But Indian potato varieties so far had an extremely limited evaluation on foreign soils. Therefore, a systematic study on adaptability of varieties in the Indian ocean rim countries, the middle East, S.W. Asia, CIS countries and Eastern Europe needs to be the major thrust of any further potato development programme.

Suggested readings

Gopal, J. 2006. Considerations for successful breeding. In; Gopal, J and SM Paul Khurana (eds.) Handbook of potato production, improvement and post- harvest management. Haworth's Press, New York.

Luthra, SK; SK Pandey; BP Singh; GS Kang; SV Singh and PC Pande. 2006. Potato Breeding in India. CPRI, Shimla Technical Bulletin No 74, 90p.

Kumar, Vinod; SK Luthra, Vinay Bhardwaj and BP Singh. 2014. Indian Potato Varieties and their Salient Features. Tech. Bull. No. 78 (Revised), CPRI, Shimla

4

GENETIC IMPROVEMENT FOR BIOTIC AND ABIOTIC STRESS TOLERANCE IN POTATO

Dalamu

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Introduction

Biotic and abiotic stresses pose potential threat to food and nutritional security. Yield reduction and rise in food demand risks the food security. According to an estimate 70% more food will be required by year 2050 (Hussain, 2015). Potato (*Solanum tuberosum*.L) holds the position of being the world's 3rd major food crop after rice and wheat and 8th in terms of area under cultivation (FAO statistics 2008). The major biotic stresses affecting potato are late blight, viruses (X, Y and PLRV), bacterial wilt and potato cyst nematodes. In the era of climate change abiotic stresses *viz.*, heat, drought, salinity and frost holds significance in yield reduction. Host resistance is the most effective, economical and eco-friendly management strategy to mitigate adversity of biotic and abiotic stress in any crop.

Biotic Stresses

Late blight

Late blight caused by *Phytophthora infestans* (Mont.) is one the most devastating disease of potato. Late blight resistance are of two types: (1) Vertical resistance: Such resistance is controlled by few major genes and are qualitative in inheritance. Eleven race-specific LB resistance genes (*R1* to *R11*) are identified in *S. demissum* and have been deployed in potato varieties. Pyramiding of race-specific resistance genes confers stronger and durable resistance. (2) Horizontal resistance: Such resistance is polygenic in nature and confer partial resistance. Several QTLs (quantitative trait loci) that imparts quantitative/field resistance against late blight are identified in potato. These QTLs have been identified in intraspecific crosses within *S. tuberosum*, crosses between cultivated species *S. phureja* and *S. tuberosum*, crosses between *S. tuberosum* and various potato wild species *viz.*, *S. berthaultii*, *S. microdontum*, *S. paucissectum, S. vernei* and crosses between cultivated species *S. phureja* and potato wild species *S. stenotomum*.

Viruses

Potato crop is affected by twelve different viruses. Among them, PVX, PVY and leaf roll (PLRV) are most important. Viruses have systemic distribution in the host and leads to degeneration of seed stocks. Viruses are serious menace due to transmission by tubers to subsequent generations. Viruses cause significant yield losses along with tuber defects like necrotic arcs on the tubers and deformed tubers. The complexity of virus infection increases due to mixed infection of multi viruses. The nature of resistance against viruses is either tolerance or resistance or hypersensitivity or extreme resistance or immunity. Among these, extreme resistance has been found to be durable and most effective. This type of resistance protects the plant against all strains of the virus and inheritance pattern of extreme resistance genes make it easy to transfer to cultivated varieties through conventional breeding techniques. Development of multiplex parental lines for virus resistance has the advantage of generating all or nearly all progenies carrying the resistance gene. Thus, saves resources required for screening and selection of the resistant progeny.

Potato Cyst Nematodes

Potato cyst nematodes belong to genus *Globodera* and comprise of two species, *Globodera rostochiensis,* having golden females, and *Globodera pallida,* having white or cream-coloured females. *G. rostochiensis* has five pathotypes and four races, whereas *G. pallida* has three pathotypes and seven races. On an average PCN infestation cause more than 10% yield loss. The characteristic symptoms of PCN infestation is yellowing of foliage, wilting and pre-mature plant mortality. The ability of cyst formation as survival mechanism renders it as among the most devastating menace for potato cultivation. The cysts are resistant to unfavourable environmental conditions and nematicides and persist more than 10 years in the soil.

Abiotic Stresses

Drought

Abiotic stresses *viz.*, drought, salinity, high and low temperatures and heavy metals are among the major stresses that affects plants. Unpredictable rainfall pattern under changing climatic conditions lead to drought like situations. Erratic rainfall and inadequate irrigation facilities create moisture stress in potato. In general, the response of plants to drought involves escapism, avoidance and tolerance. The inheritance pattern of drought response is quantitative in nature and depends on interaction between different characters such as morphological, physiological, biochemical and cellular level processes. Breeding for drought tolerance in potato is hindered by the low heritability, polygenic control, and epistatic effects of many drought tolerance traits. In addition, other abiotic stresses such as high temperatures and high irradiance affects crop simultaneously. Shallow root system (0.5 to 1.0m) and low capacity of recuperation after a period of moisture stress makes potato susceptible to drought conditions. Drought stress affects morphological and physiological parameters of the potato plant like leaf size, leaf number, shoot height, rate of photosynthesis, tuber number, tuber yield and biomass. Genetic variability exists for drought tolerance in cultivated potato and the wild species. The approaches to improve drought stress tolerance are: 1) utilization of natural variations by direct selection or through the mapping of QTL and marker assisted breeding and 2), transgenic approach through novel genes or altered expression levels of existing genes. Information regarding genetics of drought tolerance in potato is limited, and few QTLs have been identified for potato drought tolerance traits eg under *in vitro* osmotic stress, three QTLs of root to shoot ratio were identified controlling 41.1% of the variance for this trait (Anithakumari *et al.*, 2011).

Heat stress

Global temperature will rise up to 6.2°C by the year 2100 (*Peters et al.*, 2013) thus pose challenge to sustain potato cultivation. World potato production will reduce by 18 to 32% without adaptation in production methods and 9 to 18% with adaptation of new planting system and heat tolerant cultivars (Hijmans, 2003).The temperate origin of potato makes it very susceptible to heat stress. Temperature affects growth and yield in potatoes. The optimum range of soil temperature for tuberization is 15-20°C. High temperature (25°C) promotes vegetative growth. Heat stress or high temperature exposure leads to tuber malformation, chain tuberization or secondary tuber formation, heat sprouting, internal tuber necrosis and reduced dry matter content. Heat tolerance in potato is multigenic. Changing cropping pattern eg wheat-based systems in Asian region leads to potato cultivation in summer and make it prone to heat and moisture stress. Heat tolerance is an important trait particularly for potato varieties of subtropics and the tropics.

Breeding Strategies for Host Resistance Against Biotic and Abiotic Stresses

The impact of biotic and abiotic stresses can be minimised by a synergistic approach of genetic improvement and cultural practices. Development of resistant or tolerant cultivars has been long practised by conventional breeding techniques. Conventional potato breeding involves hybridization followed by recurrent selection in the clonal generations. For introgression of desirable genes, hybridization of the wild/donor species with cultivated tuberosum potato followed by repeated backcrossing to tuberosum and selection for the trait of interest is done. Marker assisted selection hastens the process by quick and reliable parental identification and selection of superior clones genotypically at seedlings stage.

Diagrammatic representation of potato population improvement and cultivar development is depicted in Fig 1.

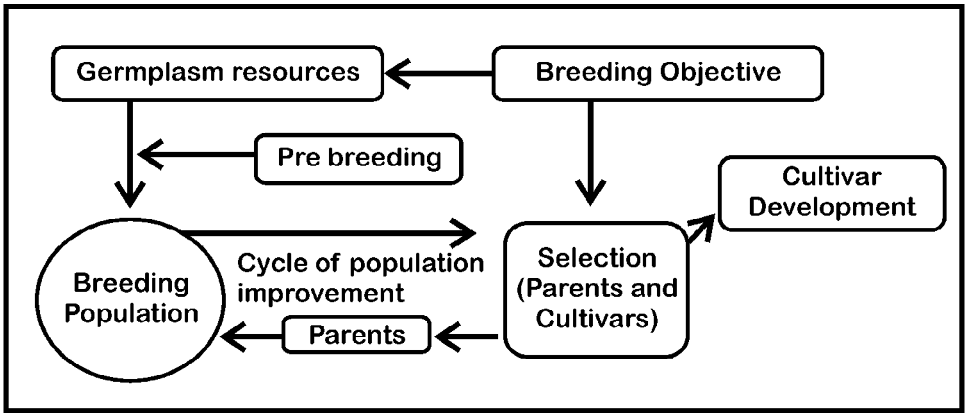

Fig. 1. General steps of potato population improvement and cultivar development programme
courtesy: Mark F. Paget, Ph.D. thesis, University of Canterbury

Utilisation of Crop Wild Relatives for Genetic Improvement

Genus *Solanum* comprise of 150 tuber bearing wild species (Sleper and Poehlman, 2006) having ploidy ranging from diploid (2n = 2x = 24) to hexaploid (2n = 6x = 72). The genetic base of cultivated potato cultivars worldwide is narrow owing to cross compatibility hampered by difference in endosperm balance number (EBN), interspecific pollen-pistil incompatibility and nuclear-cytoplasmic male sterility. Thus, evidence of introgression of resistance genes from wild species into cultivated potato is limited in number. Breeding strategies for introgression of resistance genes from wild *Solanum* donor species is hybridization followed by repeated backcrossing and selection for the desired genotypes in narrowly distant species. Molecular marker assisted introgression hastens process compared to conventional back-cross breeding. Molecular marker helps in parent selection on the basis of their genotypes. Bridge crosses and ploidy manipulation using intermediate species facilitate gene introgression from widely distant species. Somatic hybridization by protoplast fusion offers alternatives for transfer of resistance genes from wild species into cultivated background.

Table 1. Crop Wild Relatives of potato possessing resistance genes

Trait	Crop Wild Relatives
Late Blight	*S. berthaultii*, *S. bulbocastanum*, *S. chacoense*, *S. demissum*, *S. kurtzianum, S. microdontum, S. mochiquense*, *S. phureja*, *S. pinnatisectum*, *S. polytrichon*, *S. ruizceballosii*, *S. stoloniferum, S. vernei*
Viruses (PVX, PVY, PLRV)	*S. acuale, S. berthaultii, S. brevidense, S. cardiophyllum, S. chacoense, S. curtilobum, S. demissum, S. etuberosum, S. microdontum, S. multidissectum, S. polyadenium, S. stoloniferum, S. sucrense, S. tuberosum* ssp. *andigena*
Potato Cyst Nematodes	*S. acaule*, *S. chacoense*, *S. demissum*, *S. ehrenberjii*, *S. fendleri*, *S. gourlayi*, *S. microdontum*, *S. multidissectum*, *S. oplocense*, *S. phureja*, *S. sparsipilum*, *S. spegazzinii*, *S. sucrense*, *S. tarijense*, *S. tuberosum* ssp. *andigena, S. vernei*
Drought	*S. cardiophyllum*, *S. chaucha*, *S. curtilobum*, *S. gandarillasii*, *S. juzepczukii*, *S. tarijense*, *S. tuberosum spp. andigena*, *S. stenotomum*
Heat	*S. berthaultii, S. chacoense, S. commersonii*, *S. demissum*, *S. microdontum*, *S. stoloniferum*

Conclusion

Yield is the most important parameter for improvement in any crop. However, biotic and abiotic stresses tremendously impact the crop yield. Emergence of new pests and pathogens and their strains and pathotypes renders breeding for resistance a continuous process. With climate change and depleting natural resources, better management practises, cost effective and accurate phenotyping methods are to be developed specifically for abiotic stress. Diversification is required wrt to in-depth utilisation of wild species as source of resistance genes.

Suggested Readings

Awais Khan M., Susan Munive and Merideth Bonierbale (2015). Early generation *in vitro* assay to identify potato populations and clones tolerant to heat. *Plant Cell Tiss Organ Cult* 121:45-52.

Anithakumari A.M., O. Dolstra, B. Vosman, R.G.F. Visser and G. van der Linden (2011). In vitro screening and QTL analysis for drought tolerance in diploid potato. *Euphytica* 181: 357-369.

Bradshaw J. E., G. J. Bryan and G. Ramsay (2006). Genetic resources (including wild and cultivated Solanum species) and progress in their utilisation in potato breeding. *Potato Research* 49: 49-65.

Bradshaw, J.E. and G.R. Mackay 1994. Breeding strategies for clonally propagated potatoes. In: Bradshaw, J. E. and Mackay, G. R. (eds) Potato Genetics, pp. 467-497. CAB International, Wallingford.

Dalamu, Vinay Bhardwaj, R Umamaheshwari, Reena Sharma, SK Kaushik, TA Joseph, BP Singh and C Gebhardt (2012). Potato cyst nematode (PCN) resistance: Genes, genotypes and markers – an update. *SABRAO Journal of Breeding and Genetics* 44 (2): 202-228.

Khurana, S.M.Paul and SK Pandey. Potato in subtropics edited book.

Hijmans RJ. (2003). The effect of climate change on global potato production. *Amer J Potato Res* 80:271-279.

Hussain B. (2015). Modernization in plant breeding approaches for improving biotic stress resistance in crop plants. *Turk J Agric* 39:1-16.

Peters G.P., Andrew R.M., Boden T., Canadell J.G., Ciais P., Le Quere C., Marland G., Raupach M.R. and Wilson C. (2013). The challenge to keep global warming below 2°C. *Nat Clim Change* 3:4-6.

Monneveux P., Ramirez D.A. and Pino M.T. (2013). Drought tolerance in potato (*S. tuberosum* L.): can we learn from drought tolerance research in cereals? *Plant Sci* 205–206:76-86.

Sleper D.A. and Poehlman J.M. (2006). Breeding field crops, 5th ed. Blackwell Publishing Professional. 2121 State Avenue, Ames, Iowa.

Shekhawat, G.S., S.M. Paul Khurana and B.P. Singh. 1999. Important diseases of potato and their management. In: Potato Global Research and Development, Vol. 1 (Khurana, S.M. Paul, G.S. Shekhawat, B.P. Singh and S.K. Pandey, Eds.), pp 281-303. Indian Potato Association, Shimla.

5

LITERATURE SEARCH AND INFORMATION RETRIEVAL IN AGRICULTURE SCIENCES: CURRENT INFORMATION LANDSCAPE

Dr. Rakesh Mani Sharma

Contents

Introduction

"Literature search and information retrieval is a well thought out and organized process to search and retrieve all literature published on a given topic." A well-structured literature search is the most effective and efficient way to locate evidence based information on the subject being researched. Evidence may be found in books, journals, government documents and on the internet.

The literature search in today's agricultural information landscape differs strikingly from that of a generation ago. The abundance of scientific information in volume and formats make researchers simply confused as what to search (which information), where to search (source) and how to search (techniques) to acquire the relevant and authentic information. To avoid this confusion one has to formulate an efficient search strategy. Search strategy here mean to the operations and decisions involved in the search process from the time a user approaches the system with some information need till he construct a search statement that adequately and accurately expresses the information need of the user.

Why Literature Search?

Basically literature searching has two main goals:

(a) To retrieve only those references/papers that are relevant to the search question (this is called "precision/specificity"); and

(b) Not to miss any of those relevant papers (this is called "recall/ sensitivity").

These goals are especially important in conducting the rigorous searches and retrieving the relevant information to support the decisions making and implementation of the best practices in agricultural research and farming by facilitating the evidence based authentic knowledge generated from systematic agricultural research that has been conducted using sound methodologies.

However to realize the aforesaid goals of literature search, adoption of an efficient search strategy is a prerequisite.

An Efficient Search Strategy

In devising a search strategy that is both sensitive and specific, it is helpful to identify the different components of the question at hand, and formulate as many search terms (including synonyms) for each component as possible. A separate search is then performed for each component, combining all synonyms with the appropriate Boolean operators AND OR, AND, NOT. While the use of AND operator combines the two concepts and fetch the less number of relevant records. The use of NOT operator excludes the concepts to which is precides with the result is fetches the less number of records. The use of these two operators while enhances the specificity, the use of OR operator in creasing the record retrieval leading to exhanstivity of the search results. These steps, if executed properly, enhance sensitivity and ensures that only those references that match all components of the search question are retrieved, thus enhancing specificity.

In identifying search terms and synonyms for each component, it is useful to consider cross-cultural differences in nomenclature and spelling, trade names, and nomenclature that have changed over time.

Many search engines offer extensive thesauri/indexes to facilitate searching. In employing such thesauri, such as the AGROVAC (Agricultural Vocabulary) used by FAO as subject headings in its AGRIS database and CAB Thesaurus for CABI database- a search is automatically broadened to include synonyms and word variants of the term that is searched. As citations/ references are usually indexed based on the full-text of the article, a search that includes use of the thesaurus could yield citations that might otherwise have been missed. This is especially relevant in cases where no abstract is included in the database itself. However, using thesaurus for formulating search strategy have certain drawbacks also.

In most databases a thesaurus based search is by default “exploded” to include all terms lower in the thesaurus hierarchy. This inevitably increases the number of retrieved records and often reduces the specificity of the search. Also, there is a time lag between the date an article is published and the date it is indexed. Consequently, when only thesaurus terms are used in a search, the most recent relevant articles might not be retrieved. Because previously indexed articles are often not retroactively modified to reflect changes made to the thesaurus. Thus, articles published before a certain term was added to the thesaurus will not be retrieved when that thesaurus term is used in a search. As such the use of thesaurus terms might decrease the specificity of a search and should always be accompanied by a search for free text terms or terms occurring in title and abstract only. This can be achieved by adding so called “field tags” to the selected search terms. An example of a field tag in AGRIS and CABI is “[ti]”, which limits searches to the title fields. Adding the field tag [ti] disables automatic mapping of the search term to the thesaurus. In addition, it prevents searching in fields like “author name” and “affiliation”, thereby increasing specificity.

Where to Search (Source)?

Like any other scientific discipline, the most comprehensive source for literature search in agriculture science is the electronic databases – bibliographic or full text - online or on CDs. Now a days they are considered to be the core source of literature search in agriculture.

The Electronic Databases

It is important to consider the electronic databases in which the formulated search strategy will be executed. Although AGRIS and CABI, with over 10 million references from 1973 onwards having 3, 50,000 annual addition of records in agriculture and biosciences, is often used as the starting point for literature searching in the agricultural and biosciences [1, 2]. Still to make the search more comprehensive the other databases e.g. AGRICOLA, ASFA, Biological Abstracts, Current Content, Derevent Biotechnology Abstracts, PubMed and many more should also be taken into account for literature search.

All electronic bibliographic databases, like CAB ABSTRACTS, AGRIS or AGRICOLA can be thought of simply as very large collection of electronic files of research articles references or citation indexes. Although one can't physically see the records and the indexes en-mass within the database, the two are structured in the same way. They each have a section that contains the records as well as a separate section that contains the indexes that allow the user to "find" or "search" for the records in which the researchers are interested. In a typical printed abstract journal, such as Forestry Abstracts or Potato Abstracts published by CABI, the journal will have a section containing all the records as well as an Author and a Subject index at the back.

An electronic database works exactly in the same way as printed journal index. It has a section that contains all the records, each with its one unique record number, and a section that contains all the indexes used to search for those records. The one major difference is the size of the electronic database and the large number of indexes that can be created without the limitations that a print journal imposes. In the case of the CAB ABSTRACTS database, for example, there is an index of Title words, an Author index, a Source index, an Address field index, a Language index and several Descriptor indexes. In addition to these individual indexes, that correspond to an individual field within a CAB ABSTRACTS record, there is also what is called a Free-Text Index which combines many of these individual indexes into one large index and which allows the user to search for words and phrases from the complete record. The Free-Text index is the one that is most commonly used for quick and simple searches and is the index that is searched by default.

When we search for a term (keyword) in one of the search indexes, the system simply looks for the term in the index and, when it finds it, it counts the number of record numbers and returns a result to the search screen that says something like: #1 7553 Potato

The exact format of the returned results depends upon the search interface being used. This is an example from CABCD where #1 is the number of the search, the 7553 is the number of records that the search has found, and the word Potato is the term that have been searched for. The reference numbers, within the search index, are used to locate and display the records on the screen.

How to search and retrieve (Technique)?

While going for literature search and information retrieval one has to follow the following steps.

Keywords and their Selection

One of the most important aspects of searching is the selection of all the appropriate search terms or Keywords, as they are often known, and the building of the search profile. The steps to creating a search profile are as follows:

Understand the question

Write down exactly what information you as an end-user want. If you are performing a search for someone else, make sure that you are absolutely clear about what it is they want.

Select all the important concepts

From the search question, select all the search terms. A typical search question might be:

"I want 50 recent references about the irrigation of rice in South East Asia." An experienced searchers will often try and search for the phrase "irrigation of rice in South East Asia". If you do this, the system will look only for records that contain exactly that phrase and it is likely to find very few records if, indeed, it finds any at all. Instead, we need to select out the different concepts and key workds expressing those concepts, then search for each separately. In this example, the key concepts are:

Irrigation, Rice and South East Asia

What we now need to do is to instruct the search system to look for records that contain all three of these "concepts" or "Keywords"

Add synonyms, singulars and plurals

Once you have selected the keywords from the search question, you should consider if there are any alternative words, scientific names or spellings variants of those words, that you should include in the search. Remember, the system only looks for what you ask it to. Typical examples are singular words or plurals, American versus British spelling, common names like Potato or scientific names like *Solanum Tuberosum*. The more variations that one can add to the search profile, the more records are likely to retrieve, particularly when performing a **FREE-TEXT search**. Many databases will use a controlled indexing vocabulary like the CAB Thesaurus and, if this is available, it can be a valuable source of Keywords and alternative terms. For singulars and plurals, most search engines offer a technique known as truncation. You simply enter the singular term followed by a truncation symbol (usually an *, a $ or?) and this symbol tells the search engine to look for all words that start with the term entered.

As an example, searching Nutri*, on CAB Direct, would retrieve all the records containing the words Nutria, Nutrient, Nutrients, Nutrition and Nutritional. On CAB Direct, the Question Mark (?) can also be used for truncation where each? represents up to one character. For example, searching for CAT? Would retrieve records containing the word CAT or the word CATS but not the word CATTLE. The ? may also be used for character "masking" within a word, e.g. Int??net would search for Inernet or Intranet.

Creating the Search Profile

When searching, each time a term or group of terms is searched, the system creates and stores a set of the records that it finds. In the very simplest of searches, the user may only create one set of records and then print or display them. However, in most cases, the search will need to be a little more complex than a single keyword. Searches for more complex subjects that contain many keywords will require the creation of a more complex search profile, and will usually result in the creation of many sets of records, where these sets themselves are then combined to obtain the final result. Let's look at our example of Irrigation of Rice in South East Asia. We have already selected our three keywords as:

Irrigation, Rice and South East Asia

In a simple search, we would search for each term separately. This would result in the creation of three separate sets as in the following example:

#1 20972 irrigation

#2 27332 rice

#3 20072 south east Asia

This is the "Search History" and shows the three sets of records, the numbers of records found for each of the terms searched and the terms themselves. In order to complete the search to find the records that contain all three of these search terms, we now need to combine these three sets together.

Combining Sets of Records

Sets of records are combined together using one or more of the three search operators AND, OR and NOT. These three words are often referred to as "Boolean Operators". So what do these words do?

AND is used to instruct the search system to retrieve only records that contain all the terms chosen. In our example, we want only records that contain all three search terms Irrigation AND Rice AND South East Asia. We don't want records that only contain Rice and Irrigation. The AND operator narrows down a search. It reduces the number of records but increases the relevance of those records.

OR is used to broaden a search; to make the set of records bigger. An example might be a search for all records about sheep or goats. Here the user wants all records that are just about goats plus any records that are just about sheep as well as all the records that might be about both sheep and goats. Here the search would be Sheep OR Goats

NOT is used to exclude certain terms from a search as in a search for records about Rice where the user is not interested in papers about the diseases of rice. Such a search would be performed as Rice NOT Disease*.

These Boolean Operators can be used directly with keywords, as in these examples, as well as with set numbers. If we go back to our example, the final search would be to combine the three sets with the AND operator:

#1 AND #2 AND #3

Note: In the case of a search on CABCD (Ovid's version using the Silver Platter search interface) you must include the # symbol, otherwise the system would simply search for records containing the number.

This final search creates a set of records, #4, which contains all the records that include all three of our search terms. So, to finish, let's take a look at the complete search history:

#1 20972 irrigation

#2 27332 rice

#3 20072 south East Asia

#4 197 #1 and #2 and #3

This shows that we have found 197 records about the irrigation of rice in South East Asia. Once the search has been performed, one can see the records, it is a good idea to check the records for other possible keywords that you may have missed in your original profile. Because you are able to create sets when searching, it is perfectly possible to continue to modify a search by adding in new Keywords, and creating and combining new sets of records until satisfied with the obtained results.

Text Mining and Semantic Search

All search techniques mentioned so far are based on finding specific terms within a database, either directly, through the use of a thesaurus or filter, or by using the results of searches conducted by third-party sources. With the exponential growth of scientific information on the web, there is growing interest in different ways of searching using **text mining techniques**. In text mining, free text is searched for patterns, rather than individual search terms, to retrieve high-quality information. One approach to this effect may be on the proposed architecture of the semantic web [3] that focuses on the relationship between terms, thus taking into account their contextual meaning. Searching for relationships, rather than individual search terms, could enhance search specificity. Recently, an experimental biomedical search engine was launched that makes use of semantic search algorithms [4]. In addition, text mining could be used to improve cross-linking of information in biological and agricultural databases – for instance, those containing gene and protein sequences – with evidence in the literature [5]. There is ongoing debate in this field as to whether text mining should be facilitated a priori – for example, by letting authors prepare structured abstracts in a computer-readable format [6] – or whether it should be done a posteriori using natural language processing[7]. Finally, a triangle of publications, databases and end-users can be envisaged, with users annotating information in a Web2.0 environment like Facebook and Tweeter[8]. Besides web publishing of scientific information, there is growing possibility of open access to scientific contents in agricultural sciences as it is gaining very active momentum world over.

Open Access

Knowing that information exists (for example, finding a citation/ reference. In AGRIS/CABI) is of little significance if the information itself is not available (i.e. the full-text article cannot be accessed). For example currently, only 53% of citations in CABI contain a link to the free full-text article [9], either through the publisher directly, or through open access journals and institutional digital archive/repository on agriculture. Over the last few years, the Open Access publishing model [10, 11] has been gaining momentum, resulting in a growing number of open access journals and institutional repositories. Many publishers are developing business models to accommodate Open Access – some examples are BioMed Central [12] and Springer Open Choice [13]. Moreover, various funding agencies – like the FAO at the international level and ICAR at national level promoting the open access movement in science of agriculture. Therefore, access to free full-text scientific articles in agriculture science will likely continue to improve.

Agricultural Libraries Role

The role of the agricultural libraries remains same “connecting users to his/her information” even in a changing information landscape, but on different magnitude and methods. Despite of well stacks of bound issues of scientific journals and books users have little inclination to come over the library to make use of library information, resources rather they want to use it on their desktop, laptop. Now users want everything online digital. Therefore one of the main roles of the agricultural library today is to provide a digital portal to scientific information. On a library’s website, multiple search engines can usually be accessed, including commercial search engines to which users would have no free access otherwise. Often, libraries provide a direct link from search engines to the full-text articles in journals to which the library subscribes. Apart from offering access to databases and full-text journal articles, the agricultural libraries can also play an important role in educating the users in information literacy skills, enabling them to search the scientific literature effectively. Almost all SAUs and deemed agricultural universities and institutions conducts one credit course in library usage, scientific writing etc at the PG and Doctoral level to educate and increase the efficiency in literature search and retrieval.

Conclusions

The ability to carry out an efficient literature search is a key skill for researchers faced with an abundance of online scientific information. Future developments in text mining techniques, as well as the Open Access movement are expected to further increase the amount of scientific information that will be available to end users. Agricultural libraries continue to play an essential role in the dissemination of scientific literature and the training/educating of information literacy skills. These developments are definitely going to enhance the empowerment of users in information access and use of scientific information they need.

Suggested readings

Haines LL, Light J, O'Malley D, Delwiche FA. Information-seeking behavior of basic science researchers: Implications for library services. J Med Libr Assoc 2010; 98(1):73-81.

Gerstein M, Seringhaus M, Fields S. Structured digital abstract makes text mining easy. Nature 2007; 447 (7141):142.

Quertle. Available at: http://www.quertle.info. Accessed July 14, 2013.

Altman RB, Bergman CM, Blake J, Blaschke C, Cohen A, Gannon F, et al. Text mining for biology - The way forward: Opinions from leading scientists. Genome Biol 2008; 9(SUPPL. 2):S7.

Hahn U, Wermter J, Blasczyk R, Horn PA. Text mining: Powering the database revolution. Nature 2007; 448 (7150):130.

Altman RB, Bergman CM, Blake J, Blaschke C, Cohen A, Gannon F, et al. Text mining for biology - The way forward: Opinions from leading scientists. Genome Biol 2008; 9(SUPPL. 2):S7.

Subarsky P. Open Access Publishing: Prelude to a paradigm shift in the dissemination of scientific literature. Hypothesis 2004; 2(1):8-10.

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6

DNA FINGERPRINTING FOR VARIETAL IDENTIFICATION AND GENETIC FIDELITY

Vinay Bhardwaj, VU Patil, Krishan Gopal,
Reena Sharma and Rahul Sharma

Contents

Introduction

Until recently, the identification and characterization of plants was essentially based on external characteristics such as morphological traits or productivity. Such classical phenotypic features are still extremely useful but can be widely influenced by environmental conditions. The morphology of the same plant may extremely vary depending on the external conditions. The fundamental genetic characters may be masked and make the identification very difficult. Moreover, this visual identification is time consuming and requires the plant to be grown to suitable developmental stage before certain characters are scored. DNA based markers allow us to overcome some limitations of the morphological determination.

The term DNA-fingerprinting (DNA typing or Genetic fingerprinting) was introduced for the first time by Alec Jeffrey in 1985 for identifying individuals by the particular structure of their DNA. DNA fingerprinting/profiling is used to describe the combined use of several single locus detection systems and is being used as versatile tools for investigating various aspects of plant genomes. These include characterization of genetic variability, genome fingerprinting, genome mapping, gene localization, analysis of genome evolution, population genetics, taxonomy, plant breeding, and diagnostics. DNA fingerprinting techniques have the advantage that the DNA content of a cell is independent of environmental conditions, organ specificity and growth stage (Ainsworth *et al.*,1996). The basic technology of DNA profiling involves extraction of DNA. The next steps are of four types; (a) PCR-based gel technologies, (b) non-PCR-based gel technologies, (c) hybridization Chip - based, and (d) sequence-based (e.g., full genome sequence analysis).

Properties desirable for ideal DNA markers

- Highly polymorphic nature
- Codominant inheritance (determination of homozygous and heterozygous states of diploid organisms)
- Frequent occurrence in genome
- Selective neutral behaviour (the DNA sequences of any organism are neutral to environmental conditions or management practices)
- Easy access (availability)
- Easy and fast assay
- High reproducibility
- Easy exchange of data between laboratories.

The best molecular markers are those that distinguish multiple alleles per locus (i.e. are highly polymorphic) and are co-dominant (each allele can be observed). Details of few DNA markers widely used in fingerprinting/ genotyping of field crops are discussed below.

Random Amplified Polymorphic DNAs (RAPDs)

RAPDs are DNA fragments amplified by the polymerase chain reaction using short (usually 10 bp) synthetic primers of random sequence. These oligonucleotides serve as both forward and reverse primer, and are usually able to amplify fragments from 1 to 10 genomic sites simultaneously Amplified fragments, usually within the 0.5–5 kb size range, are separated by agarose gel electrophoresis, and polymorphisms detected, as the presence or absence of bands of particular sizes.

Uses: RAPs are used for linkage map preparation, identification/profiling of genetic resources and fingerpriting of host/pathogen.

Strengths: 1) RAPDs are easy, quick and easy to score. 2) No sequence data is required for primer construction. 3) RAPDs have a very high genomic abundance and are randomly distributed throughout the genome.

Weaknesses: 1) Have low reproducibility 2) RAPD markers are not locus-speciûc, band profiles cannot be interpreted in terms of loci and alleles (dominance of profiles), and similar sized fragments may not be homologous.

Microsatellites or Simple Sequence Repeats (SSRs)

SSRs are di-, tri- or tetra- nucleotide repeats shown to be abundant, dispersed throughout the genome, highly conserved and polymorphic than other genetic markers in eukaryotic genomes. They are detected by PCR using primers flanking the repeats and resolved on the agarose gels.

Uses: SSR resources are useful for cultivar identification, pedigree analysis, characterization of germplasm diversity and genetic mapping studies.

Strengths: 1) SSRs are codominant markers 2) High genomic abundance and random distribution throughout the genome 3) PCR based technique so requires very low quality and quantity of DNA (10–100 ng per reaction) 4) SSR is a single-locus technique, multiple microsatellites may be multiplexed during PCR or gel electrophoresis if the size ranges of the alleles of different loci do not overlap. 5) Reasonably reduced cost 6) Screening of SSRs may be automated.

Weaknesses: 1) High developmental cost. Although microsatellites are in principle codominant markers, mutations in the primer annealing sites may result in the occurrence of null alleles (no amplification of the intended PCR product), which may lead to errors in genotype scoring (poor "cross-species amplification"). 3) A very common observation in microsatellite analysis is the appearance of stutter bands that are artifacts in the technique that occur by DNA slippage during PCR amplification and these may lead to confusion between heterozygotes and homozygotes.

Inter Simple Sequence Repeats (ISSRs)

The ISSR technique involves amplification of DNA segments present at an amplifiable distance between two identical microsatellite repeats oriented in opposite directions. The technique uses microsatellites, usually 16–25 bp long, as primers in a single primer PCR reaction. This targets multiple genomic loci, and usually yields dominant markers.

Uses: ISSRs are used for generating genetic profiles for genotypes for genetic variation studies.

Strengths: 1) No sequence information is required for primer construction. 2) Low quantities of template DNA are required (5–50 ng per reaction. 3) ISSRs are randomly distributed throughout the genome.

Weaknesses: 1) ISSRs, like RAPDs, can have reproducibility problems. 2) These are generally dominant markers.

Single Nucleotide Polymorphism (SNP)

SNP is a single nucleotide difference in the sequence of a gene or segment of the genome. There are typically tens of 1,000s of SNPs and a variety of methods for analyzing them, including highly automated/high throughput procedures with simultaneous scoring of many markers. Detection of SNPs can be done without gels.

Strengths: 1) Once the location of SNPs is identified and appropriate primers designed, one of the advantages they offer is the possibility of high throughput automation. Mycroarrays or the automated sequencers are used for the purpose. 2) SNP analysis may be useful for cultivar discrimination in crops where it is difficult to find polymorphisms, such as in the cultivated tomato. 3) Complementary tool in loss of heterozygosity studies. 4) Functional analysis of allelic variants of a single gene. 5) Haplotype studies.

Weaknesses: 1) To date, SNP markers are not yet routinely applied in genebanks, in particular because of the high costs involved.

Suggested Readings

Spooner, D. Van Treuran, R and De Vicente 1996 Molecular markers for genebank management. *IPGRI Technical Bulletins.*

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7

SOMATIC HYBRIDIZATION IN POTATO IMPROVEMENT

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Vinay Bhardwaj and Bir Pal Singh

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Introduction

Gene transfer is the basis for almost all crop improvement including potato. Conventionally, this is achieved through sexual hybridization; this rather limits the range of species from which gene flow can occur into a crop species. Wild species have contributed remarkably to the success of latter, they allowed the crops to retain their commercial status. As a result plant breeders have sought to utilize an increasing number of wild species as a source of valuable genes ranging from disease resistance to grain yield and produce quality. But many sources of useful genes cannot be included in crop improvement programme primarily because of sexual incompatibilities. Genetic transformation, a focussed and direct gene transfer approach, require identification, isolation and cloning of the concerned genes. Further it is expensive and technically most exacting, although it may represent the ultimate strategy. However, some characters of interest may be govern by two or more and yet unknown genes; transfer of such characters through genetic transformation may pose many difficulties. Finally transfer of cytoplasmic organells, *viz.*, chloroplast and mitochondria may often be desired objectives; this, however is not possible through genetic transformation, while it can readily achieved by somatic hybridization.

Wild and cultivated species of potato have been effectively used in potato breeding but represent only a tiny fraction of the available potato biodiversity. Utilization of the wild tuber-bearing diploid species has been remained untapped potential source for transferring resistance trait into common potato (Bradshaw *et al.* 2006). Wild tuber-bearing *Solanum* species are widely distributed from southwestern USA to central Argentina and Chile. This extensive geographical range has resulted in types adapted to a broad range of climatic and soil conditions. In the course of evolution, these plants have also developed resistance/tolerance to different pathogens and pests. Much of this effort has involved the examination of wild species for various resistance traits related to potato. This trait is particularly attractive to breeders to widen the potato genetic base, but the barrier between the cultivated potato and the many wild species has proved a difficult task, even when unconventional crossing methods are used (Orczyk *et al.* 2003).

Many useful genes derives from wild sources cannot be transferred through conventional technique because of sexual incompatibilities are primarily due to difference in ploidy and endosperm balance number (EBN) (Spooner and Salas, 2006). It is extremely difficult to cross 1 EBN wild species directly with common cultivated 4 EBN potato. Limited success has been obtained by utilizing bridging species but the incompatibility of 1 EBN wild species has generally prevented the use of this particularly valuable trait. However, modern research and new techniques have made it possible to expand considerably the genetic resources available for use in breeding programs. A few methods have now become available to overcome this problem. These methods include: manipulation of ploidy and endosperm balance number (EBN), bridge crosses, mentor pollination and embryo rescue, hormone treatment and reciprocal crosses (Jansky, 2006). Somatic hybridization, which removes prezygotic and some postzygotic barriers, can likewise surmount the barrier between cultivated and wild species. Somatic hybridization can provide a means of bypassing sexual incompatibility between *Solanum* species, leading to fertile plants that can be used directly in breeding programs.

Somatic hybridization generates functional combinations of large sets of genetic material, which makes it similar to sexual hybridization. This method can also be used to overcome limitations of genetic transformation. Many of the important traits are predominantly polygenic such as late blight resistance and thus unavailable as isolated and characterized sequences that are ready for genetic transformation. Therefore, efficient methods of transformation are yet to be available for multiple genes that are expressed in a coordinated manner (Orczyk *et al.* 2003). On the other hand, somatic hybrids obtained directly after fusion contains all organelles from the cytoplasms of both parents. Somatic hybridization via protoplast isolation, electrofusion and regeneration is a useful tool to transfer polygenic traits such as late blight resistance in a single step. It enables a development of tetraploid somatic hybrid between diploid wild species and dihaploid of common potato. As a result, tetraploid somatic hybrids may be utilized in conventional breeding for late blight resistance and improvement of other traits. Thus, production of somatic hybrids between tetraploid 4EBN *S. tuberosum* and diploid 1EBN wild species has been envisaged for imparting durable resistance to late blight. In consequence, aim of this somatic fusion technology is creditable to enrich the cultivated potato gene pool by incorporating genes from a new exotic wild species, in order to enhance resistance to late blight disease.

Hence, somatic hybridization is the technique enables to transfer agronomically important traits by bypassing such sexual barriers, besides the conventional and recombinant-DNA technologies approaches. Despite these crossing-barriers, many researchers have used this technique and subsequently produced somatic hybrids with cultivated potato. Production of hybrid plants through the fusion of protoplasts of two different plant species/varieties is called somatic hybridization and such hybrids are called somatic hybrids. Therefore, somatic hybridization can be resorted to only when the following two criteria are satisfied: i) isolation of protoplast in large quantity and ii) totipotency of the isolated protoplasts.

Procedures

The protoplast fusion by electric field requires sufficient amount of suitable plant material for protoplast isolation and their culture after electrofusion for obtaining plant regeneration. The procedure involves the following stages.

- *In vitro* culture of donor plants

- Protoplast isolation from leaf meshophyll tissues
- Verification of protoplast viability and protoplast fusion
- Protoplast fusion by electric field
- Regeneration and culture of fusion products
- Characterization of putative somatic hybrids

1) Material required or prepare materials

- Three-week-old *in vitro*- grown microplants, raised from single nodal cutting

2) Microplant incubation condition

- 16 h photoperiod/40 μ mol m^{-2} s^{-1}/20ºC.

3) Pre-isolation (protoplast) incubation

- 48 h/dark/20ºC

4) Protoplast isolation

- Mince young leaf tissues (1-2 g) in a Ø 90 mm Petri dish containing digestion solution: 10 ml digestion solution for 1 g tissue.

5) Incubation (for protoplast isolation)

- 16 h/ dark/ 25ºC/ optional: gyratory shaking at 40-50 rpm; not exceeding 50 rpm.

6) Post-isolation handling

- Add 0.3 M KCl (sterile) to the digestion medium/ solution containing released protoplasts (protoplast suspension) in a 1:1 ratio (KCl: solution). For example, add 15 ml 0.3 M KCl to 15 ml digestion medium/ solution.
- Filter the suspension through 40 μ nylon mesh and collect in centrifuge tubes; 60 μ can be used but debris and/ or undigested tissues will be much.

7) Protoplast purification

- Centrifuge the filtrate at 50 x g (60 RCF) for 5 min.
- Discard supernatent and then resuspend the pellets in 10 (or 9) ml of 0.6 M sucrose (sterile).
- Overlay 1 ml of 0.3 M KCl onto this protoplast suspension.
- Centrifuge at 50 x g (60 RCF) for 5 min.
- Recover the protoplast (green upper portion/live protoplast) from sucrose: KCl interface
- Dilute the recovered protoplasts with 10 ml of 0.3 M KCl.
- Centrifuge at 50 x g (60 RCF) for 5 min to form pellet of the protoplast.
- Resuspend the pellets in 1-2 ml 0.5 M mannitol (sterile), centrifuge at 50 RCF) for 5 min., then retain pellets and discard supernatants
- Finally resuspend the pellets in 400-500 µl 0.5 M mannitol (sterile) to a final density of $1x1^{06}$ protoplast/ml for electrofusion.

8) Electrofusion medium

- 0.5 M mannitol (sterile)/ sterile-filtered (0.2 µ)/ pH 7-7.3/ adjust pH with 0.1 N NaOH

9) Symmetric fusion

- 1:1 of each species

10) Electrofusion settings

Chamber	BTX Microslide Model 453/3.2 mm gap
Alignment amplitude	16 V
Alignment time	25-30 s
Alignment field strength	50 V cm^{-1}
Electrofusion amplitude	260 V
DC pulse width	60 µs
Number of pulses	2

Electrofusion field strength 812 V cm^{-1}

11) Post-fusion culture

- Dispense 50 µl Na-Alginate in each box of castor rack and mix well the 50 µl fusion products into it
- Add 2-3 ml Solution No 3 in each box and incubate at RT inside laminar for 30 min followed by the adition of 2-3 ml Solution No 2 and incubate same for 1.30-2 h
- Remove Sol 2 & 3 by Pasteur pipette and add 5 ml VKMG (VKM Glucose) and tightly wrapped with parafilm.
- Incubate the castor racks under dark at 25ºC for the regeneration of calli.

Applications

Symmetric protoplast fusion approaches involving diploid *Solanum* species in combination with dihaploid *S. tuberosum* have been essentially used to develop tetraploid somatic hybrids potato having desirable introgression from wild relatives (Table 1). In the current years, application of this technology has been observed widely for the production of multiple resistant somatic hybrids. Interspecific potato somatic hybrid between commercial cultivars of potato *S. tuberosum* Agave and Delikat and wild diploid species *S. cardiophyllum* (1 EBN) has been produced for resistances to Colorado potato beetle, foliage blight and PVY (Thieme *et al.* 2010). In addition, somatic hybrids between a diploid potato clone DG 81-68 susceptible to *P. infestans* and a resistant diploid tuber-bearing species *Solanum* x *michoacanum* were generated (Szczerbakowa *et al.* 2010). Polzerová *et al* (2011) have developed interspecific somatic hybrids between wild diploid species *S. pinnatisectum* (1 EBN) and *S. tuberosum* for the late blight resistance in potato. Following the successful production, somatic hybrids have been applied in the potato breeding for the development of advance progenies for transferring the resistance trait. For example, Thieme *et al.* (2008) have developed novel somatic hybrids and their fertile BC_1 progenies having resistances to late blight, Colorado potato beetle and PVY from a diploid wild species *S. tarnii* into common potato.

Interspecific potato somatic hybrids at CPRI

Interspecific potato somatic hybrids between 1 EBN wild *Solanum* species *S. pinnatisectum* (+) dihaploid *S. tuberosum*, and ii) S*. etuberosum* (+) dihaploid *S. tuberosum* have been produced following optimized protocol of the protoplast isolation, electrofusion and regeneration of plantlets (Sarkar *et al.* 2011; Tiwari *et al.* 2010, 2011). The somatic hybrids *S. pinnatisectum* (+) *S. tuberosum* have resistance for late blight resistance, whereas *S. etuberosum* (+) *S. tuberosum* have resistance for potato virus Y. These potato somatic hybrids have been confirmed for the hybridity through molecular (RAPD, ISSR, SSR and Cytoplasmic markers) and phenotypic assessments. Hybrids were also evaluated for the disease resistance. Ploidy level (tetraploid) of somatic hybrids has been examined through flow cytometry and guard cell count. At present, work is under progress on the development of more interspecific potato hybrids involving diverse 1 EBN wild species obtained from foreign gene banks. Molecular analyses of the potato somatic hybrids produced at CPRI, Shimla are shown in Figs. 1 and 2.

Table 1. Symmetric protoplast fusion in potato for incorporation of desirable traits from wild diploid species into *S. tuberosum*

Diploid wild species	Trait(s) transferred	References
S. acaule	PVX resistance	Yamada *et al.* 1997
	Bacterial ring rot resistance	Rokka *et al.* 2005
	Glycolkaloid composition	Kozukue *et al.* 1999
S. berthaultii	Salinity tolerance	Bidani *et al.* 2007
S. bulbocastanum	Late blight resistance *Meloidogyne chitwoodi* resistance	Bo³towicz *et al.* 2005 Mojtahedi *et al.* 1995
	Bacterial stem rot resistance	Rokka *et al.* 1994
S. brevidense	Tuber characteristics and insect resistance	Serraf *et al.* 1991
	Tuber soft rot resistance	Polgar *et al.* 1999
	Early blight resistance	Tek *et al.* 2004
S. cardiophyllum	Late blight, PVY, Colorado	Thieme *et al.* 2010

	potato beetle resistances	
S. chacoense	Colorado Potato Beetle resistance	Cheng *et al.* 1995
S. circaefolium	Late blight and nematode resistances	Oberwalder *et al.* 2000
S. commersonii	Frost resistance	Nyman and Waara, 1997
	Bacterial wilt resistance	Kim-Lee *et al.* 2005
	Tuber traits	Caruso *et al.* 2008
S. etuberosum	Tuber characteristics	Novy and Helgeson, 1994
	PVY resistance	Novy *et al.* 2007
	PLRV resistance	Novy *et al.* 2007
S. x michoacanum	Late blight resistance	Szczerbakowa *et al.* 2010
S. nigrum	Late blight resistance	Szczerbakowa *et al.* 2003
S. phureja	Bacterial wilt resistance	Fock *et al.* 2000
S. pinnatisectum	Late blight resistance	Polzerová *et al* 2011
S. stenotomum	Bacterial wilt resistance	Fock *et al.* 2001
S. tarnii	Late blight, Colorado Potato Beetle and PVY resistance	Thieme *et al.* 2008
S. torvum	Resistance to *Verticillium dahliae*	Jadari *et al.* 1992
S. tuberosum	Late blight resistance	Rasmussen *et al.* 1998

Phenotypes of the interspecific potato somatic hybrids *S. tuberosum* spp. *tuberosum* (+) *S. pinnatisectum* and *S. tuberosum* spp. *tuberosum* (+) *S. etuberosum* produced at CPRI, Shimla are shown below (Figs. 1 and 2).

Advantages

- Somatic hybrids can be produced between species, which cannot be

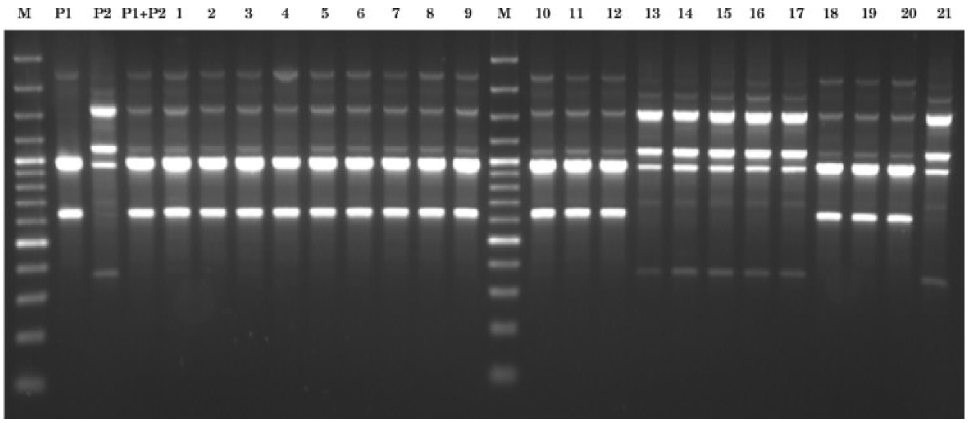

Fig. 1 RAPD profiles generated by primer OPAC-13 on 1.6% agarose gel. M=100 bp ladder. P_1 (Parent 1) = C-13, P_2 (Parent 2) = *S. etberosum* P_1+P_2 = Pooled parental DNA, 15 clones (No. 1 to 12 and 18-20) were confirmed as somatic hybrids. Whereas, 6 clones (No. 13-17 and 21) were not somatic hybrids **(continued on Fig. 2)**

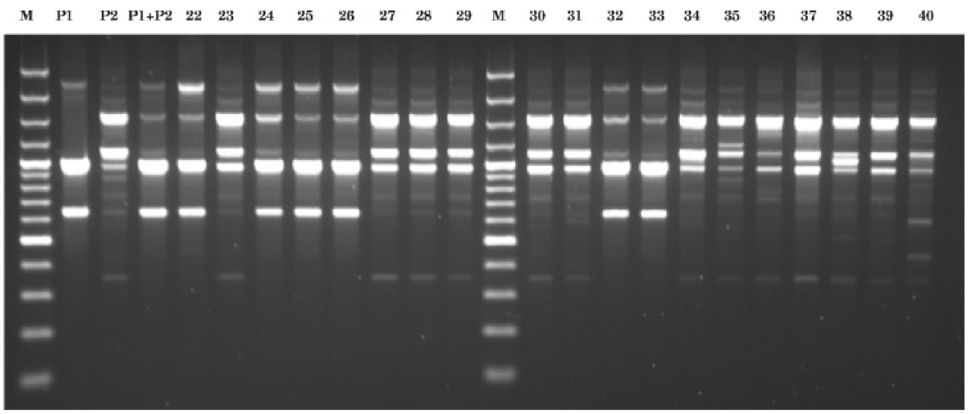

Fig. 2 RAPD profiles generated by primer OPAC-13 on 1.6% agarose gel. M=100 bp ladder. P_1 (Parent 1) = C-13, P_2 (Parent 2) = *S. etberosum* P_1+P_2 = Pooled parental DNA, 6 clones (No. 22, 24 to 26 and 32, 33) were confirmed as somatic hybrids. Whereas, 13 clones (No. 23, 27-31, 34-40) were not somatic hybrids

hybridized sexually.

- Somatic hybrids can be readily used in breeding programme for transfer of resistance genes
- Hybrids can be produced even between such clones, which are completely sterile.

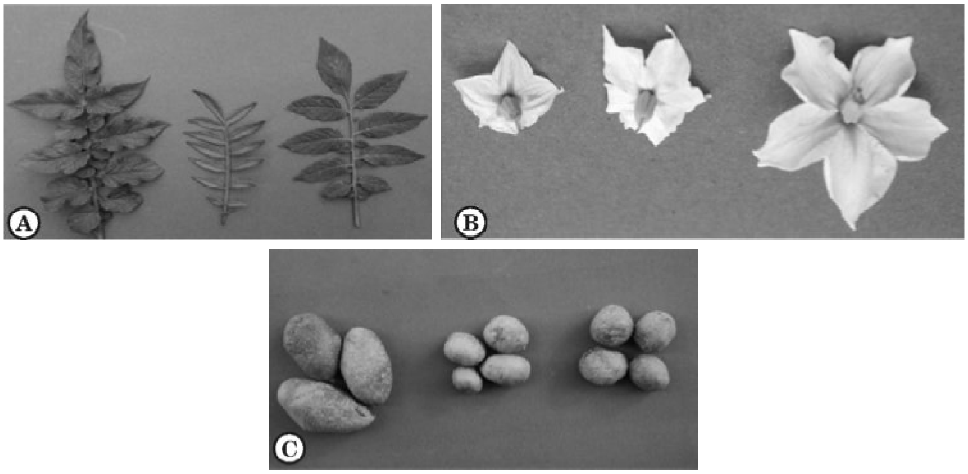

Fig. 1 (A) Leaves, (B) Flower and (C) tubers of parents (di) haploid C-13, 1 EBN wild species *S. pinnatisectum* and somatic hybrid, respectively (in sequence from left to right)

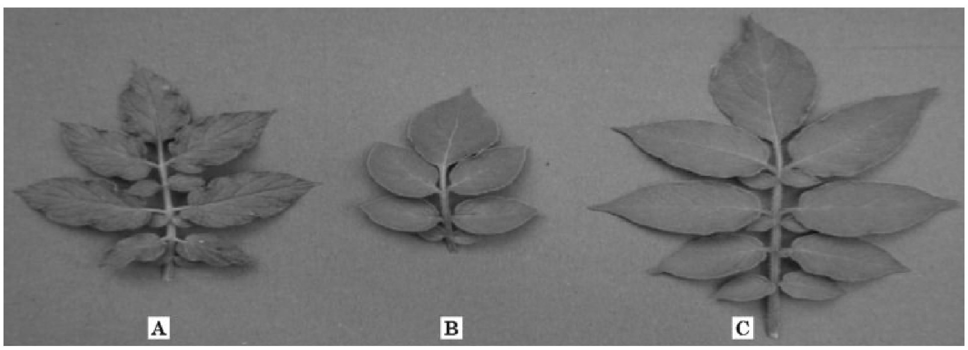

Fig. 2 Leaf of (a) parent S. tuberosum dihaploid C-13, (b) parent *S. etuberosum* and (c) somatic hybrid clone C-13 (+) *S. etuberosum*

- **Cytoplasm transfer can be done in one year, while back crossing may take 5-6 years. Even where backcrossing is not applicable, cytoplasm transfer can be made using this approach.**
- **Mitochondria of one species can be combined with chloroplast of another species. This may be very important in some cases and is not achievable by sexual means even between easily crossable species.**
- **Recombinant organelle genomes, especially of mitochondria, are generated in somatic hybrids. Some of these recombinant genomes may possess useful features.**

Limitations

- Techniques for protoplast isolation, culture and fusion are very complicated, tedious and time consuming.
- In many cases, chromosome elimination occurs from somatic hybrids leading to asymmetric hybrids. Such hybrids may be useful, but there is no control on chromosome elimination.
- Many somatic hybrids show genetic instability, which may be an inherent feature of some species combinations.
- Many somatic hybrids either do not regenerate or give rise to sterile regenerants. Such hybrids are useful for crop improvement. All interfamily somatic hybrids are genetically unstable and/or morphologically abnormal, while intergeneric and intertribal hybrids are genetically stable, but produce abnormal and/or sterile plants.

Conclusion

Somatic hybridization allows transfer of cytoplasmic organelle in a single generation and offer unique opportunities for combining mitochondria of one species and chloroplast of another species in a single hybrid. This capability may permit improvement of characteristics certain cytoplasmic male sterile line, which may lead to their commercial exploitation. In addition, even non-flowering and non-tuber bearing species can be utilized in breeding programme. The transfer of gene governing resistance to biotic and abiotic stresses is an important objective. In potato, this technique is already being used in commercial breeding programme of the Netherlands and Germany. In general, somatic hybrids have low to high levels of pollen fertility and most fertile can be used as male parents in backcrossing with one of fusion parents. It is likely that the approach of somatic hybridization will find greater applications in potato improvement for enabling transfer of useful genes from sexually incompatible species. In this context, it is important that the DNA segment carrying the desired gene from wild species is introgressed into the genome of cultivated potato and stable inherited. The possible mechanissm for such introgression are homeologous pairing leading to crossing over and intergenomic translocation. An understanding of the gene introgression mechanism may enable their enhancement using suitable treatment; this, in turn will enhance the opportunities for utilization of somatic hybrids in potato improvement.

Suggested Readings

Bidani A, Nouri-Ellouz O, Lakhoua L, Sihachakr D, Cheniclet C, Mahjoub A, Drira N, Gargouri-Bouzid R (2007) Interspecific potato somatic hybrids between *Solanum berthaultii* and *Solanum tuberosum* L. showed recombinant plastome and improved tolerance to salinity. Plant Cell Tiss Organ Cult 91:179–189

Bo³towicz B, Szczerbakowa A, Wielgat B (2005) RAPD analysis of the interspecific somatic hybrids *Solanum bulbocastanum* (+) *S. tuberosum*. Cell Mol Biol Lett 10:51–162

Bradshaw JE, Bryan GJ, Ramsay G (2006) Genetic resources (including wild and cultivated *Solanum* species) and progress in their utilisation in potato breeding. Potato res 49:49–65

Caruso I, Castaldi L, Caruso G, Frusciante L, Carputo D (2008) Breeding potential of *Solanum tuberosum – S. commersonii* pentaploid hybrids: fertility studies and tuber evaluation. Euphytica 164:357–363

Cheng J, Saunders JA, Sinden SL (1995) Colorado potato beetle resistant somatic hybrid potato plants produced via protoplast electrofusion. In Vitro Cell Dev Biol 31:90-95

Fock I, Collonier C, Purwito A, Luisetti J, Sonvannavong V, Vedel F, Servaes A, Ambroise A, Kodja H, Ducreux G, Sihachakr (2001) Use of *S. stenotomum* for introduction of resistance to bacterial wilt in somatic hybrids of potato. Plant Physio Biohem 39:899-908

Jadari R, Sihachakr D, Rossignol L, Ducreux G (1992) Transfer of resistance to *Verticillium dahliae* Kleb. from *Solanum torvum* S.W. into potato (*Solanum tuberosum* L.) by protoplast electrofusion. Euphytica 64:39-47.

Jansky S (2006) Overcoming hybridization barriers in potato. Plant Breeding 125:1-12

Kim-Lee H, Moon JS, Hong YJ, Kim MS, Cho HM (2005) Bacterial wilt resistance in the progenies of the fusion hybrids between haploid of potato and *Solanum commersonii*. Amer J Potato Res 82:129-137

Kozukue N, Misoo S, Yamada T, Kamijima O, Friedman M (1999) Inheritance of morphological characters and glycoalkaloids in potatoes of somatic hybrids between dihaploid *Solanum acaule* and tetraploid

Solanum tuberosum J Agric Food Chem 47:4478-4483

Mojtahedi H, Brown CR, Santo GS (1995) Characterization of resistance in a somatic hybrid of *Solanum bulbocastanum* and *S. tuberosum* to *Meloidogyne chitwoodi*. J Nematol 27(1):86-93.

Novy RG, Gillen AM, Whitworth JL (2007) Characterization of the expression and inheritance of potato leafroll virus (PLRV) and potato virus Y (PVY) resistance in three generations of germplasm derived from *Solanum etuberosum*. Theor Appl Genet 114:1161–1172.

Novy RG, Helgeson JE (1994) Somatic hybrids between *Solanum etuberosum* and diploid, tuber bearing *Solanum* clones. Theor Appl Genet 89:775-782

Nyman M, Waara S (1997) Characterisation of somatic hybrids between *Solanum tuberosum* and its frost-tolerant relative *Solanum commersonii*. Theor Appl Genet 95:1127-1132

Oberwalder B, Schilde-Rentschler L, Loffelhardt-Ruob B, Ninnemann H (2000) Differences between hybrids of *Solanum tuberosum* L. and *Solanum circaeifolium* Bitt. obtained from symmetric and asymmetric fusion experiments. Potato Res 43:71-82

Orczyk W, Przetakiewicz J, Nadoloska-Orczyk A (2003) Somatic hybrids of *Solanum tuberosum*-application to genetics and breeding. Plant Cell Tissue Organ Cult 74:1–13

Polgar Z, Wielgus SM, Horvath S, Helgeson JP (1999) DNA analysis of potato + *Solanum brevidens* somatic hybrid lines. Euphytica 105:103–107.

Polzerová H, Patzak J, Greplová M (2011) Early characterization of somatic hybrids from symmetric protoplast electrofusion of *Solanum pinnatisectum* Dun. and *Solanum tuberosum* L. Plant Cell Tiss Organ Cult 104:163–170

Rasmussen JO, Nepper JP, Kirk H-G, Tolstrup K, Rasmussen OS (1998) Combination of resistance to potato late blight in foliage and tubers by interspecific dihaploid protoplast fusion. Euphytica 102:363–370

Rokka V-M, Tauriainen A, Pietila L, Pehu E (1998) Interspecific somatic hybrids between wild potato *Solanum acaule* Bitt. and anther-derived dihaploid potato (*Solanum tuberosum* L.) Plant Cell Rep 18:82-88

Sarkar D, Tiwari JK, Sharma S, Poonam, Sharma S, Gopal J, Singh BP, Luthra SK, Pandey SK, Pattanayak D (2011) Production and characterization of somatic hybrids between *Solanum tuberosum* L. and *S. pinnatisectum* Dun. Plant Cell Tiss Organ Cult 107: 427-440.

Serraf I, Sihachakr D, Ducreux G, Brown SC, Allot M, Barghi N, Rossignol L (1991) Interspecific somatic hybridization in potato by protoplast electrofusion. Plant Sci 76: 115-126

Spooner DM, Salas A (2006) Structure, Biosystematics, and Genetic resources. In: Gopal J, Khurana SM Paul (eds.), Handbook of potato production, improvement and postharvest management. Food Product Press, New York, pp 1-40

Szczerbakowa A, Maciejewska U, Zimnoch-Guzowska E, Wielgat B (2003) Somatic hybrids Solanum nigrum (+) S. tuberosum : morphological assessment and verification of hybridity Plant Cell Rep 21:577–584

Szczerbakowa A, Tarwacka J, Oskiera M, Jakuczun H, Wielgat B (2010) Somatic hybridization between the diploids of *S.* x *michoacanum* and *S. tuberosum*. Acta Physiol Plant 32:867–873.

Tek AL, Stevenson WR, Helgeson JP, Jiang J (2004) Transfer of tuber soft rot and early blight resistances from *Solanum brevidens* into cultivated potato Theor Appl Genet 109:249–254

Thieme R, Rakosy-Tican E, Gavrilenko T, Antonova O, Schubert J, Nachtigall M, Heimbach U, Thieme T (2008) Novel somatic hybrids (*Solanum tuberosum* L. + *Solanum tarnii*) and their fertile BC1 progenies express extreme resistance to potato virus Y and late blight. Theor Appl Genet 116:691–700

Thieme R, Rakosy-Tican E., Nachtigall M, Schubert J, Hammann T, Antonova O, Gavrilenko T, Heimbach U, Thieme T (2010) Characterization of the multiple resistance traits of somatic hybrids between *Solanum cardiophyllum* Lindl. and two commercial potato cultivars. Plant Cell Rep 29:1187–1201

Tiwari JK, Poonam, Sarkar D, Pandey SK, Gopal J, Kumar SR (2010) Molecular and morphological characterization of somatic hybrids between *Solanum tuberosum* L. and *S. etuberosum* Lindl. Plant Cell Tiss Organ Cult 103:175–187

Tiwari JK, Sarkar D, Poonam, Sharma S. and Gopal J. (2011) *Solanum tuberosum* (+) *S. pinnatisectum* somatic hybrids: a new source of horizontal resistance to potato late blight in India. SOL Newsletter March 2011, p 4.

Yamada T, Misoo S, Ishii T, Ito Y, Takaoka K, Kamijima O (1997) Characterization of somatic hybrids between tetraploid *Solanum tuberosum* L. and dihaploid *S. acaule*. Breed Sci 47:229-236

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8

POTATO TRANSGENICS FOR IMPROVEMENT OF AGRONOMIC AND QUALITY TRAITS

Virupaksh U Patil, Hemant B. Kardile and Clarissa Challam

Contents

Introduction

Given the significance of the potato, research on the genetic improvement of this crop is important. Potato breeders are challenged by an autotetraploid genome, asexual propagation, breeding principles and practices that are quite different from those employed for the majority of diploid (or allopolyploid), seed-propagated crops and numerous market limiting traits. Moreover, the genetic base of the cultivated potato is considered to be narrow and yield stasis exists within the potato germplasm. However, potato has an extremely rich gene pool with seven cultivated and 199 wild species. To broaden the genetic base of the cultivated potato and introduce new traits, potato species have been used as a source of new genes.

Potato has always been a close companion to biotechnology. Potato, being vegetatively propagated crop, is highly amenable to asexual clonal propagation techniques *in vitro* and consequently genetic engineering. Besides, potato has the distinct advantage of possessing a commercially viable carbon sink in the form of tuber. Therefore, it has also been looked upon as a potential bioreactor for the production of novel compounds of therapeutic and industrial values. A brief account of successful application of biotechnology in potato production and improvement is discussed here.

In vitro culture

Potato is perhaps the premier example of a crop plant to which *in vitro* technology has been most extensively applied in all aspects of production, improvement and germplasm handling. This in vitro propagation capacity of potato has helped tremendously to overcome genetic nature of this crop imposing several limitations on seed multiplication, conservation of genetic resources and genetic improvement. The first successful establishment of tissue cultures from potato tubers was reported as early as 1951. Since then, the *in vitro* produced disease-free plants, somaclones, haploids and somatic hybrids, plant resistant to diseases and microtubers produced in test tubes have been moved from laboratory to the field and propagated on a large scale in various countries. Nodal segment culture in which axillary buds and terminal buds grow into new plants is predominantly used for the initial *in vitro* shoot multiplication in potato. *In vitro*-derived microplants are used either as direct transplants in the greenhouse/field for the production of minituber/tubers or as explant sources for the production of microtubers *in vitro*. Micropropagation revolutionizes potato seed production system by supplying disease-free transplants without any seasonal barrier. *In vitro* potato cultures have also been used to conserve and distribute valuable genetic resources, which are otherwise difficult or impossible using the conventional approaches.

Microtubers

Microtuber has subsequently augmented potato seed production. Microtubers are miniature tubers developed under tuber-inducing conditions *in vitro*. These small dormant tubers are particularly convenient for handling, storage and distribution. Unlike micopropagated plantlets, they do not need the time-consuming hardening period in a greenhouse, and can be adapted easily to large-scale mechanized planting in the field. The ease, with which microtubers can be produced, handled and exported, bolsters potato seed production schemes.

Potato transgenic

Genetic modification has many advantages for plant breeding, and these advantages are even more striking in crop with comlex inheritance such as potato. While conventional breeding manipulates genomes in a largely uncontrolled fashion, requiring generations of selection to assemble and fix the maximum number of desirable traits, transformation offers a direct approach, allowing introgression of a single, distinct trait without linkage drag. Thus genetic modification allows rapid and often powerful improvement of crop plants and is not limited by compatibility barriers. In cases where genetic diversity among sexually compatible relatives of crop species is insufficient for a particular trait, genetic modification may represent the only possibility for improvement in that trait. Transformation offers a highly effective means of adding single gene to existing elite potato clones with no or very minimal distrubances to their genetic background. This is virtually impossible via traditional breeding as, due to the high heterozygosity in the tetraploid potato genome, the genetic integrity of potato clones is lost upon sexual reproduction as a result of allele segregation. As a consequence, potato transformation results the only effective way to produce isogenic lines of specific genotypes/cultivars.

Like most Solanaceous species, potato is readily transformed by *Agrobacterium tumefaciens*. Potato was first transformed in 1987 in order to compare the expression of an organ-specific endogenous gene and a tagged variant introduced by *Agrobacterium* mediated transformation. Also in 1987, De Block and colleagues reported the generation of transgenic potato expressing the *bar* gene, which confers herbicide resistance to bialaphos. Soon after these initial transformation experiments, the Mosnanto Company announced the creation of transgenic potatoes resistance to potato Colorado beetle and viruses X and Y (New Leaf-First transgenic potato commercialized in 1984 by USDA and FDA). Very recently J.R. Simplot has obtained USDA and FDA permission to commercialize Innate - A transgenic potato with low bruising and acrylamide when used by processing industries to make chips and french fries. To date potato has become one of the model crops for transformation studies. The progress was motivated by the advantages that transformation offered for the genetic improvement in potatoes relative to the genetic limitations associated with traditional potato breeding. Till date various tansformation approaches have been successfully applied in potato like, *Agrobacterium tumefaciens* mediated (Ooms *et al.* 1986), *Agrobacterium rehizogenes* medicated (Stiekema *et al.* 1988), direct DNA uptake (Valkov *et al.* 2011), particle bombardment (Romano *et. al.* 2003), PEG mediated (Craig *t al.* 2006) and ensife adherence (Wendt *et al.* 2012). However, among these *Agrobacterium* mediated gene transfer is the most preferred approach and is being routinely performed in laboratories worldwide.

Potato transgenics for viral resistance

Genetic engineering by employing different strategies for virus resistance is one of the major success stories in potato transgenic biology. Virus-resistant transgenic plants can be developed by employing the pathogen-derived resistance (PDR). It can be achieved by expressing the viral sequence in plant cells leading to plant protection (prins et al, 2008). A prerequisite for the use of PDR is that viral sequence should not interfere with essential host functions. Transgene for PDR can be separated into protein mediated resistance and nucleic acid-mediated resistance. Various viral proteins can be used for PDR are replicases, movement proteins, proteases and, most often, coat protein(s) (CP) (Tepfer, 2002). Coat protein of the potato virus Y (pvy cp) confers resistance to potato virus Y (PVY). The CP gene of Potato mosaic virus (PMV) strain N605 provides resistance in transgenic potato plants against this virus strain and also to the related strain 0803 (Malnoe et al, 1994). Mixed virus resistance were achieved for PVX and PVY by engineering potato cultivar with CP genes from both the viruses (Lowson et al, 1990). Apart from the Cp genes, other viral genes can be used as the transgene for developing the viral resistance. For instance viral replication genes replicase domain (*plrv orf1*) and helicase domain (*plvr_orf2*) is silenced to achieve the PLRV resistance in potato. Eukaryotic initiation factor, eIF4E-1, isolated from *Solanum chacoense, S. demissum,* and *S etuberosum* also plays important role in providing the viral resistance. Over-expression of Eva 1 in transgenic potato plants silenced for the native eIF4E-1 conferred the viral resistance to PVY. Since the gene sources of Eval are sexually compatible with potato, molecular strategies can be employed to produce intragenic potato cultivars (Duan et al, 2012). Broad-spectrum resistance against three RNA viruses is achieved by silencing ORF2 gene of Potato virus X, Helper Component Protease gene of Potato virus Y and Coat protein gene of Potato leaf roll virus (Arif et al, 2012). A novel strategy has been employed to control viroids, which encode none of the proteins necessary to support their own replication but rely on host components for survival. Resistance against potato spindle tuber viroid (PSTVd) was achieved by expressing a double stranded RNA-specific ribonuclease from yeast. Since the first field test of transgenic potato expressing the coat protein gene, there have been many large-scale field trials of transgenic potato, which confirmed durability of the trait.

Potato transgenics for fungal disease resistance

Fungal pathogens cause several important diseases in potato. Among these, late blight (caused by *Phytophthora infestans*) was responsible for the infamous Irish potato famine of 1845 and has become a global threat to potato production, especially during the last decade because of emergence of complex races of the pathogen. Recently, a dominant resistant gene (*RB* gene) has been cloned from wild potato species *S. bulbocastenum*. Durable disease resistance can be achieved by functional stacking of broad spectrum resistance (R) genes in potato. Functional stacking of three broad spectrum potato resistance genes (Rpi), Rpi-sto 1 (*Solonum stoloniferum*) Rpi-nvnt 1.1 (*S. venturii*) and *Rpi-blb3* (*S. bulbocastamum*) provided the durable resistance for late blight of potato. Elicitin Resistance (ELR) gene from *Solamnum microdontum* targets elicitin, a conserved protein with an important biological function, making it less likely that the pathogen will evolve to evade resistance. ELR works in association with a key gene in the immune system, BAK1/SERK1. Potato transgenics with ELR Gene provided more resistance to several strains of blight. Introduction of RB gene into susceptible cultivars conferred late blight resistance. Limited field trials of RB transgenic potato lines conducted by Central Potato Research Institute, Shimla demonstrated durable resistance under Indian condition. Another strategy used for developing late blight resistance in potato is RNAi technology. Using Host delivered (HD) RNAi-mediated gene silencing technology successful late blight resistant transgenic potato lines have been developed by silencing the disease causing pathogen *avr* genes.

Potato transgenics for insect pest resistance

Potato tuber moth (*Phtorimaea operculella*) is one of the most important pests in tropical and subtropical regions. All attempts to improve potato plants for resistance to Potato tuber moth using conventional breeding methods have been failed. One of the best and common methods for biological control of the pests is the *cry1Ab* gene. This gene encoding a crystal protein that causes perturbance of the digestive apparatus of lepidopteran insects and insect death follows. Cry1Ab protein has high mortality effects on potato tuber moth. Cry3A confers resistance to coleopteran insects of potato. CPRI, Shimla has developed transgenic potato lines carrying *CryIAb* gene from *Bacillus thurengenisis* against potato tuber moth (PTM). Transgenic tubers stayed free from PMT damage in both *In vitro* and field assays.

Potato transgenics for improved quality traits

Potato protein suffers from deficiencies in sulfur containing amino acids. Plant breeding has had limited success in improving the nutritional quality of plant proteins. Introduction of gene encoding seed albumin protein from amaranth (*AmA I*), which is rich in cysteine and methionine, has elevated the level of sulfur containing amino acids of potato proteins. Amylopectin rich potato has been developed by silencing the granule-bound starch synthase (GBSS) gene. CPRI, Shimla in collaboration with National Centre for Plant Genome Research (NCPGR), New Delhi has already introduced this gene into several Indian potato cultivars. This may partly help addressing protein-calorie malnutrition in the country. Transgenic potato lines to improve cold-chipping attributes by RNAi-mediated silencing of vacuolar invertase gene (*Va-INV*) and UDP Glucose Phosphatase (*UGPase*) gene are in different stages of development and evaluation.

Conclusions

From the 16th century Andean highlands to the 21st century cultivated potato species worldwide, biotechnology has transformed potato from test tube to the field in such a way that its production, especially in developing countries, has outpaced all other crops. These developments have far-reaching implications not only in the production and improvement of present day potato but also for the induction of genetic variability, which would enable the synthesis of novel future potatoes.

Table: List of traits targeted for developing the potato transgenic world wide

Gene introduced	Gene Source	Product	Function
		Viral Resistance	
Plrv_orf1	Potato Leaf Roll Virus (PLRV)	Putative replicase domain of the PLRV	Confers resistance to PLRV through gene silencing mechanism
Plrv_orf2	Potato Leaf Roll Virus (PLRV)	Putative helicase domain of the PLRV	Confers resistance to PLRV through gene silencing mechanism
Pvy_cp	Potato Virus Y (PVY)	Coat proteine of the PVY	Confers resistance to PVY through "pathogen-derived resistance "mechanism
Eva1	*S. chacoense, S. demissum, S.etuberosum*	Eukaryotic intiation factor	Confers the viral resistance to PVY
Pvx orf2	Potato virus X (PVX)		Confers the viral resistance to PVX
Helper Component Protease	Potato virus Y (PVY)	Helper Component Protease	Confers the viral resistance to PVY
Cp	Potato Leaf Roll Virus (PLRV)	Coat proteine	Confers the viral resistance to PLRV
		Fungal Disease resistance	
RB	*S.bulbocastenum*		Late blight resistance
Rpi-sto 1	*S.stoloniferum*		Late blight resistance
Rpi-vnt 1.1	*S.venturii*		Late blight resistance
Rpi-blb3	*S.bulbocastanum*		Late blight resistance
ELR	*S. microdontum*	Targets elicitin	Resistance to several strains of blight

Insect Pest Resistance			
Cry3A	*B. thuringiensis*	Cry3A delta endotoxin	Confers resistance to coleopteran insects by selectively damaging their midgut lining
CryIAb	*B. thuringiensis*	CryIAb delta endotoxin	Confers resistance to potato tuber moth (PTM)
Quality Traits			
asn 1	*S.tuberosum*	Double stranded RNA	Triggers the degradation of Asn 1 transcripts to impair asparagine formation
gbss	*S.tuberosum*	No fuctional granule-bound starch synthase (GBSS) anzyme is produced	Reduces the level of amylose and increases the level of amylopectin in starchgranules
pPhL	*S.tuberosum*	Double stranded RNA	Triggers the degradation of PhL transcripts to limit the formation of reducing sugars through starch degradation
pR1	*S.tuberosum*	Double stranded RNA	Triggers the degradation of R 1 transcripts to limit the formation of reducing sugars through starch degradation

Suggested Readings

Debasis Pattanayak, Virupaksh U Patil, Jagesh Tiwari, SK Chakrabarti and BP Singh (2010) Role of Biotechnology in Potato Improvement. December, 2010, *CPRI, News Letter*.

Pris M, Laimer M, Noris E, Schubert J, Wassenegger M, Tepfer M (2008) Strategies for antiviral resistance in transgenic plants. Mol Plant Pathol., 9, 73-83.

Tepfer M (2002) Risk assessment of virus-resistance transgenic plants. Annu. Rev. Phytopathol., 40, 467-491.

Tenllado F, Llave C, Diaz-Ruiz JR (2004) RNA interference as a new biotechnological tool for the control of virus diseases in plants. Virus Res., 102, 85-96.

Duan H, Richael C, Rommens CM (2012) Overexpression of the wild potato eIF4E-1. Transgenic Res. 2012 Pct' 21(5): 929-38. doi: 10.1007/s11248-011-9576-9. Epub 2011.

Arif M, Azhar U, Arshad M, Zafar Y, Mansoor S, Asad S (2012) Engineering broad-spectrum resistance against RNA viruses in potato. Trans Res., 21, 303-311.

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AGRO-TECHNIQUES FOR POTATO PRODUCTION

SS Lal

Contents

Introduction

Seed is the costliest input in potato production and accounts about 40-50% cost of cultivation. This is primarily due to high seed rate per hectare and its high cost. The importance of seed size tubers in the produce and its preferential prices cannot be ignored in seed potato production programme. Since it is a short duration crop, schedule of all the cultural operations is always very tight and time bound. The following factors are important to get good yields of seed potato crop.

Climate

Potato plant is sensitive to several climatic factors, such as temperature, rainfall, humidity and photoperiod which exert a considerable influence on its growth and tuber development. Good crop growth is observed when days are sunny and nights are cool. Low temperature, high light intensity and short days are conducive for early initiation of tuberization and subsequent tuber development. Seed tubers produced at 16-22°C have been found superior to those produced at temperature above 27°C. The maximum tuberization takes place at the mean temperature of 18 to 20 °C and is inhibited at temperatures above 29 °C. In nutshell, frost free, sunny days and cool nights are ideal for potato crop.

Growth Stages

In potato, three critical growth stages have been identified *i.e.* stolon formation, tuber initiation and tuber bulking. The first two stages are important from the nutritional point of view and serve as an index of final potato yields while the last stage *i.e.* tuber bulking is generally linked to the appearance of fungal and bacterial diseases. In hills, where the crop is generally taken under long day conditions during summer months, the moisture stress at stolon formation stages causes considerable reduction in potato yields.

Soil Preparation

The seed crop is raised in a field free from soil borne diseases. No solanaceous crop should be grown before the seed potato crop. The potato grows well on well-drained sandy loam to clay loam soils rich in humus having good drainage facilities. Potato plant prefers soil in acidic to neutral range (pH 5.5 to 7.5). High or low pH hinders plant growth besides affecting nutrients availability to the plant.

A fine textured soil with minimum clods is considered good for potato cultivation. The field is ploughed to a depth of 20 cm and planking is done immediately to avoid soil moisture loss. In the hills two ploughings with mould board before snowfall in October-November and two ploughings before potato planting give desirable soil tilth. Where as in the plains after deep ploughing and burying the green manure crop, two ploughings with disc harrow and plankings before potato planting are sufficient. Hot weather cultivation consisting of ploughings the field during summer months (May-June) reduces the incidence of soil borne diseases and pests and also controls perennial weeds.

Planting Time and Method

Planting and harvesting time varies with agro-climatic conditions and availability of aphid free period for seed potato crop. The crop period for growing seed potato crop is given in table-1.

Pre-sprouting: Seed tubers are pre-sprouted before planting which helps in developing multiple, thick, stout, green and healthy sprouts. This also reduces the emergence time and uniform plant stand, beside early maturity.

In the hills, the seed tubers are pre-sprouted by keeping them in small slotted wooden trays of 15-20 kg capacity or spread in a thin layer on semi-*pucca* floor in the shade. The tubers having no sprout or thin sprouts or hairy sprouts should be rejected. While in the plains, potato seed tubers should be taken out from the cold stores 10-15 days before planting and kept in baskets, wooden or plastic trays in the shade having diffused light.

Method of planting

More than 80 per cent of area under potato is planted manually after opening the shallow furrows, broadcasting or placement of fertilizer mixture, placing seed tubers followed by ridging with spade or bullock drawn or tractor drawn ridger. Another method is that first ridges are formed after application of fertilizers and insecticides and then tubers are dibbled with *Khurpi* (a narrow blade tool) 5-7 cm deep on the ridges manually. Care has to be taken that tubers do not come in direct contact with the fertilizers and should remain 4-5 cm above or side of fertilizer zone. Potatoes are also planted with a tractor drawn semi and automatic potato planters which combine few or all the operations *viz*., opening the furrows, application of fertilizers, placement of seed tubers, ridging and application of insecticides in one operation.

Seed size, spacing and seed rate

Seed rate depends on the size of tubers used in planting for ware as well as seed crop. Tubers of different sizes can be used effectively without increasing seed rate by space adjustment. In general, 25-50 g tubers are recommended for ware as well as seed production in the plains. About 25 to 35 q/ha seed rate is required depending on the size of seed tubers. The inter row spacing for seed crop for manual, bullock drawn and tractor drawn implements can be kept at 45, 50 and 60 cm, respectively. A plant population of 1.00 to 1.11 lakh per ha is maintained to derive the maximum benefit and stem density of at least 40-45 stems/m^2 for optimum number and yield for seed purpose.

Weed management

Weeds pose a serious problem in potato crop in the plains as well as in the hills. They compete with the main crop for moisture, nutrients, light and space during crop growth period and in addition make difficult the intercultural operations at earthing up and towards maturity and harvesting. They also serve as an alternate hosts of several insects/pests and diseases. Early control of weeds is obligatory from the seed production point of view to avoid serving as alternate hosts for viruses and vectors. After weeding and hoeing, earthing up is to be done immediately to conserve soil moisture and proper ridge formation.

Use of herbicides for weed management is of great significance in potato. It checks early weed growth, reduces mechanical damage to the plants, quick and less laborious. It also minimises the spread of mechanically transmitted viruses like virus X and S by omitting manual weed control during crop growth period. The herbicides used for weed management in potato along with their time of application and types of weed flora checked are given in table 2.

Roguing: Before final inspection for certification minimum three roguings are required during the crop period. First roguing should be carried out soon after the completion of emergence. It should be done after 40-45 days and 30-35 days after planting in the hills and plains, respectively. The second roguing is required after 60-65 days of planting in the plains and 70-80 days (at flowering) in the hills. Third roguing is done at near maturity. During roguing all atypical plants and those showing symptoms of mottling, mosaics, veinal necrosis, crinkle, rolling of leaves and development of purple or yellow colour should be removed. While roguing, the diseased plants are removed along with the tubers.

Haulms destruction: Haulms destruction is done to avoid spread of diseases caused by viruses through aphids and fungi. The haulms destruction is done by cutting, pulling out or killing through herbicides, 15-20 days before harvesting when aphid population reaches above the critical limits *i.e.* 20 aphids/100 compound leaves.

Harvesting and Yield

The skin of the tubers can be hardened by withholding the irrigation at least 10 days before harvesting. Utmost care is taken to see that the tuber skin is hard enough to withstand impact of harvesting tools and machinery. Therefore, crop is to be harvested at 15-20 days of haulm cutting and at proper soil moisture. The harvesting in plains must be completed before March to avoid charcoal rot and damage by high temperature.

Potato harvesting manually is most time and labour demanding operation and requires more than 100 man days/ha. It may be done by tractor drawn one or two row potato digger or by the bullock drawn one row digger or with the help of spade or *Khurpi*. With tractor drawn single row potato elevator digger the man power is reduced to 50 man days/ha and covers one ha per day with exposure of over 85 per cent tubers. On the other hand, with animal drawn single row potato digger, a whole day is required to cover one ha and about 3.0 per cent potatoes are cut during digging operation.

In the hills and regions where crop is taken under long day conditions and is rainfed, the harvesting is completed after the offset of rains. In the hills, the harvesting is done either manually with small tools or with bullocks mainly because of small terrain and holdings. The harvested produce is dried in open.

Yield: In potato, yield is a function of number of stems, number of effective stolons, number and weight of tubers/plant and varies with variety and agro-environmental conditions under which crop is grown. These parameters vary with cultivars. The yield of seed crop ranges from 20 to 25 tonnes/ha depending upon the duration of crop and time of haulms cutting.

Seed certification standards

For certified seed, the following standards are to be observed. These limits should not exceed for the certified seed production.

Off type	:	0.1%
Mild mosaic	:	3.0%
Severe mosaic/ PLRV/PVT/LST	:	1.0%
Brown rot	:	3 plants/ha
Common scab	:	5% incidence
Black scurf	:	5% incidence
Cut/bruised tubers	:	5% tubers
Late blight	:	1% incidence
Dry rot	:	1% incidence
Total disease	:	5% incidence

Other requirements of seed certification: The general requirements for seed certification crop are:

a. **Choice of aphid free locations and period:** In the hills healthy seed production programme can be taken up in the higher hills at 2500 M above the sea level. In such places climatic conditions do not permit multiplication and spread of aphids (the virus vector). In the plains the healthy seed tubers can be produced during low aphid period from October to January.

b. **Isolation:** Isolation of seed crop is very essential to avoid contamination. The seed crop should be separated from the crop of ware potatoes by a distance at least 20 meters. To avoid mixture between the varieties, 5 meters distance is suggested between the two varieties of the same seed grade or category.

c. **Crop rotation:** Potato seed crop should not be grown in a field in which potato crop has been grown in the previous year. Suitable crop rotation will not only help in the elimination of soil borne pathogens but will also help to control the problem of ground-keepers which posses a problem for maintaining varietal purity in the hills. It is also desirable that solanaceous crops like tomato, chillies, brinjal and tobacco are not grown in the previous years.

d. **Variety and seed:** In seed production programme, only approved/ released variety should be grown for the production of healthy seed. The healthy seed of such varieties should be obtained form a reliable source like NSC or State Department of Agriculture/Horticulture.

e. **Cultural practices:** It is essential that all agronomic practices are adopted which help to produce maximum yield of seed size tubers.

f. **Plant protection measures:** All plant protection measures which effectively control the spread and multiplication of insect vectors and other pathogens are to be adopted.

g. **Methods of Inspection for certification:** The crop should be fully grown at the time of inspection and the emergence should be uniform. Too early or too late inspection serves no purpose of seed certification. Final field inspection for certification is carried out by taking minimum four counts of 100 plants, each are taken randomly on four spots in an area of one hectare. For additional each hectare or part thereof one sample of 100 plants is observed for all visible mosaics, other diseases and off types. After the dates are disclosed on the basis of actual aphid count for haulms cutting, certification authority is to ensure that haulms at the ground level are removed on due dates and there is no regrowth of stems at all. Finally the graded produce is inspected for tuber grades and surface infections.

Table 1. The crop period for seed production in different parts of the country

Zones	Crop Period
North-Western hills	April-September
North-Western plains	1st week of October- Mid January
North Central plains	2nd week of October-Mid January
North-Eastern plains	3rd week of October- End January

Table 2. Herbicides for weed management in potato

Name of herbicide	Dose (kg a.i./ha)	Time of application	Type of weed flora controlled
Fluchloralin	0.70-1.00	Pre-planting*	Annual grasses and broad leaf weeds
Pendimethalin	0.50	Pre-planting*	Annual grasses & broad leaf weeds
Atrazine	0.50	Pre-emergence	Annual grasses and broad leaf weeds
Isoproturon	0.75-1.00	Pre-emergence	Broad leaf weeds
Linuron	0.50-0.75	Pre-emergence	Annual grasses and broad leaf weeds
Methabenz-thiazuron	1.00	Pre-emergence	Annual grasses and broad leaf weeds
Metribuzin	0.75-1.00	Pre-emergence	Annual grasses and broad leaf weeds
Oxyfluorfen	0.10-0.20	Pre-emergence	Annual grasses and broad leaf weeds
Simazine	0.50	Pre-emergence	Annual grasses and broad leaf weeds
Paraquat	0.40-0.60	Post-emergence**	Annual grasses and broad leaf weeds

* Spray on soil before planting and incorporate in soil to reduce volatilization losses. ** At 5 percent plant emergence of potato crop as directed spray on weeds.

Suggesting Rading

Dua VK, JP Singh, Manoj Kumar, PM Govindakrishnan, SS Lal and BP singh. 2012. Cultural Management of Crops in Potato Based Cropping Systems in India. CPRI Extension Bulletin No. 39 (Revised), Central Potato Research Institute, Shimla, Himachal Pradesh, India, 69 pp.

Gaur PC. 1999.Manual for True Potato Seed (TPS) Production and Utilization. CPRI Extension Bulletin No. 30 (E), Central Potato Research Institute, Shimla, Himachal Pradesh, India, 14 pp.

Gupta V.K., S. Kumar, U. Sah, S. Kumar and PH Singh. 2004. Quality seed potato production in NEH Region in India. CPRI Extension Bulletin No. 62, Central Potato Research Institute, Shimla, Himachal Pradesh, India, 32 pp.

Pushkarnath. 1976. Potato in sub tropics orient Longman Ltd. New Delhi 289 pp.

Region specific technologies for potato production in India (Eds.) *AICRP (Potato) Bulletin No. 3,* All India Coordinated Research Project on Potato, Central Potato Research Institute, Shimla 171 001. P 164+vi

Sharma, A., A.S. Chadel, V. Kumar and B.P. Singh. 2012. Potato Cultivation in North Western Himalayas. CPRI Extension Bulletin No. 95 (Revised), Central Potato Research Institute, Shimla, Himachal Pradesh, India, 72 pp.

Singh Sarjeet and Birbal. 2007. *Beej Aaloo ka Utpadan – Siddhant evam kaarak.* Nirmal Vijay Printer, pp. 117.

Singh, V.P., Maiti, R. K, Anureet Kaur and A. Benavides Mendoza. 2002. Potato Agro Technology *In* :Advance in Potato Science (RK Maiti and VP Singh Eds.) Gaurav society of ARIC, Hisar,India. 343-83 pp.

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10

ORGANIC POTATO PRODUCTION

NC Upadhayay

Contents

Introduction

During the last two decades, 'Organic Agriculture' has emerged as a dynamic 'Alternate Farming System'. This has been necessitated as a consequence of resource degradation in our efforts to achieve high yields in various crops to meet the increasing demand of food by the burgeoning population. Simultaneously, there is also a growing global awareness on food health and environment. Like other food stuffs, the consumers are also concerned about the potato, they eat. Both the international and domestic communities are becoming more and more conscious on issues like residues of poisonous agrochemicals in potatoes and their associated health and environmental hazards. In view of such growing awareness, there has been a paradigm shift and interest to adopt organic potato production systems, which are ecologically and economically viable and socially just. India with its varied climate and variety of soils has an enormous potential for organic production of potato. The wide product base, high volume of production round the year, strategic geographic location, high international demand, abundant sunlight and availability of labour at comparatively low cost make India an apt location for organic potato production. The primarily goal of organic potato production is to optimize the health and productivity of interdependent communities of soil, plants, animals and people.

The potato produced without the use of agrochemicals *viz*. fertilizers, pesticides, herbicides, synthetic growth regulators *etc*. is called organic potato. Its production depends mainly on improved seed including genetically engineered potato strains, crop rotation, minimum tillage practices, manuring through organic materials (*viz*. crop residues, animal excreta, nitrogen fixing legumes, green manure, off farm organic residues), mineral bearing rocks (*viz*. rock phosphate and gypsum), management of pest and diseases through non-polluting substances like bio-pesticides application of biological control principles including use of sulphur dust, extracts of toxic plants and antibiotics derived from fermentation. It permits use of biologically produced plant growth regulators, wind energy and solar energy. The weed control is affected through crop rotations and manual weeding. The operative principal objectives of organic potato production are:

- Produce potato of high nutritional quality in sufficient quantity.
- Work with natural systems rather than seeking to dominate them.
- Make maximal but sustainable use of local resources.
- Encourage and enhance the biological cycle within farming system involving micro-organism, soil flora and fauna, plants and animals.
- Ensures the basic biological functions of soil-water-nutrients-human continuum.
- Maintain and increase the long term fertility of soils.
- Use as far as possible, renewable resources in locally organized agricultural systems.
- Work, as much as possible, within a closed system with regard to organic matter and nutrient elements.
- Avoid all forms of pollution that may result from agricultural techniques.
- Maintain the genetic diversity of potato and its surroundings.
- To allow potato producers adequate returns and satisfaction from their

work, including a safe working environment.

- To consider the wider social and ecological impact of potato cultivation.

Approaches to produce organic potato

The different approaches available to be used alone or in combination to produce organic potato are as following:

1. Organic amendment

i) Bulky organic manures (viz. FYM, vermicopost etc.)

ii) Green manure (viz. dhaincha, sunnhemp etc.)

iii) Concentrated organic manures (viz. groundnut cakes, neem cake etc.).

2. Biofertilizers (*viz. azotobacter, phosphorus solubilizing bacteria, mycorrhiza etc.*)

3. Biodynamic

4. Homoenutrients and protectants.

5. Bio em enzyme approach

6. Agnihotra

7. Panchagavya

Out of these, the results of five approaches used in potato are as following:

Bulky organic manures

A list of bulky organic manures available is given in Table-1. The studies conducted in Central Indo-gangetic alluvial plains have revealed that vermicompost is a better source of organic manure than FYM. The reasons could be presence of enzymes, hormones, growth regulators along plant nutrients in vermicompost (Kumara Swamy, 2002). In first year, Kufri Anand, Kufri Sutlej, Kufri Pukhraj, Kufri Chipsona-1 and Kufri Chipsona-2 produced 14.04, 17.52, 16.02, 16 and 12.04 t/ha tubers, when vermicompost was used as a source of organic manure. The corresponding yield from farmyard manure was 20.6, 21.7, 18.5, 18.4 and 13.6 t/ha. Compared to organic manure, the tuber yields from inorganic fertilizers wre 26.68, 22.01, 2404, 15.02 and 16.8 q/ha in Kufri Anand, Kufri Sutlej, Kufri Pukhraj, Kufri Chipsona-1 and Kufri Chipsona-2 respectively. A perusal of grade wise tuber yield revealed that the seed size (25-75 g) and chats (<25g) were more, when raised organically and increase in yield from inorganic fertilizers was primarily due to increase in large size >75g) tuber. An increase in tuber size by application of nitrogen and potassium through inorganic fertilizer is well known (Grewal et.al. 1992). In succeeding years, the organic tuber yield increased consistently 70-80%) in all cultivars, when raised on same plot each year (Figs.1& 2), indicating trend towards yield stabilization.

Table 1: Average nutrient content

Amendment	Percentage content (dry wt)		
	Nitrogen	Phosphoric acid(P_2O_2)	Potash (K_2O)
Bulky organic manures			
Farmyard manure	0.95	0.62	2.20
Rural compost	0.75	0.63	1.05
Urban compost	1.35	0.62	1.43
Sewage sludge	2.75	0.75	0.35
Sewage sludge activated.	5.41	3.15	0.62
Vermicompost	1.80	0.22	0.40
Green manure crops			
Dhaincha (Sesbania aculeata)	2.01	0.32	2.03
Sunhemp (Crotalaria juncea)	2.16	0.48	2.11
Cluster bean (Cyamopsis tetragonoloba)	1.46	0.25	1.89
Cowpea (Vigna catjang)	2.45	0.56	2.32
Concentrated organic manure			
Castor cake, Cotton seed cake, un– decorticated	4.3	1.8	1.3
Neem cake	3.9	1.8	1.6
Safflower cake	5.2	1.0	1.4
Un– decorticated	4.9	1.4	1.2
Ground net cake	7.3	1.5	1.3
Linseed cake	4.9	1.4	1.3

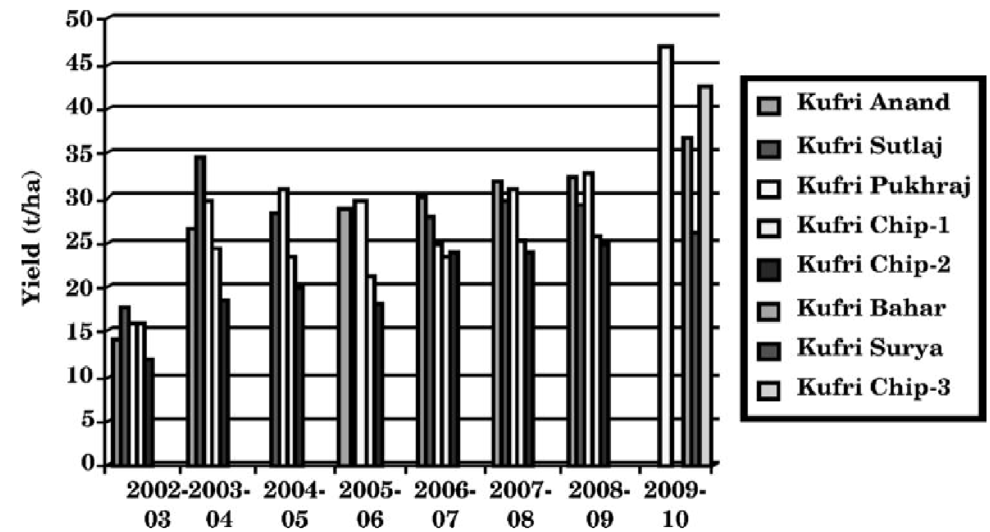

Fig. 1: Improvement in organic tuber yield in successive years from vermicompost

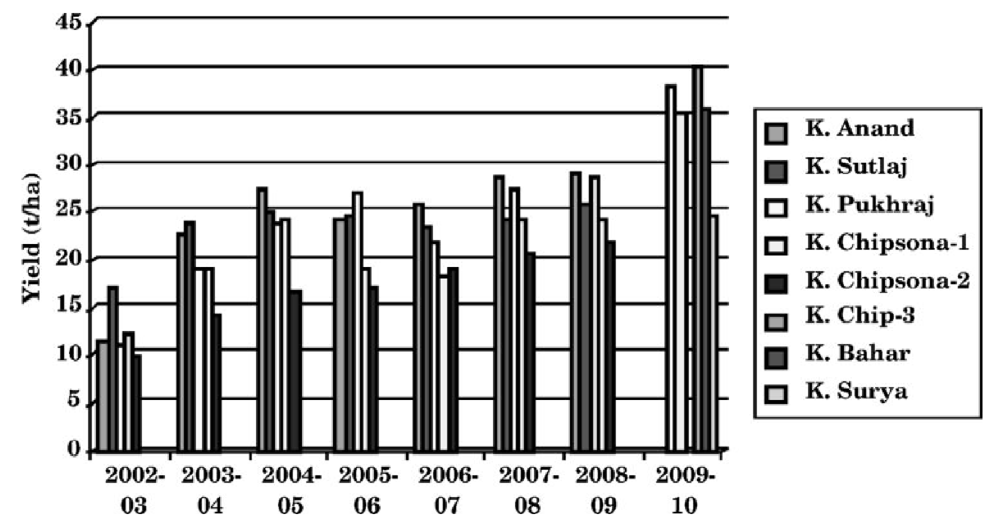

Fig. 2 Improvement in organic tuber yield in successive years from FYM

Biodynamic approach

Biodynamic agriculture is based on sound principles of soil biotechnology and microbiology, and can be defined as systematic and synergistic harnessing of energies from cosmos, mother earth, plants and cows. It does not require sophisticated facilities and most of the manures and biopesticides used are prepared on the farm. Biodynamic compost and field spray preparations (BD-500-507) are components of biological agriculture, capable of affording long-term sustainability to agriculture and particularly to the ecosystem. Basic principles of biodynamic farming are to restore organic matter in the soil in the form of humus, increasing microbial population, skillful application of the factors contributing to the soil life and health, and treating manure/compost in a biodynamic way. The biodynamic practices include application of vermicompst (12.5 t/ ha) at planting, spraying of micronutrient tonic 'Shakti', tuber treatment by dipping in 'Gur' (Jaggery) solution (2%) containing 5 kg CPP/ ha , use of insecticide 'Urja' and two sprays of fungicide 'Divya'.

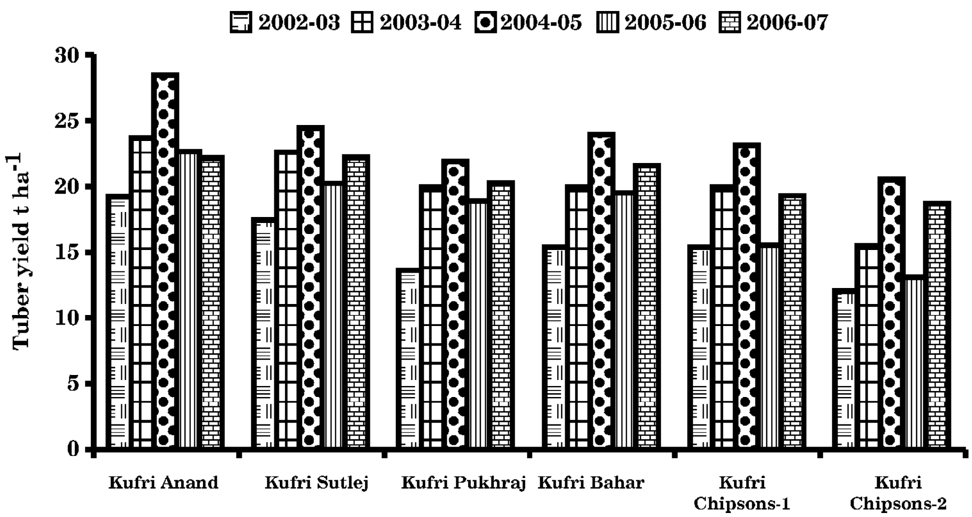

Fig. 3 tuber yield in biodynamically raised potato on same site in successive years

Homoeopathic approach

Homoeopathy has proved to be the most natural, miraculous ultra-scientific and very economical, yet systematic approach (operating on the low of similar) for combating ailments of various origins, whether physiological or pathogenic. This approach can afford safer protection, faster pollination and effective cure. With these facts in view, homoeopathic drugs have also been tried to our plant diseases.

The studies conducted at Modipuram campus have revealed that the approach is not suitable in potato production.

Bio em enzyme approach

The approach includes dipping of tubers in Bio-smart @ 3gm/lt solution and drying in shade before planting. This is followed by spraying of Bio charge @ 3ml/lt. at 20 and 30 days after planting (DAP). At 45 days old crop, Yes-Winner is applied @3ml/lit. The third spray of Bio- smart with Nitrobenzene @ 2.5 – 3ml/lit. is done at 60 DAP followed by fourth spray of Bangaram (1ml/lt) and Bio – Gold Sp (1- 1.5 gm./lit at 70 DAP. The spray of Bio- smart and Bio-charger continues at weekly interval till105 DAP. The results at Modipuram have revealed that there is no significant effect of Bio em enzyme approach on tuber production.

Agnihotra approach

In ancient days, the "Rishis" of the land were very powerful and were serving the humanity by blessing them with happy living. The sloka "Loka Samastha Sukhinobhavanthu" was uttered repeatedly to keep the humanity to bliss. As a perform several rituals. One of them was the "Fire Ritual" which envisages invocating the concerned Devas or Gods in Incharge of certain assigned areas of life. The scriptures say that there is an Inner Government in the kingdom of Devas, just as our governments wherein each Lord is assigned with a job of being in-charge of certain areas. In the fire ritual, a fire is lit and certain material mostly derived from vegetable kingdom, each of which is connected to the concerned God are offered to him through the fire God. In order to burn that item, it is dipped in cow's ghee as inflammable. The fire is "Agni" who after receiving the item absorbs within himself and conveys to the concerned Lord. The invocation is made by uttering a Mantra while offering. This sound uttered through the Mantra invokes the concerned Lord, who receives the offering through Agni, the purifier. The Lord thus invocated, pleased by the offerings, blesses the offerer to cherish the desire. A part of the above ritual is this Agnihotra. Here only the Sun God is invocated both at sunrise and sunset, through a simple utterance.

"Prajapathaye Swaahaa, prajapathaya idam mamama"
at Sunrise

&

"Adithyaya swaahaa, adithaya idam mamama"
at Sunset

The approach has not been found effective in potato production.

Panchagavya approach

Panchagavya consists of five products from the cow *viz*. dung, urine, milk, cure and ghee. When suitably mixed and used, has miraculous effects that sound mystic. The Indian wisdom says that except in the cells of cow's body, the five basic elements *viz*. Earth, Water, Fire, Air and Space, of which all earthly beings are made up, are at non-equilibrium everywhere. That is shy, the cow has been accepted as next to Divine in Indian culture and worshipped as God (Kamadhenu) from time immemorial. The products out of cow's body have the capability to bring the flow of cosmic energy whenever and in whatever form, they are used. The cosmic energy, when made to pass through a living system, transforms the living thing to wholesomeness removing the inequalities in its physical chemical, biological and physiological phases, which revitalize growth process. The latest form of "Panchagavya" suited to various agricultural and horticultural crops has the following composition:

(a) Cow dung slurry (from Goober gas plant)	=	4kg
(b) Fresh cow dung	=	1 kg
(c) Cow's urine	=	3 litres
(d) Cow's milk	=	2 litres
(e) Cow's curd	=	2 litres
(f) Cow's ghee	=	1 kg
(g) Sugarcane juice	=	3 litres
(h) Tender cococut water	=	3 litres
(i) Banana (ripe)	=	12 Nos.
(j) Toddy (if available)	=	2 litres

All the above items are added to wide mouthed mud pot, concrete tank or plastic cans as per the above order 1 to 10. The container is kept open under shade and stirred twice a day both in the morning and evening. The "Panchagavya" stock solution is ready after 7th day. The approach has revolutionzed and revitalized organic agriculture in Tamil Nadu and as per the prediction of its advocators, will sweep the whole world in days to come. In case of potato, this has not been found useful.

Organic potato and tuber quality

The organic potatoes have more shining surface than conventionally raised tubers from fertilizers. Studies conducted at Modipuram (Meerut), have revealed that compared to inorganic treatment (100% NPK through fertilizers), the use of organic manure resulted in more number of medium size tubers. Thus, the organic approach can be a useful technique in seed production programme, where seed size tubers are desirable. The organic production of potato also improved the tuber dry matter, specific gravity and chip colour (Table-2) in both processing and non- processing potato varieties.

Factors affecting organic potato production

Optimum nitrogen supply to crop at tuber bulking

It has been observed that from initiation (viz 30 days after planting) onwards, till tuber bulking, there is a progressive increase in crop yellowing, when grown organically. As a result, the growth of the crop gets stunted, phoma spot appear on leaf and forced crop senescence develops. The photosynthetic area and crop growth period thus gets reduced, resulting in yield decline. In general, a normal crop of potato, yielding 30 tons tubers, removes 120 -140 kg nitrogen from the soil. But as per the dynamic of nutrients release, release from organic manure, the particularly nitrogen from organic source is not able to keep pace with bulk requirement of short duration potato crop. Studies conducted at Modipuram have revealed that repeated potato production on same site, resulted in progressive increase in soil nitrogen supply and tuber production.

Variety

In general, among the present day commercial potato varieties, non processing, medium to long duration viz Kufri Anand, Kufri Sutlej, Kufri Pukhraj, Kufri Bahar, Kufri Arun, Kufri Suriya etc have produced more than processing varieties viz Kufri Chipsona-1 and Kufri Chiposna-2.

Organic approach used

Bulky organic manures (viz vermicompost, farmyard manure) produced

Table-2 Processing character of different potato cultivars as influenced by organic, inorganic and integrated sources of nutrients at Modipuram

Treatments	Potato Cultivars					
	Kufri Anand	Kufri Sutlej	Kufri Pukhraj	Kufri Chipsona 1	Kufri Chipsona 2	Mean
	Dry matter content (%)					
100% NPK through inorganic	17.03	19.43	19.29	22.4	22.18	20.07
65% NPK + 15 tones FYM	18.92	22.44	20.78	24.19	22.48	21.76
100 % NPK through Vermicompost	19.81	22.35	21.38	25.03	23.48	22.41
100 % NPK through FYM	19.93	20.64	21.59	24.63	22.87	21.93
Mean	18.92	21.22	20.76	24.06	22.75	
LSD (0.05) Nutrients (N) : 1.7; Variety (V) : 2.0; (N x V) : 2.2						
	Specific gravity					
100% NPK through inorganic	1.078	1.075	1.071	1.087	1.092	1.08
65% NPK + 15 tones FYM	1.082	1.079	1.075	1.093	1.095	1.08
100 % NPK through Vermicompost	1.081	1.081	1.074	1.094	1.098	1.09
100 % NPK through FYM	1.082	1.079	1.076	1.091	1.098	1.09
Mean	1.081	1.079	1.074	1.091	1.096	
LSD (0.05) Nutrients (N) : 0.002;; Variety (V) : 0.004; N x V : 0.005						
	Chip colour					
100% NPK through inorganic	5.5	5.0	5.5	4.0	3.0	4.60
65% NPK + 15 tones FYM	4.5	4.0	4.5	2.5	2.5	3.60
100 % NPK through Vermicompost	3.5	4.5	4.5	3.0	2.5	3.60
100 % NPK through FYM	4.0	4.5	3.5	2.5	2.0	3.30
Mean	4.4	4.5	4.5	3.0	2.5	
LSD (0.05) Nutrients (N) : 0.52; Variety (V) : 0.78; N x V : 0.82						

more than biodynamic approach. The homeopathic, bio fertilizer and Bio em enzyme approaches were not found effective at all in organic potato production.

Growing potato on same site

Depending upon variety, during first year, organic potato production was 40-60% lower than conventionally produced potato, using inorganic fertilizers at Modipuram But in subsequent years, by growing potato on same site, the difference in yield from two approaches narrowed down. But even after continuous cultivation of organic potato on same site for five years, the yields are not at par with conventionally raised crop using inorganic fertilizers.

Source of organic manure

Vermicompost has been found more effective than farmyard manure (both rural compost as well as city compost) for higher tuber yield.

Diseases and pests

It has been observed the aphid during main crop season and leaf hopper, mite in early crop is the main pests of potato in plains. In hills, white fly, tuber moth, cut worm and white grub are very serious pests. To control them in organic potato crop, a lot of biopesticides like neem/ other botanical extracts, Trichoderma, nucleo polyhydrosis virus, Bacillus thuvinginsis, urja (under biodynamic approach) and samhar, Sasya Rakshini (under homeopathic approach) have been tried.. But these have been found only partially effective. Like pests, to control potato diseases like phoma, blight (early and late), soft rot, dry rot, common scab etc., biocontrol agents like B_4 and B_5 (Bacillus subtilis) have been found partially effective. Field studies conducted at Modipuram have revealed that sprays of fungicide “Divya” and “Sambhavi” under biodynamic and homoeopathic approach respectively, have not been able to control late blight and viral diseases in plains. The results are thus contradictory to earlier literature based report of Khurana and Gupta (1981) that plant diseases, particularly of viral/ fungal origin, can be safely, economically and feasibly prevented even in fields upon treatment with homoeo drugs.

Future strategies for improving organic potato production

In order to harvest a good crop of organic potato, selection of suitable varieties is one of the most important pre-requisites. The use of varieties that are better adapted to local biotic conditions (e.g. biological control of pests and diseases, climatic stress) shall be promoted. All the best varieties/ land races of the conventional farming may not be suitable for organic potato production. Conventional plant breeding is known to be slow, therefore marker aided selection can accelerate the development of varieties suitable for organic farming. Similarly additional genes conferring resistance to potato crop against disease and insect-pests need to be introduced. Improved nutrient use efficiency is required for better utilization of nutrients that will in turn, result in production of higher biomass, partitioned efficiency to improve the harvest index/economic yield. Potato varieties with a long period of nutrients uptake can make better use of slow, but prolonged release of available nutrients. The possibilities to supply nutrients particularly nitrogen and suppression of diseases through periodic spray of vermiwash should be investigated. Similarly studies on use of biopesticides to minimize reported fifty percent yield loss in organic potato production due to insects and pests should be given due attention. Biological controls may have been weakened or destroyed by chemicals and efforts should be made to build up them.

Suggested Readings

Grewal, J.S., Sharma, R.C. and Saini, S.S. (1992) Agro techniques for intensive potato cultivation in India, ICAR Publication. New Delhi, pp 39 -47.

Khurana, S. M. Paul and Gupta, G.C. (1981) Homeopathy: promise & prospects for plant protection. Advancing homoeopathy 1: pp 107 - 116.

Kumaraswamy, K. (2002) Organic farming relevance and prospects. Indian Soc. Soil Sci. Newsletter, No. 12 p. 1.

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11

MICRO IRRIGATION SYSTEM AND WATER MANAGEMENT IN POTATO PRODUCTION

Name Singh

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Introduction

Potato (*Solanum tuberosum* L.) is a herbaceous plant with sparse and shallow rooting system, it requires light and frequent irrigation throughout period of crop growth. The water requirement of crop varies from 400-600 mm depending upon soil type/texture, atmospheric conditions, duration of variety, length of growing period, cropping pattern and management practices etc. Drought at any stage can prove detrimental, the excess water is also equally harmful as it creates aeration problem and favours certain diseases and pests. The crop productivity and quality of the produce both largely depends upon proper balance between soil air and soil water in the plant root zone. In the present day context, due to continuous cropping and raising of high water requiring crops, the over draft of ground water at rates higher than recharge had led to decline in the water table in many areas of north-western and central plains of India. The per capita comfortable level of 2100 m^3/yr is estimated to reduce to the stress level of 1700 m^3/yr by 2030 and to the scarcity level a few years later. Due to increasing water scarcity and recurring droughts in many parts of the country, the use of (micro-irrigation system) drip and sprinkler irrigation have become extremely important. These methods improve efficiency of irrigation water and fertilizer nutrients, and also hydro-thermal regimes and physical conditions of the soil by maintaining proper balance between soil air and soil water in the plant's root zone for better root growth and tuber development, which results in to higher yield of quality tubers.

Water requirement of potato

Water requirement of crop constitute the amount of water required to mature the crop, encompassing consumptive water use (evapo-transpiration plus water required to build up plant tissues) and economically unavoidable water losses in the form of deep percolation and surface run off. The techniques used to evaluate water requirement or scheduling of irrigations can be broadly grouped into following classes-

i) **Transpiration approach:** Transpiration ratio is the quantity of water transpired by a crop to produce a unit amount of dry matter. The experiments were conducted in the pots and water was added at different intervals on the basis of periodic weighing, but the values obtained were far from those applicable to the field conditions and hence had a limited practical utility in relation to irrigation scheduling.

ii) **Time interval approach:** In this approach different depths of water were applied at different intervals for scheduling of irrigation. The study based on delta interval approach revealed that about 45-65 cm water was needed by the crop and irrigations were required to be applied at 7-10 days interval.

iii) **Soil moisture /tension approach:** According to this concept, irrigations were scheduled whenever soil moisture tension increased to defined levels and sufficient water applied at each irrigation to bring back the soil moisture in the root zone to the field capacity. Tensiometers were used to monitor change in soil moisture tension. The highest potato yields were obtained by frequent irrigations scheduled at low soil moisture of 0.2 to 0.3 atmosphere tension at 15-22 cm soil depth. With this regime, at least 63% of available soil water remained in the root zone before irrigation. This corresponded to irrigation interval of 7-12 days.

iv) **Climatological approach:** The role of climate in governing the water needs of crop was also recognized and the criteria based on evapo-transpiration and evaporation were utilized for scheduling of irrigations. Experiments designed on the basis of CPE values revealed that the potato yields in sandy soils were highest when irrigations applied at 15-20 mm CPE, on sandy loam soils at 25 mm CPE, on clay loam soils at 40 mm CPE and in loamy sand soils at 20 mm CPE. However, in another approach, irrigations applied at IW/CPE ratio of 2.0 produced yield comparable to that based on 0.25 bar soil moisture tension, but, former approach saved 12 cm water in loamy sand soils of Ludhiana.

v) **Leaf water potential (ø1) approach:** Plant is the integrating component of soil water stress and atmospheric conditions. As such water status of the plant in terms of leaf water potential may serve as a sound basis for scheduling irrigation. Work carried out on this aspect in tarai soils of Pantnagar has shown that irrigation at -2.5 bar (ø1) gave comparable results with the approaches based on days interval, soil moisture depletion and CPE values, but more work is required on this aspect in order to draw practical conclusions.

vi) **Stress day index approach:** Hukkery et al advocated that SDI approach for timing of irrigation for potato by subjecting the crop at different stages of its growth to different pre-defined levels of soil moisture stress. Stress day index was formulated as: SDI = CS x SD

Where CS is the crop susceptibility factor indicating the magnitude of yield reduction due to stress at a given stage, when compared without stress. SD is the stress day factor indicating the degree of imposed stress which may be in terms of soil or plant water deficit.

SDI concept not only reveals the critical stages in the growth of a crop but also gives quantitative information on yield reduction due to a given stress. When SDI and CS are known for different stages of growth, the SD for scheduling irrigation (SDI/CS =SD) could be worked out. However, a strong negative co-relation of the yield with the values of SDI was observed.

vii) **Critical stages of crop:** Studies conducted by with-holding irrigation at one or the other growth period without giving any consideration to actual soil moisture content, have revealed controversial results. According to some reports, the crop does not tolerate any stress at any growth stage, while in others, some stages are reported to be more critical than the others. However, most of the reports, have indicated stolonization followed by tuberization as the most critical stages for potato.

viii) **Irrigation under specific situations:** In North-Western parts of India , where frost is a problem, crops in such areas may have to be irrigated even on alternate days to prevent frost damage. The last irrigation to the main crop could be timed 10-14 days before the haulms die down or are killed deliberately. Early crops are harvested green and are generally irrigated till the harvest, although it is desirable to withhold the last irrigation a few days before harvest particularly if the produce has to be transported to long distances. Lifting the crop when the soil is too moist impairs the transportability and keeping quality of the produce.

Need for irrigation

Potato crop grown in hilly areas is mostly rain fed. The total rainfall received during the crop season is adequate or more than the crop water needs, but crop suffers from drought or excess water as the rains are not equally distributed. In certain areas like Nilgiris hills, the rainfall is low during winter (Jan-May). Since this period is generally dry, and irrigation is often required. Where as, in the plains and plateau areas, the crop grown in winter and rainfall is insufficient to meet the crop water requirement. So, the light and frequent irrigations are necessary to obtain the sustainable crop yield.

Depth and time of irrigation under furrow method

The water applied at each irrigation should be just sufficient to restore the soil moisture in the plant root zone to the field capacity or to make up the soil moisture deficit. Generally, 4-5 cm of irrigation water should be applied at each irrigation. The water should never overflow the ridges as it can poses critical physical problems like aeration and higher bulk density etc., which can inhibit the plant growth and tuber development. As regard, the time of irrigation, 7-12 days interval depending upon the climatic conditions, growth stage and soil type is found to be best. The scheduling of irrigation at 25 mm CPE value or IW/CPE ratio of 2.0 produced highest potato yields under sandy loam soils.

In case of micro irrigation method, the irrigation should be applied through drip method at alternate day on the basis of 125% of CPE, and twice in a week at 150% of CPE by using sprinkler method. But, these methods require high initial investment and technical knowledge how to operate. The time of application can be worked out by using following formula:

$$\text{Application rate (mm/hr)} = \frac{\text{Discharge of water (in lts/hr)}}{\text{Spacing between dippers (m)} \times \text{Spacing between two rows of system (m)}}$$

Methods of irrigation

Among various irrigation methods *viz.* surface, sub-surface, drip and sprinkler methods of irrigation, the **furrow irrigation** is commonly used for potato cultivation. The land for furrow irrigation method must be leveled and the slope should not be more than 0.5%.The furrows may takes many forms such as i) long furrows perpendicular to field channels, ii) short furrows running either perpendicular or parallel to field channels, iii) furrows between broad ridges, each with five rows of plants, iv) contour and serpentine furrows. The field channels of about 70–100 cm width serve bilaterally a set of 6-8 furrows in each bed. The ridges may be wetted to about 2/3 of their height leaving the rest to be moistened gradually by capillary movement of water.

Drip method of irrigation

The drip irrigation involves slow application of water in to the plant's root zone. In this method, the field is subjected to leveled before ridges and furrows are drawn for planting. In traditional planting under drip irrigation, the ridges and furrows width are 30 cm each and seed tubers should be planted on the ridges at 60x20 cm spacing. While in wide raised bed two rows of planting, the broad ridges and furrows of required dimensions *i.e.* 90:30 cm spacing, respectively should be formed before planting of seed tubers at 20x20 cm inter and intra-row spacing, respectively and the single drip lateral placed at 120 cm distance on each bed. In this system, two rows of potato are brought together at 20 cm inter row spacing followed by a wide gap of 100 cm. The number of rows per hectare remains same, but the advantages are that wide spacing reduced drip laterals which minimize the cost of drip installation by 40-45%. Similarly, in the triple rows wide raised bed planting, three rows are brought together at 20 cm inter row spacing followed by a wide gap of 80 cm and the tubers should be planted at 20 cm intra-row spacing along with single drip lateral placed at 120 cm distance on each bed.

The studies based on drip irrigation approach, revealed that the irrigation scheduled at 125-150% CPE water level (cumulative pan evaporation) at alternate day were needed for best yield of potatoes. This corresponded to operate the drip system (single drip lateral placed on each ridge at 60 cm distance with inline/flat dippers 16mmOD/30cm/2lph) for 35-45 minutes at each irrigation for traditional potato planting, whereas, for paired/triple rows wide raised bed potato planting, the drip system should be operate for 1¼ to 1½ hour at each irrigation depending upon the prevailing soil moisture conditions in potato field. One pre-emergence irrigation through furrow irrigation method could be applied for quick and uniform emergence in the field. However, the increase or decrease the quantity of water depends upon the prevailing climatic conditions and crop growth stages. The drip irrigation system is not recommended to operate more than 1¼ to 1½ hour at a stretch to avoid water losses through leaching. On the other hand irrigation interval generally is not kept more than three days to avoid moisture stress to the crop plants.

Under **drip fertigation** approach, 1/3 dose of NPK fertilizers should be applied at planting and remaining 2/3 fertilizers applied directly in to the plant root zone through drip irrigation in eight splits twice in a week up to 45-50 days of crop growth (starting from the plant emergence). For fertigation, fill the fertilizer tank with 35 liters of water and add 15 kg fertilizer and close the lid of fertilizer tank tightly and then run the system for at least 35-45 minutes. Results revealed that drip method economized 40-50% water and increased crop yield by 25-35% along with saving of 25% NPK fertilizer nutrients in comparison to furrow method of irrigation.

Sprinkler method of irrigation

The sprinkler irrigation method could be used in special situations *viz.* i) undulating topography, ii) extremely sandy or fine textured soils and iii) costly and scare water supply but assured returns. If sprinkler system, properly designed and operate gives uniform distribution of water without compacting the soil surface and reduces water losses in the form of deep percolation. The uniformity of water is assured only by over lapping pattern of spray from different size nozzles. The rate and time of water application is regulated according to the discharge and distribution of water and the sprinkler's specifications. The field is subjected to leveled before ridges and furrows are drawn for potato planting. In traditional planting, the ridges and furrows width are 30 cm each and seed tubers should be planted on the ridges at 60x20 cm spacing. While in case of raised/wide bed for triple rows planting under sprinkler irrigation, the broad ridges and furrows of required dimensions *i.e.* 90:30 cm spacing, respectively should be formed before planting of seed tubers at 20x20 cm inter and intra row spacing, respectively.

The studies based on sprinkler irrigation approach, revealed that the weekly two irrigations at 150% CPE water level (cumulative pan evaporation) were needed for best yield of potato. This corresponded to operate the system (*e.g.* 560 lph discharge/10x10 m distance between two rows of sprinkler lines and two sprinklers) for 2.0- 2½ hours at each irrigation depending upon the prevailing soil moisture conditions in potato field. For quick and uniform plant emergence, one pre-emergence irrigation through furrow method should be applied. However, the increase or decrease the quantity of water depends on prevailing climatic conditions and crop growth stages.

Under **sprinkler fertigation**, 1/3 nitrogen should be applied as basal at planting alongwith full dose of phosphorus and potash and the remaining 2/3 nitrogen given directly to the crop as foliar spray through sprinkler irrigation in eight splits twice in a week up to 45-50 days growth (starting from plant emergence). For fertigation, fill the tank with 35 liters water and add 15 kg N fertilizer and close the lid of fertilizer tank tightly and then run the system for at least 30-45 minutes. Results revealed that the system economized 40% water with higher crop yield of quality potatoes. The fertigation through sprinkler irrigation increased potato yield by 15-25% and saved 25% nitrogen against furrow method of irrigation.

Efficient use of irrigation water: Potato is an efficient user of irrigation water, but its needs are also inflated by unproductive water losses. The application of mulch increases yield both in plains and hills. The beneficial effect has been attributed not only to an improvement in moisture status but also to favourable temperature adjustment. Under sprinkler and drip methods of irrigation, the favourable hydro- thermal and physical regimes of soils together with the steady supply of irrigation water and fertilizer nutrients through fertigation technique increased potato yields by 15-25 and 25-35%, respectively. For the best yield of potato, the crop should be raised with optimum level of other inputs.

Suggested Reading

Keshavaiah, KV and AS Kumaraswamy. 1993. Fertigation and water use efficiency in potato under furrow and drip irrigation. *J Indian Potato Assoc.* **20** (3-4): 240-244.

Name Singh, RC Sharma and BP Singh. 2003. Effect of NPK fertigation and planting patterns on yield and economics of potato under drip irrigation. *J. Indian Potato Assoc.* **30** (1-2): 69-70.

Name Singh, MC Sood and SP Singh. 2010. Yield and economics of potato (*Solanum tuberosum* L.) as influenced by raised bed planting patterns and drip layout systems under fertigation. *Progressive Agriculture Journal* **10** (1): 29-34.

Name Singh, MC Sood and SP Singh. 2010. Optimizing irrigation water and nutrient requirement of potato (*Solanum tuberosum* L.) under drip fertigation. *Progressive Agriculture Journal.* **10** (1):192-195.

Name Singh, MC Sood and SP Singh. 2010. Effect of sprinkler fertigation on tuber yield, nutrient content, uptake and percent recovery of N, P and K nutrients in potato. *Progressive Agriculture Journal.* **10** (2): 221-224.

Name Singh and MC Sood. 2008. Fertigating potato crop for higher returns. Technology published in : *Indian Horticulture,* Special Issue, November- December, 2008. pp 18-20.

Singh, N and MC Sood. 1994. Water and nitrogen needs of potato under modern irrigation methods. Potato: Present & Future. Proceedings of the National Symposium held at Modipuram, Meerut (U.P.), during 1-3 March, 1993: 142-147.

Singh, N and MC Sood. 1996. Effect of planting methods and nitrogen on potato (*Solanum tuberosum* L.) production under drip irrigation. *Indian J. Agron.* **41**(2): 296-300.

Singh, N and MC Sood. 1997. Productivity of potato as influenced by methods of irrigation (drip and furrow), cultural practices and nitrogen application. Paper presented in National Seminar on Potato Production Constraints in Low Productivity Areas held at OUA&T, Bhubaneshwar on September 6, 1997. pp. 12.

Singh, N and SS Lal. 1998. Effect of irrigation schedule through drip and sprinkler and lifting dates on total yield and seed size tubers. *J. Indian Potato Assoc.* 25 (1&2): 39-41.

Singh, N, MC Sood and RCSharma. 2000. Efficient and economic use of irrigation water and nitrogen through sprinkler irrigation in potato. Extended Summary presented in the "International Conference on Managing Natural Resources for Sustainable Agricultural Production" in the 21st Century held at IARI, New Delhi during 14th-18th February, 2000. pp. 506.

Singh, N, MC Sood, and RC Sharma. 2002. Effect of irrigation levels, cultural practices and nitrogen application on potato production under drip and sprinkler methods of irrigation. In Potato, Global Research and Development Vol. II (Khurana et al., Eds.). *Indian Potato Assoc.* pp. 923-925.

Sood, MC and Name Singh. 2008. Micro - irrigation and Fertigation. In ''Twenty Steps Towards Hidden Treasure –Technologies That Triggered Potato Revolution in India''(Pandey, SK and Chakrabarty, S.K. Eds). CPRI, Shimla. pp 215- 226.

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NUTRIENT MANAGEMENT IN POTATO PRODUCTION

VK Dua

Contents

Introduction

Potato is very intensive crop and requires nutrients at very high rate due to higher dry matter production per unit area and time as compared to other field crops. Since most of our soils are poor in available nutrients and the crop has shallow and sparse root system, nutrient demand is generally not met by the soil. That is why, the crop responses well to external source of nutrients. The use of blanket fertilizer recommendation may result in under utilization and also into considerable losses of nutrients resulting into pollution to the environment. Therefore, appropriate nutrient management is required to ensure high fertilizer use efficiency so that the amount of unutilized fertilizers is reduced to environmentally acceptable levels. Most of potato growing area lies in the Indo-Gangetic plains and plateau region, where soils are mostly low in organic carbon and available nitrogen, low to medium in P and medium to high in K. Secondary and micronutrients are also reported to be deficient from many intensively cropped areas.

For the nutrient management of production of processing potatoes in general and Chips in particular one has to take very special care. It should be designed in such a way that it produces maximum processing grade tubers, having high dry matter and specific gravity as these parameters has direct influence on recovery and quality of processed product (Table 1). The management practice must improve the yield of processing grade tubers without deteriorating its quality. In ware crop at yield level of 350 q/ha and considering harvest index of 85% and 18% dry matter the total dry matter production is about 74 q/ha, whereas, in processing potatoes at the same yield level and harvest index due to higher dry matter (say 22%) total dry matter production is around 90 q/ha. In addition one has to take care that ware or seed crop may be harvested little early prematurely considering other factors, the processing potatoes must be harvested at its full maturity normally at more than 100 or 110 days. Therefore, the nutrient requirements of these cultivars are accordingly more.

The information on nutrient deficiency symptoms, suitable source, dose, time and method of fertilizer/manure application can be of help to efficiently manage nutrient as well as to better production of processing potato.

Primary Nutrients

Nitrogen has a great influence on crop growth, tuber yield and its quality. Plant takes nitrogen in NH_4^+ and NO_3^- form but majority of the nitrogen in soil is in complex organic combination so its availability depends on the mineralization of organic matter. Rate of which is often too low to meet the potato requirement. A mature ware crop of potato yielding 25-30 t/ha tuber remove 120-140 kg N/ha and for processing cultivars it is supposed to be still higher. Therefore, application of nitrogen in the form of fertilizers and manures becomes indispensable to meet N needs of the crop.

The potato plants with sufficient N are characterized by vigorous growth, increased leaf area index, large tuber size as well as numbers. Whereas, its deficiency leads to pale green coloration of leaf margins at initial stage turning to pale yellow foliage in case of acute deficiency. These symptoms first appear at lower leaves and later on whole plant gives yellowish look leading to dropping of lower leaves thereby decreasing photosynthetic activity. On the other hand excess of N delays tuber initiation, onset of linear phase of tuber growth ultimately resulting in lower yield.

The economic potato response for ware crop in alluvial soils of Indo-Gangetic plains in the country has been noticed up to 180 kg N /ha. Some of the varieties like Kufri Anand and Kufri Sutlej may respond up to 240 kg N/ha. In recent years with newer cultivars the optimum dose of nitrogen was in the range of 190-240 kg/ha at Patna. At Ranchi response of nitrogen was observed up to 240 kg/ha, whereas, under river bed cultivation in Dessa (Gujarat), crop has respond up to 600 kg N/ha. The response to each kg of N varied with dose and follows the law of diminishing returns. Experiments with processing potatoes has shown that N requirement of these cultivars are about 150% of those of ware potatoes and for Kufri Chipsona-1 and Kufri Chipsona-2 the optimum dose to get high production of processing grade tuber was 270 q/ha in sandy loam soils of the west central plain.

Source, time and method of application: Among different sources, ammonium sulphate (21% N) is the most preferred one due to S contained in it, followed by calcium ammonium nitrate (25% N). However, urea (46% N) being cost effective, is most commonly used. The poor performance of urea has been found to be related to its adverse effect on plant emergence by increasing the osmotic pressure particularly at higher doses. Therefore, care must be taken to avoid direct contact of urea with seed tubers at the time of planting.

In potato crop, sufficient N is needed in early stages to build up crop canopy and to enhance leaf area thus giving longer period for tuber development during tuber bulking phase, which is 40-60 days in plains. Hence, the time of application of N should be scheduled in such a way that sufficient N is made available at the aforesaid critical period. In general, application of N in two split dose *i.e.* half at planting time and rest at time of earthing up produces higher yields and results in higher N recovery than applying entire dose at planting. For convenience in use it is recommended that half of N be applied at planting through calcium ammonium nitrate and remaining at earthing up at about 25-30 days after planting through urea.

The uptake and efficacy of N fertilizer depend upon the method of application. Potato having sparse root system, it is important to place the fertilizer where interception by active roots is more. The placement of N fertilizer in side bands (10 cm deep and 5 cm away from seed tubers) at planting has been found to be beneficial to broadcasting and furrow placement with respect to tuber yield and nutrient recovery.

Phosphorus and Potassium are the second and third limiting nutrient, respectively in potato production. A healthy crop of potato removes about 25-30 kg P_2O_5 and 170-230 kg K_2O/ha indicating that potato needs for P and K are much higher than that of cereals. Phosphorus is involved in wide range of plant processes from permitting cell division to the development of a root system as well as root growth and hastening crop maturity. On the other hand, application of K increases plant height, crop vigor and impart resistance against drought, frost and diseases. Its application activates number of enzymes involved in photosynthesis, carbohydrate metabolism and proteins and assists in the translocation of carbohydrates from leaves to tubers. It also increases the yield by increasing the number and yield of large sized tubers, therefore, it has special significance in processing potato production.

In the event of P deficiency, the growth of plant is retarded, particularly during early growth stages (Table 2). The plants are stunted with dull dark green leaves without luster. The leaves are curled with purple pigmentation sometime with marginal scorching. The vegetative growth continues beyond normal time of maturity and tuberization is delayed. The deficiency of K normally coincides with onset of tuber initiation period. The mild K deficiency starts with dark bluish green leaves and shortened internodes. Terminal leaves show bronzing accompanied with necrotic spots with increasing K deficiency. In case of acute deficiency, leaf margins may dry up and often premature death of plant occurs.

Phosphorus and potassium needs of the crop vary with the agro-climatic region, variety, crop sequence taken and soil type. Being a shallow rooted crop the fertilizer use efficiency for P is 10-15% while that for K it ranges between 50-60 per cent. The optimum dose for P and K varies from 60 to 100 kg P_2O_5/ha, and 100-150, kg K_2O/ha, respectively, for plains. In high crop intensity area, application of K on removal basis is needed rather than its application on response basis. For processing potatoes, due to its larges tuber size and higher dry matter, requirement of K is normally more than ware crop. Application of 150 kg K_2O/ha as basal dose is rocommended for Kufri Chipsona-1 and Kufri Chipsona -2.

Source, time and method of application

The most common P fertilizer used in potato cultivation is a single super phosphate. The other P carriers tried are di ammonium phosphate, pyrophosphate and rock phosphate. Farmyard manure is another important source of P, which over the long run increases the available P status of soils. Among potassium fertilizers potassium chloride (MOP) and potassium sulphate (SOP) have been studied in depth and potassium sulphate has been found to be the best in term of its beneficial effect on tuber quality viz., dry matter, ascorbic acid and sugar content but due to its high cost, it has not found of much use and MOP is most commonly used. The proper placement of the fertilizer has a great influence on the P and K use efficiency in this crop. Potato plant needs most of P at early stages of development thus its application at planting is considered more useful. Its furrow placement has been more economical than broadcasting or band placement. Like P, application of K at planting time in furrows is better than its application above or below seed tubers or as broadcasting.

Effect of P and K on tuber quality: Application of P at optimum rates increases tuber starch and vitamin C content but higher levels adversely affects protein content. Application of SOP produces tubers with higher dry matter, starch and Vitamin C content. The chip quality of potato tubers is also affected by K source. Application of K through MOP has been reported to decrease enzymatic discoloration and phenol content thereby reducing the browning of potato chips.

Secondary nutrients

Sulphur is now rated as fourth major nutrients after N, P and K and its importance is being recognized in view of its role in improving crop quality. In potato, sulphur is required in many metabolic activities and its deficiency is similar to N in many ways. In case of N deficiency, the yellowing of leaves starts from lower leaves while in case of S, it is upper leaves which show chlorosis. Severe deficiency of S results in retarded plant growth, reddening of stems and curling of leaves inward. The major sulphur carriers are elemental S (85-100% S), ammonium sulphate (23.7% S), single super phosphate (12.0%S), potassium sulphate (18.0%S) and gypsum (13-15%S). Potato response to applied S depends upon the S status of the soils. Potato can not utilize soluble S from the deeper layers in soil profile thus the soils sufficient in available S for cereal crops are likely to be deficient in S for potato crop and light textured soils low in organic matter may require S from external source.

Calcium and Magnesium are next important secondary nutrients. Ca deficiency manifests with the failure of development of terminal buds of the apical tips. In mild deficiency, a light green band appears along the margin of young leaves of terminal buds. Leaves do not develop normally and have wrinkled appearance. In severe deficiency, the young leaves at top remain folded and later tips dies. On the other hand magnesium deficiency appears at lower leaves. Plants become slightly pale, older leaves develop central necrosis, turn yellow or brown, interlineal areas become bronzed and wither prematurely. In severe deficiency of Mg, leaflets become thick and brittle and show a definite bulging with leaves rolling upwards.

Not much work on calcium and magnesium has been done on potato crop from processing point of view, however, soil application of $CaCl_2$ at 20 kg/ha was more effective than foliar application of $CaCl_2$ (0.01%) in increasing the potato yield mainly due to increase in yield of large and medium sized tubers. The improvement in specific gravity of tubers supplied with Ca application thus enhances tuber quality for processing. Its application also reduces the severity of soft rot during storage and results in emergence of healthier sprouts.

Micro-nutrients

Each of these nutrients have specific role so far as potato tuber quality is concerned. Translocation of photosynthates from leaves to tubers and their subsequent conversion to starch and the photosynthetic rate has been shown to increase in the presence of zinc and manganese. Zinc, iron, boron and molybdenum have been reported to increase the tuber number of medium and large grade. Zinc, copper, manganese, boron and molybdenum have been shown to increase ascorbic acid content of tubers. Zinc fertilization reduced the content of compounds which is implicated in enzymatic discoloration

Even though, micronutrient elements are needed only in traces, many soils do not supply them in sufficient quantity for healthy growth and optimum yield of potato. The use of high analysis pure NPK fertilizers and high yielding potato varieties with increased nutrient demands, the decreasing availability of farmyard manure and negligible recycling of residue, have combined to increase the demands made on the soil in terms of its ability to supply micronutrients to plants. It is becoming evident that without the use of some of the micronutrients, it is not possible to get the maximum benefit of other inputs.

Deficiency symptoms

Zinc: Its deficiency in potato, often known as fern leaf or little leaf, appears on young developing leaves. Deficient plants show severe stunting and bronzing or yellowing of the foliage, usually around the leaf margins, starting from the tips. Youngest leaves are cupped upwards and rolled to such an extent that the terminal growth resembles that of ferns. Leaves of affected plants are smaller and their upper internodes are shorter.

Iron: Its deficiency appears initially as a yellowing of young leaves near the growing point of the plant. With time, the leaves become light yellow to nearly white. During the deficiency stage, blade tips remain green for longer time. Netted green veining occurs when traces of iron are absorbed and translocated along the veins for chlorophyll formation. Green veining is actually an iron recovery symptom.

Manganese: The first sign of its deficiency is yellowing and slight cupping of younger leaves. Pinkish colour develops at the base of younger chlorotic leaves and relatively old leaves show dark to black spots. With increased deficiency, dark to black spotting develops between the veins with a large increase in spotting, appearing along larger veins and the mid rib. These symptoms, darkening and cupping, increase in severity with time. During mild deficiency, upper parts of the plants become somewhat chlorotic but do not develop dead spots.

Copper: An early sign of its deficiency is the development of a uniform, light green colour of young, immature leaf blades similar to those of molybdenum, manganese and iron deficiencies. Thereafter, its deficiency is manifested primarily by a pronounced upward cupping and inward rolling of the young, relatively large, leaf blades. This is a sharp contrast to the small, narrow leaf blades of zinc deficiency.

Boron: Its deficiency causes the formation of a bushy plant with droopy leaves. Blades crinkle, cup upwards and are bordered by light brown tissue. Its deficiency, like calcium deficiency, affects the growing points. Immature central leaves become deformed and the growing point dies. In case of mild boron deficiency, slight upward curling of the margins of the older leaves is visible.

Molybdenum: The symptoms of its deficiency are marked chlorosis, associated with reduction in growth and yield.

Methods of micronutrient application: There are three main approaches to tackle micronutrient disorders in potato. These are: application of a micronutrient carrier to the soil, foliar application of micronutrients to each crop and treating mother seed tubers, with micronutrient compounds. Foliar spray during dry spell should be avoided between 11 a.m. and 3 p.m. to prevent scorching of leaves. The optimum doses of different micronutrients are presented in table 3. Generally, most of them are taken up during the early growth stages thus, it favours early fertilization with micronutrients. Sulphate salts of different micronutrients are the most common sources.

Organic manures: Well-decomposed farmyard manure (FYM) and compost made from animal excreta and litter, are bulky in nature and supply small amounts of plant nutrients are classified as bulky organic manures. They are generally applied @ 15-30t/ha depending upon availability. These organic materials contain enough of secondary and micronutrients, besides primary nutrients, that contribute significantly to increased crop yields, soil fertility and physical condition. Soil's physical condition is improved through increased water infiltration, water holding capacity, aeration and permeability, soil aggregation, rooting depth and decreased soil crusting, bulk density, run off and erosion.

Green Manuring: It improves the fertility and productivity of soil. The green manure crop supplies organic matter as well as additional nitrogen, particularly if it is a legume crop. A leguminous crop producing 10-20 tons of green manure per hectare adds about 60-100 Kg/ha of nitrogen when ploughed under. The increase in tuber yield after green manuring is usually of the order of 30-50 percent.

In general it is recommended that for production of high dry matter processing potatoes cultivars like Kufri Chipsona-1, Kufri Chipsona-2 in the light textured soils of Indo-Gangetic plains the doses of N and K may be increased to 150% of recommended for ware crop and secondary and micronutrients may be applied on soil test basis. It will always be beneficial to grow green manure crop before potato and use FYM or vermicompost for cultivation of chips or other processing cultivars.

Table 1. Quality requirements of potato for chip processing

Tuber shape	Tuber size (mm)	Eyes	Sp. gravity	Dry matter (%)	Starch (%)	RS (%) d.w basis	Texture
Round to oval	40-60	Shallow	1.085	22-25	15-18	1.25	Firm to mealy

Table 2. Critical levels of soil available P and K for potato

Soil nutrient status	Soil test values (ppm)	
	Olsen's P	Ammonium acetate-K
Low	< 10	< 105
Medium	10 - 20	105 - 150
High	> 20	> 150

Table 3. Critical limits and doses of micronutrient application for correction of their deficiency in potato

Micro-nutrient	Source	Critical limits in Soil (ppm)	Soil appli-cation (kg/ha)	Spray appli-cation (g/100 lit. water)	Tuber soak-ing treat-ment (g/100 lit. water)
Zinc	Zinc sulphate	0.75	25	200	50
Iron	Ferrous sulphate	6.60	50	300	75
Manganese	Manganese sulphate	2.00	25	200	50
Copper	Copper sulphate	0.32	25	200	50
Molybdenum	Ammonium molybdate	0.20	2	100	20
Boron	Sodium borate	0.50	2	100	20

Suggested Readings

Grewal, J.S. and S.P. Trehan. 1993. Phosphorous and Potassium nutrition of potato *In :* Advances in Horticulture Vol. 7 (K.L. Chadha and J.S. Grewal. Eds.) Malhotra publication Agency. pp 231-60.

Marwaha, R.S., D.S. Uppal, D. Kumar and S.K. Sandhu. 2003. Potato Processing. In : *The Potato Production and Utilization in Sub-Tropics* (S.M. Paul Khurana *et al.* Eds.), Mehta Publishers, New Delhi, pp. 336-46.

Pandey, S.K. and S.K. Chakrabarti. Twenty Steps Towards Hidden Treasure – Technologies that triggered potato revolution in India. Malhotra publishing house, New Delhi: 278

Sharma, R.C. and N.C. Upadhayay. 1993. Nitrogen nutrition of potato *In* : Advances in Horticulture Vol 7(K.L. Chadha and J.S. Grewal. Eds.) Malhotra publication Agency. pp 231-60.

Sharma, R.C., Grewal, J.S. and N. C. Upadhayay. 1991. Nitrogen management in potato. CPRI Technical Bulletin No. 32 Central Potato Research Institute, Shimla, Himachal Pradesh, India, 74 pp.

Sud, K.C., and, R.C. Sharma. 2003. Major and secondary nutrients*. In:*

the potato – production and utilization in Sub-tropics *Tropics* (S.M. Paul Khurana *et al.* Eds.), Mehta Publishers, New Delhi, pp. 136-47.

Sud, K.C., N.C. Upadhayay, S.P. Trehan, M.K. Jatav, Manoj Kumar and S.S. Lal. 2008. Soil and Plant Tests for Judicious Use of Fertilizers in Potato. CPRI Technical Bulletin No. 91 Central Potato Research Institute, Shimla, Himachal Pradesh, India, 80 pp.

Trehan, S.P. and R. C. Sharma . 1999. Micro Nutrient requirements of potato. CPRI Technical Bulletin No. 23 (revised) Central Potato Research Institute, Shimla, Himachal Pradesh, India, 42 pp.

Trehan, S.P., N.C. Upadhayay, K.C. Sood, Manoj Kumar, M.K. Jatav and S.S. Lal. 2008. Nutrient Management in Potato. CPRI Technical Bulletin No. 90 Central Potato Research Institute, Shimla, Himachal Pradesh, India, 64 pp.

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13

FARM MECHANIZATION FOR POTATO PRODUCTION

Sukhwinder Singh, Sunil Gulati and Manjeet singh

Contents

Introduction

Potato is a highly voluminous and labour intensive crop which requires about 600 man-hrs/ha for different operations, if done manually. Seed (25-35 q/ha) and produce (250-300 q/ha) is perishable in nature and need quick and careful handling to avoid damage to tubers, especially during planting, harvesting and post harvest operations. Although, in agriculturally developed countries of the production of potato was made highly mechanized during 50's and 60's itself, but in India, importance of mechanization was felt in 70's and different machines were developed in ICAR and agricultural universities. These machines were slowly adopted in Punjab, Haryana, Western Uttar Pardesh and in some other potato growing areas which helped in increasing potato production and bringing brown revolution in India.

Though basic machines like semi automatic planters, inter row cultivators, ridgers, sprayers, digger plows, digger elevators etc. are being used for the last couple of decades, but in recent years, significant developments in research and development has taken place and a variety of new designs of machines has been added to the existing pool. Following are some of the recent advances:

Field preparation

From 1995-2000 experiments were conducted on non invertive deep tillage in potato and results indicated that 10-15% extra yield can be obtained with deep tillage. Also deep tillage saves potato crop to some extent from water logging and drought conditions. Based on these results improved designs of subsoiler for deep tillage were developed. Deep tillage operation is done to a depth of 12-14 inches, in dry field conditions before planting of potato crop. Besides disc harrows, cultivators, plankers etc. recently **rotavators/rototillers** have started becoming popular with potato growers. With this machine fine tilth can be obtained in one operation itself.

Fig 1. Two tine subsoiler for deep tillage and roto-tiller for field preparation

Planting

Traditionally, in most of the parts of India, potato is planted manually or with animal drawn aids. In north western areas revolving magazine and belt cup type planters are popular where farm workers sit behind the machine and put seed tubers in revolving cells or belt cups. Seed pieces

are dropped in line and are covered by ridge making units of the machine. In recent years automatic planters have been successfully designed and are being adopted by farmers. In these machines, machine automatically picks up seed tubers and drops in lines which are ultimately covered by ridgers. These machine have more capacity, missing is minimum and planting can be done at night also. These machines are also provided with fertilizer application units.

Belt cup planter

Magazine type planter

Cup type automatic planter

Finger type automatic planter

Fig 2. Different type of potato planting machines

Inter row cultivation and top dressing

Potato being an underground crop, is highly responsive to inter-row-cultivation. Traditionally, after 21 days inter row cultivation is performed with cultivator, fertilizer is applied manually and earthing operation is done with 3 row or 5 row ridgers. This involves multiple entry of tractor farm workers into field. To economize following multipurpose machines have been developed: (i) Inter row cultivator- cum –fertidrill-cum-ridger (ii) Inter row cultivator-cum-fertidrill

These machines may not be suitable in some conditions where soil is heavy and weed intensity is high.

Fig 3. Spring tine inter row cultivator

Fig 4. Multipurpose (3 in 1) machine

Fig 5. Single nozzle and multi-nozzle hand operated sprayers

Plant protection

For many decades the choice of sprayers was limited. These were manually operated low capacity machines. Performance of these machines depends upon operators endurance. Recently, high capacity, tractor operated sprayers have been developed which are more efficient, give consistent performance and can cover large area in short span of time to save crop from deadly diseases like late blight.

Fig 6. High capacity tractor operated sprayers can cover large acreage in short time

Harvesting

In majority of potato growing areas digging is done with hand tools like *khurpa*, spade, plow and animal drawn plows. In areas where tractor is main source of farm power, tractor operated two row plows and digger elevator are commonly used. In recent years improvements have been made and multipurpose digger, digger shaker and digger windrower have been developed.

i) ***Multipurpose digger:*** **This low cost, tractor operated tool can be used for early (without cutting haulms) as well as main crop after cutting vines.**

ii) ***Digger shaker:*** **In this machine soil, clods and trashes are separated from tubers in two stages. This machine drops tubers gently on soil surface and causes less damage to tubers.**

iii) ***Digger windrower:*** **A lot of man power is required for picking of tubers after the operation with any kind of digging machine. Digger windrower lifts potatoes from under the ridges and place these into a narrow band where picking becomes easier and less labour is required for collection of tubers.**

iv) ***Digger for potato sugarcane intercropping:*** **It is an established fact that intercropping system of potato with sugarcane is highly remunerative as compared to sole potato and sugarcane crop. Till 2004 there was no dedicated machine or equipment for this important system of intercropping, therefore, most of the field operations in general and harvesting in particular was difficult to accomplish. In 2004 CPRI developed a special tractor operated equipment which is helpful in digging potato from its intercrop with sugarcane and simultaneously inter row cultivation is also done.**

Picking of left over potatoes

While harvesting with any kind of tool or machine, about 2-10% potatoes are left in the fields which are picked up later on. CPRI has developed a simple harrow for exposing left over potatoes. This is simple but very useful tractor operated equipment, which consists of three point hitch system and

Hand tool

Multipurpose digger

Digger shaker **Digger windrower**

Fig 7. Different kind of potato harvesting tools and machines

a main sturdy frame which is fitted with 27 square section pegs of 40.6 cm length, in a staggered manner on the rear and front. During operation, equipment combs the soil of the field, expose the left over tubers and facilitate easy picking, thus reduce the losses.

Grading and seed treament

Potato grading and treatment has been done manually for the last couple of decades. In the recent years new graders and seed treatment machines have been developed to carry out these operations mechanically. But still the adoption of these machines is not as much as required initial investment is high and manual grading and treatment is cheaper.

Fig 8. Potato rubber spool grader and treatment machine

Potato handling

In potato produciton seed and produce is moved from one place to another 6-7 times befor sending to market. This requires a huge number of farm labours and is time consuming. Further, as material is shifted in tokras, bags and trays over the head, it involves a lot of drugery to the workers. To reduce drudgery, time and labour requirement, recently handling aids have been developed which has made potato handling quite easy. For small farmers 50 kg and 200 kg capacity trolleys have been developed. With these trollys workers don't need to place load on head or shoulder. One person can move double or tripple the load without much drudgery. For large farms pallets of capacity 500 kg to 1300 kg have been developed which are used with the help of fork lift.

Manual handling

Two tray (50 kg) trolley

Eight tray (200kg) trolley

Fork lift assisted handling
(50 trays/1250 kg)

Fig 9. Potato handling with trolleys and fork lift

All these machines are slowly being adopted by farmers. These new machines are helpful in timely planting, inter row cultivation, spraying, harvesting, grading and seed treatment. By using these machines different farm operations can be completed well in time, therefore, planing of other crops of the system are not delayed and farming in general, and cultivation of potato in particular, can become a good business proposition.

Suggested Readings

Atwal, JS, Sunil Gulati and R. Singh.1992. Design and development of animal drawn potato planter. In proceedings of National colloquium on potato mechanization in India, held at College of Agricultural Engineering, Punjab Agricultural University, Ludhiana on Nov. 11-12, 1992.16-22.

Bishop, CFH & Maunder, WF., 1980. Potato mechanization and storage. *Faming Press Ltd. Wharfedale road, Ipswich*, Suffock. 97-102.

CPRI. 1999-2000. *Annual Report*, Central Potato Research Institute, Shimla, H.P., India.

CPRI. 2000-2001. *Annual Report*, Central Potato Research Institute, Shimla, H.P., India.

CPRI. 2002-2003. *Annual Report*, Central Potato Research Institute, Shimla, H.P., India.

Hall, Carl W. 2008. Agricultural mechanization in developing countries. Shin Norinsha.

Singh, Manjit and Sunil Gulati. 2008. Farm equipment and machines for potato production. *Technical bull. No.93*. CPRI, Shimla, India.

Singh, Sukhwinder, Sanjay, Rawal and Manjit, Singh.2007. Design and development of offset type digger for sugarcane + potato intercropping. *Potato Journal* 34 (3-4): 227-230

Singh, Sukhwinder. 2006. Design, development and field testing of a multipurpose potato digger. *Potato Journal*. 33(3-4): 121-125.

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14

CROP MODELING, REMOTE SENSING AND G.I.S.

PM Govindakrishnan

Contents

Introduction

In the pre green revolution era, the input levels in agriculture were low and were primarily generated within the household, hence, dependence on external inputs was minimum. With the release of high yielding varieties during the green revolution period, the need for increasing input use was felt since these varieties generally yielded well under high input levels only. Therefore, farmers were encouraged to increase their input levels through external sources. General recommendations for different inputs were developed which were based on average conditions. This led to over use of inputs at some situations while in others there was under use. However, this was not a very serious problem since generally the input levels were lower than the recommended doses, therefore, situations of over use of inputs were rare under Indian conditions. The input use has however, increased over the years while the response to applied inputs is decreasing. Moreover, with the increased awareness and concern of environmental impact of inappropriate use of resources in agriculture, high cost of inputs and decreasing profit margins, the need for tailoring input use and management decisions to critically defined target situations is being increasingly realized. Thus, management of agricultural production needs to undergo a sea change. Decisions for specific situations would need detailed information about the target areas based on which relevant decisions can be made. This necessitates the need to collect and analyze a huge amount of data as well as develop user friendly delivery mechanism *viz*. decision support systems (DSS) and this is possible only through greater use of information technology (IT) tools. Geographical information system (GIS), remote sensing (RS) and crop modeling are some of the tools being used to address the above concerns. Studies on the use of these tools in potato R&D in India are briefly discussed below.

Geographical Information System

The term GIS is applied to a hardware and software system capable of computerized storage, processing and retrieval of data that are geographically referenced (spatial data and corresponding attribute information). Thus although a GIS is designed as a database for spatially referenced data, it also has very strong visualization and modeling features which makes it much more powerful than conventional database software. Some of the uses of GIS in agriculture include precision farming, land use planning, watershed management, pest and disease management, irrigation management, biodiversity management, resource inventory, mapping and modeling, yield forecasting and natural resources management.

At CPRI, initially GIS was used as a spatial database tool to store, retrieve and thematically present potato statistics *i.e.* area, production and productivity at the district level. These data were thematically presented as a series of maps which included area, production, productivity, relative yield index *etc*. The thematic classification of the acreage map showed that the distribution of potato in India is widespread and barring a few districts it is grown in most of them. There are 10 districts in the country having more than 20,000 ha under the crop out of which as many as 9 districts [Agra, Firozabad, Kannauj, Farrukhabad (UP), Paschim Medinipur, Hooghly, Bardhaman and Jalpaiguri (WB)] are in the Indo-Gangetic plains (IGP) region. Hassan (Karnataka) is the only district outside the IGP region having more than 20, 000 ha under the crop. There are only 5 districts in the next highest category *i.e.* between 15,000 to 20,000 ha [Jalandhar (Punjab), Hathras, Badaun (UP), Patna (Bihar) and Bankura (WB)]. Similarly the classification of the production map showed that most of the districts in the IGP region produce more than 1,00,000 tons of potatoes. Within the IGP region, 5 districts of Punjab, *viz.*, Hoshiarpur, Jalandhar, Ludhiana, Moga and Patiala are the major producers in the western IGP region, producing more than 1,00,000 tons. There are as many as 20 districts producing more than 1,00,000 tons in the central region of IGP, while barring a few almost all potato growing districts produce more than 1,00,000 tons in the eastern region of IGP showing that the eastern plains are the major producers of potato. In the other states,BanasKantha, SabarKantha, Kheda (Gujarat), Indore (MP), East Khasi Hills (Meghalaya), Hassan and Kolar (Karnataka) are the major producers (> 1,00,000 tons).

Agro ecological zonation (AEZ) is another important activity using GIS and is a method that uses biophysical attributes of the land to cluster land use types into homogenous areas. This enables targeting appropriate technologies for the homogenous areas.Van Keulen and Stol (1995) were one of the earliest workers to do agro ecological zonation of potato to establish the spatial distribution of potential growth duration, potential yield and water limited yield at global scale. Haverkort and Kooman (1997) delineated a sequence of steps for zonation *viz.* determination of suitable temperature range for the crop, determination of the suitable period for crop growth, determination of potential total dry matter yield and finally determination of the ideal moment of tuber initiation to ascertain harvest index and tuber yield.

At CPRI, zonation was carried out at sub district level to estimate potential production in different locations. The potential yield of a crop is defined as the yield achieved by a certain cultivar in a particular environment when factors such as water, fertilizers, crop management *etc.* are not limiting and no reducing factors such as diseases, pests and weeds are present. The production potential of potato in major towns/talukas of the country have been worked out using generated weather of the location and a crop model and integrated to generate a surface using a GIS. The results showed that wide spread areas in the states of the Indo-Gangetic plains and Rajasthan, Madhya Pradesh, Chattisgarh, Orissa and north eastern states have high to very high total yield potential. Reasonable total yield can be obtained even in Karnataka, Maharashtra and some parts of Andhra Pradesh indicating possibilities of yield improvement in these states.

Remote Sensing

Remote sensing is another tool the use of which is increasing rapidly in agriculture. It is defined as the science of acquiring information about an object without coming into contact with the same. Some of the different purposes to which remote sensing has been put to use include identification or classification of crops, inventory of crop acreage, forecasting of crop yield, soil survey, design and operation of irrigation projects, and assessment of damage due to various factors like frost, diseases, floods *etc*.

The basic principles of remote sensing are that energy in the form of light waves (called the electromagnetic spectrum) from the sun falls on the object. When electromagnetic energy from the sun strikes an object, depending upon the wavelength of the energy and characteristics of the individual object, the incident energy is either reflected, absorbed, or transmitted. Reflected energy bounces off the object and is readily identified by human eyes or received by the sensors. Sunlight that is not reflected or absorbed is transmitted through the leaves to the ground. Interactions between reflected, absorbed, and transmitted energy can be detected by remote sensing. The differences in colors, textures, shapes *etc.* of the object determines how much energy will be reflected, absorbed or transmitted and in turn determines the spectral signatures of the object which is defined as the reflection in the different wavelengths.

The wavelengths used in most agricultural remote sensing applications cover only a small region of the electromagnetic spectrum. The visible region of the electromagnetic spectrum is from about 400 nm to about 700 nm. The green color associated with plant vigour has a wavelength around 500 nm. Wavelengths longer than those in the visible region and up to 1 mm are in the infrared region. The infrared region nearest to that of the visible region is the near infrared (NIR) region . Both the visible and infrared regions are used in agricultural remote sensing. Vegetation indices are used to measure biomass or vegetative vigour. These are derived by addition, substraction, division or multiplication of several spectral values in such a way that a single value is obtained which indicates the amount and vigour of vegetation within a pixel. The most common vegetation index is the normalized difference vegetative index (NDVI). NDVI compares the reflectance values of the red and NIR regions and is expressed as a ratio of red-NIR to red+NIR reflectances.

Spatial, spectral, radiometric and temporal resolutions are some of the factors to be considered while designing a remote sensing methodology for a particular application.

Spatial resolution refers to the size of the smallest object that can be detected in an image. The smallest unit identifiable in an image is called a pixel. Smaller the area represented by a pixel, higher is the resolution of the image. However, higher resolution data are costly moreover their computing time would also be high. Therefore, the type of application and the accuracy desired are to be considered while deciding spatial resolution.

At CPRI, remote sensing was used for pre harvest crop acreage estimation. For this purpose the spatial resolution of the satellite image should be such that most of the fields of the target crop should be distinguished and that other crop fields should not get merged with potato fields. Initially WiFS data with a spatial resolution of 180 m was used and the accuracy of the estimates with this data was about <90%. Later AWiFS data with a resolution of 56 m was used for potato acreage estimation. The use of this data has increased the accuracy to over 95%.

As regards stresses, late blight and frost are the major stresses in the Indo Gangetic plains (IGP) during the potato season. Both these stresses occur in patches, therefore, for estimating the extent of damage higher resolution data is required. Studies at CPRI showed that late blight could be assessed through analysis of LiSS III data which has a spatial resolution of 23 m.

Spectral resolution refers to the number of bands and the wavelength width of each band. A band is the wavelength interval of the electromagnetic spectrum. Higher spectral resolution images have short wavelength widths. Multi-spectral images have several wavelength bands such as visible, red, green or NIR. In potato acreage estimation red and NIR wavelengths are used for the NDVI estimation. Spectral resolution is also important for disease estimation. Studies showed that late blight affected fields exhibited significantly different values in the different bands as compared to healthy crop. Mean values of the green, red and NIR bands in the diseased crop were 57.0, 35.5 and 64.2, respectively as compared to 67.7, 38.7 and 86.0 units in the healthy crop.

Preliminary studies at CPRI using ground based spectro radio meter hyperspectral data has been carried out for retrieval of crop bio-physical/ bio-chemical parameters in rice-potato-wheat cropping system. Most of the narrowband indices showed significant correlation with crop parameters viz LAI (leaf area index), chlorophyll and nitrogen content in the foliage of rice, potato and wheat crops. The optimum band combination for LAI estimation in potato crop was found to be 680 and 780 nm, for computing NDVI and Social Adjusted Vegetation Index (SAVI). Soil colour related radiometric indices were found to be able to discriminate between two soil textures, organic matter, and soil nutrient parameters. Significant discrimination could also be achieved between crop variety, nitrogen, water treatments and disease intensity using both hyperspectral reflectance data and the ratio indices.

Radiometric resolution refers to the sensitivity of the sensor to variations in the reflectance levels. The higher the radiometric resolution the more sensitive the sensor is to detecting small differences in reflectance values. Higher the radiometric resolution more precise picture of a specific portion of the electromagnetic spectrum is obtained *e.g.* the radiometric resolution of WiFS sensor is 8 bit, therefore, it can record 256 levels of brightness, while the AWiFS sensor with a 10 bit radiometric resolution records 1024 levels of brightness.

Temporal resolution refers to the frequency of the remote sensing platform to provide coverage of an area. Geo-stationary satellites provide continuous sensing while normal orbiting satellites can only provide data each time they pass over an area. Temporal resolution becomes important to discriminate between two objects that are closely related as regards spectral reflection properties are concerned but have different growing periods or growth patterns. In the case of potato in the IGP region, wheat is one of the interfering crops but can be distinguished from potato through temporal data. Here, the potato season starts first while the wheat season starts almost a month later. Therefore, when potato growth is at its peak, wheat growth is negligible while when wheat growth reaches its peak then potato would have started senescing. These differences get reflected in the NDVI values, thus by analyzing NDVI values in the temporal images the two crops can be differentiated from each other. In the IGP mustard, sugarcane, cauliflowers are some of the other crops present during the potato season and these are also differentiated from potato more accurately through temporal data.Temporal data is also important to monitor stresses like disease incidence, frost *etc.*

Crop Modeling

The need for quantifying the relationship between growth and yield of crops and various factors influencing it is of interest to farmers, policy planners, administrators, researchers, crop insurance companies, traders, exporters, students and teachers. Crop models are the tools to quantify, integrate and process the available information rapidly to give valuable outputs to help decision making by the various stake holders. Crop models are useful in defining research priorities, technology transfer, yield estimation, resource optimization as well as for predicting the effects of climate change and climatic variability. Models are of different types and appropriate model needs to be chosen depending on the application. During the early stages of scientific agriculture, models were mostly of statistical type wherein relationships were developed between a dependent variable and one or more independent variables. These models were location specific in that the relationships were applicable only to the places where they were developed and could not be extrapolated. Moreover, these models did not explain the behaviour of the system and therefore did not give insights of the working of the systems. Further, when the number of variables increased the relationships were difficult to develop. Over time with progress in cybernetics and systems thinking, the modeling strategy in agriculture also changed and many models were developed based on systems dynamic principles. Sinclair and Seligman (1996) opine that birth of crop modeling took place in the 1960's when simple relationships between light interception and photosynthesis were developed. According to them, the 1970's corresponded with the juvenile stage during which comprehensive models were developed aimed at understanding the interaction between growth factors and crop growth. The adolescent stage, according to the authors, occurred in the 1980's wherein simplified models called summary models came to be developed due to problems in off take of comprehensive models and for greater practical utility. They further state that since 1990's crop modeling has reached the maturity phase during which there is increased awareness of the limitations of crop models as well as their strengths that is crop models have led to quantification of the behaviour of systems and that consequences of alternate options could be forecast.

At CPRI, work on crop modeling started in the latter half of 1990's and efforts were made to adapt the generic crop model INFOCROP developed in India for simulating growth and yield of annual crop in tropics and sub-tropics to potato and this led to the development of INFOCROP-POTATO. The INFOCROP-POTATO model simulates the life cycle of potato in three development stages (DS) *viz.* from planting to emergence, emergence to tuber initiation, and tuber initiation to maturity. The daily rate of phenological development in each of these three stages is a function of thermal time (degree days). Temperature, photoperiod or day length and radiation are the most important environmental variables affecting growth and development individually or in combination. The model considers the crop growth processes, soil water, nitrogen and carbon dynamics, and crop-pest interactions. Daily weather data needed for the model are minimum and maximum air temperature (°C), solar radiation ($KJm^{-2}d^{-1}$) vapour pressure (kPa), wind speed (ms^{-1}) and rainfall (mm). Required soil inputs include depth (mm), organic carbon (%), soil texture (sand, silt, clay %), bulk density and NH_4-N and NO_3-N content in three soil layers. The crop management data needed are seed rate, sprout length of seed tubers, date of planting, depth of planting, amount and date of fertilizers applied, amount and date of irrigation applied. Apart from weather, soil and crop management data, the model requires variety specific parameters which would enable the model to simulate the growth and development of each variety *viz* maximum leaf area and its development pattern, time of tuber initiation and tuber bulking pattern, crop duration, harvest index *etc*. As many as nine genetic coefficients for potato have been included in the model as given below:

TTGERM – Thermal time from planting to plant emergence (degreedays)

TTVG – Thermal time from plant emergence to tuber initiation (degreedays)

TTGF - Thermal time from tuber initiation to maturity (degreedays)

TGMBD – Base temperature from planting to plant emergence (°C)

TVBD - Base temperature from plant emergence to tuber initiation (°C)

TGBD - Base temperature from tuber initiation to maturity (°C)

TPOPT – Optimal temperature for phenological development (°C)

TMAX – Temperature above which the rate of development becomes zero (°C)

RGRPOT – Index of early growth (unit less index of early vigour, scale 1-5)

The standard model output comprises dry weight of roots, stem, leaves and tuber fresh yield, leaf area index (LAI), rooted depth, N uptake by crop, soil water, evapotranspiration, N and water stresses *etc*. Development stage, accumulated thermal time and emission of green house gases are other important outputs. The model satisfactorily simulated the effects of agro-climate and various management inputs on potato growth and development in the tropics. Other applications of the model include optimizing the date of planting, nitrogen fertilization and irrigation as also in identifying the possible growing period in an agro climatic situation and yield forecasting.

Regarding application of crop models, INFOCROP-POTATO model was routinely used for state level yield forecasting. For this purpose the model is run under potential situations for the most popular variety of the state for the optimum time of planting. The model derived yield is then reduced to the actual yield using a management rating (derived from historical data) which is the ratio of the actual reported yield of the state to the potential yield. Another application of the model is its role in developing AEZ's and this work is being carried out at CPRI using the Versteeg and van Keulen model for thematic mapping of potential yield at different locations in India. Model based best management practices (BMPs) for locations throughout the country are also being developed.

Thus, GIS, Remote Sensing and Crop modeling are powerful tools of immense help in decision making. Each of them can be used alone as well as in combination which further boost their utility. All the tools have been exhaustively used in potato research and development efforts at the Central Potato Research Institute.

Suggested Readings

Aggarwal, P.K., N. Kalara, S. Chander and H. Pathak, 2004. Infocrop-A generic simulation model for annual crops in tropical environments. Indian Agricultural Research Institute, New Delhi. pp. 132.

Haverkort, A.J and P.L. Kooman. 1997. The use of system analysis and modeling of growth and development in potato ideotyping under conditions affecting yields. *Euphytica* **94**: 191-200.

Lal HG., JP. Hoogenboom, Calixte, JW. Jones and GH. Beinroch. 1993. Using crop models and GIS for regional production analysis. Transaction of ASAE 36(1): 177-184.

Magarey RD, Travis JW, Russo JM, Seem RC and Magarey PA. 2002. Decision Support Systems: Quenching the Thirst. *Plant Disease* **86:**1-14

Navalgund RR, JS Parihar, Ajai and PP Nageshwar Rao, 19991. Crop inventory using remotely sensed data. Current Science. 61. pp. 162-171.

Praharaj C.S., P.M. Govindakrishnan, Shashi Rawat and S.S. Lal. 2007. Evaluation of the relationship between light use efficiency and solar radiation in potato (*Solanum tuberosum* L*).* Potato Journal. 34 (1-2): 129-130.Caldiz. O.Daniel, Fernanda J. Gaspari, Anton J. Haverkort, Paul

C. Struik. 2001. Agro ecological zoning and potential yield of single or double cropping of potato in Argentina. Agricultural and Forest Meteorology 109: 311-320.

Quiroz, R. P. Zorogastua, G.Baigorria, C. Barreda, R. Valdivia, M. Cruz and J. Reinoso. 2000. Toward a dynamic definition of agro ecological zones using modern information technology tools. CIP Program Reports. pp 361-370.

Rawat Shashi, RK Chauhan and PM Govindakrishnan. 2007. Potential Yield estimation of Potato: Comparison of estimates of InfoCrop Potato and Versteeg and van Keulen methods. Potato Journal. 34 (1-2): 127-128.

Rawat, Shashi, P. M. Govindakrishnan, S. S. Lal, V. K. Dua and S. K Pandey. 2007. *Potato Scenario in India- A Thematic Analysis*. Technical Bulletin No. 84, Central Potato Research Institute, Shimla, India, 37 p.

Ray SS.,Jain, N., Das G., Miglani,A., Panigrahy, S., Parihar, J.S., Singh, J.P., Rachna & Singh, A.K. 2007. Use of hyperspectral remote sensing in agricultural applications: ground based studies. Space Application Centre, ISRO, Ahmedabad, Central Potato Research Station Jalandhar and Indian Agricultural Research Institute, New Delhi. 112p.

Shashi Rawat, PM Govindakrishnan, RK Chauhan and SK Pandey. 2008. A compendium of climate based potato zones in India. CPRI Technical Bulletin No.88. Central Potato Research Institute, Shimla, Himachal Pradesh, India, 23 pp.

Sinclair, T.R. and N. A. G. Seligman. 1996. Crop modeling from infancy to maturity. *Agronomy Journal* **88**: 693-703.

Van Keulen, H. and Stol, W. 1995. Agroecological zonation for potato production. Haverkort, A.J. and MacKerron, D.K.L. (eds) Potato ecology and Modelling of Crops under conditions limiting growth. Kluwer Academic Publishers, Netherlands, pp 357-372.

Van Keulen, H. and W. Stol. 1995. Agroecological zonation for potato production. In: Potato Ecology and Modelling of Crops under Conditions Limiting Growth (A. J. Haverkort and D. K. L. MacKerron Eds), Kluwer Academic Publishers, Netherlands, pp. 357-372.

Venkataratnam, L. 1980. Use of remotely sensed data for soil mapping. *Photonirvachak* **8**: 19-26.

Versteeg M.N., & H. van Kulen. 1986. Potential crop production prediction by some simple calculation methods as compared with computer simulations. Agricultural Systems 19. 249-272.

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15

DECISION SUPPORT SYSTEM FOR POTATO PRODUCTION

Shashi Rawat

Contents

Introduction

Information Technology (IT) is the mantra of modern world. Today IT has pervaded each and every field of human endeavour including agriculture. Unlike medicine, engineering and commerce, its application in agriculture is much slower primarily due to paucity of IT trained manpower in this sector. The Central Potato Research Institute Shimla has developed many tools for dissemination of potato related information through software tools. In this lecture, the salient features and operation of few such tools, viz., i. Potato pest manager: A computer tool for managing insect, pests and diseases of potato. ii."VarTRAC": A computer software for identifying potato varieties through morphological and molecular markers, iii. Computer Aided Advisory System for Crop Scheduling. iv. E-book on potato production v. Digitized photographic database on potato

Potato Pest Manager (PPM)

The role of information technology (IT) in agriculture is increasing rapidly with the establishment of IT villages, agricultural call centres *etc*. Full utilisation of these facilities requires Decision Support tools to the personnel manning these centres. Decision support tools for diseases/pest management are very important because they reduce yield/quality and some of them may wipe out the whole crop within a few days, if timely action is not taken. Further, there is danger of indiscriminate use of chemicals as well as economic loss in case of excess/wrong use. A simple tool "The Potato Pest Manager" (PPM) has been developed for the identification and control of 17 such potato diseases and pests. This methodology could be easily adopted for preparing similar tools in other crops as well.

In this tool the correct identity of the disease/pest is established and then appropriate management practices are recommended. These objectives are achieved in a sequence of steps as detailed below.

Step 1: Photographs showing symptoms of diseases/pests are displayed in sequence. The user is asked to match the symptoms in the photos with that in the field and select the appropriate one.

Step 2: The disease/pest corresponding to the selected photograph is confirmed, through confirmatory questions which are information about the symptoms of disease/damage of pest or conditions needed to be satisfied for the disease/pest occurrence. For example, late blight of potato is a leaf/ foliar disease, which initially appears in field as brown-purplish lesions of varying size on the foliage. The affected leaves show a whitish cottony growth on the under surface and all around a faint purplish black central lesion which may also appear to be water soaked. Varieties like Kufri Jyoti, Kufri Badshah, Kufri Sindhuri, Kufri Jawahar and Kufri Sutlej are resistant to the disease. This information is obtained from the user through a number of questions.

The questions covers every aspect of the disease symptoms as well as ancillary information required for disease/pest occurrence like location, season *etc*. to reach at a valid conclusion.

Step 3: Once all the confirmatory questions are answered, the name of the disease/pest corresponding to the photograph selected is displayed along with percent confidence in this step.

Step 4: Many seed/soil borne diseases/pests can only be controlled through preventive measures taken before raising the crop. For example common scab is a soil/tuber borne disease and its damage is noticed when the crop is harvested. Therefore, preventive measures include soil treatment and sanitary practices to be adopted before raising the crop and this information is displayed in this step.

Step 5: In this step information for controlling the disease/pest for which in season control is possible is obtained. For example the control of disease/pest can be taken only when the intensity is within limits and it is economical to use additional inputs. Further there should be sufficient time left for adopting the control measures and its effect to be manifested. The required information is obtained from the user by presenting the questions or statements with various options. For example information on the severity and age of the crop in the case of late blight, is obtained by asking questions.

Depending upon the number of questions and the number of options to each question, a number of recommendations emerge. For example in case of the above there are two questions with four options each. Thus, there will be sixteen (4 X 4) recommendations and only one of them depending upon the options selected would be displayed.

Step 6: This step displays the precise recommendation tailored to the individual situation based on the options chosen.

"VarTRAC": A computer software for identifying potato varieties through morphological and molecular markers

Authentic identification of potato cultivars is important for plant breeders, the variety registration and certification agencies, seed producers, merchants, farmers, growers, processors, and other end-users. There is also increasing interest in the descriptive characterization of plant varieties in the context of intellectual property protection rights under the recent agreements within the framework of World Trade Organization. Currently morphological descriptors are being used internationally for variety identification. However, there is a possibility of utilizing DNA fingerprint data to supplement morphological characters in near future. Central Potato Research Institute, Shimla is, therefore, developing both morphological and DNA fingerprint databases for potato cultivars' identification.

Data on 50 different morphological attributes and DNA fingerprints based on 127 alleles from 4 micro-satellite markers are currently being used at CPRI for varietal identification. Manual analysis of such huge data is not easy. Therefore, a computer software named "VarTRAC" has been developed at CPRI for speedy identification of a variety based on the morphological and DNA fingerprint data.

In this software, each morphological character is taken as a field. All the characters necessary for the identification of a potato variety have been included. Scores are given for each character in a drop-down menu format and the users have only to select the appropriate score for each character. Further help has also been provided for proper scoring. As regards DNA fingerprints, the data on 127 alleles have been recorded by giving a score of one for those alleles, which are present and zero for the absent ones. The software can make generalized abstraction even from the minimum available information. For example, if only 5 morphological attributes of any unknown cultivar are known, the software can identify the group of varieties having similarity in respect of those 5 attributes. This group can then be further analysed for final identification of the unknown sample. This particular property of the programme will be very useful to minimize the cost of DNA fingerprinting. The programme has many other user-friendly features are known, then input those 3 values and then click run button as displayed in figure below at number 2 location.

Computer Aided Advisory System for Potato Crop Scheduling (CAASPS)

Potato is a very important cash crop in India. Though it is grown in most of the country, the Northern Indo- Gangetic plains is the main potato growing belt and the acreage in the other parts of the country is low. To meet the growing demands of the population there is need to extend its acreage and improve its productivity in the other parts of the country. CPRI has developed package of practices for agroecological regions similar to the where its headquqrters and regional stations are located. However, for other regions there is need for recommending best management practices viz. optimum date of planting,best variety and the production potential at different dates of harvesting. This would enable the farmer to plan his crop schedule according to the market and cropping system of his location.

This tool consists of a database of expected yield for 10 varieties for 5 dates of planting for important places in India created using a crop model " INFOCROP-POTATO" developed at CPRI . The model has been run for the longest growing period for each season using weather derived from "MARKSIM" weather generator for potential situations. This tool enables access of this database.

The users may bear in mind that outputs have been derived for potential situations and soil moisture as well as nutritional status and other stresses have not been considered. The dates of planting chosen are for 5 dates of planting staggered at 10 days interval beginning from 10 days prior to the start of the longest growing season as delineated by thermal based screening rules.

E-Book on Potato

E-book on the Potato is meant to give a bird's eye view of practical knowledge about the potato production, utilization, *etc.* in India. It is aimed at providing appropriate information for all those interested in knowing about the ways potato is cultivated in different regions in India, the reasons for the adoption of the various agro techniques and the major abiotic and biotic stresses. This is expected to provide insights about the scientific cultivation and utilization of potato. This e-book is also meant to be a supplement to many excellent publications on potato, which could not be fully illustrated with photographs due to limitation of cost of printing. This lacuna is overcome in this e-book since cost factors are minimum in this case. Thus, this e-book apart from being used as a book *per se* would also be a pictorial supplement to other publications available in print. Through this e-book, it is hoped to further strengthen the cause of potato R&D in India using the electronic media, the use of which is becoming rampant.

Digitized Photographic Database of Potato

The creation of photographic database is a very important activity because information can be presented very easily and concisely through photograph rather than text. Therefore, a digitized photographic database was developed. It can be used by professionals in their presentations, extension lectures to the farmers/industry entrepreneurs, in publication of scientific books, technical bulletin *etc*. The database contains more than 600 photographs pertaining to all aspects of potato research and development. The use of this database does not require any specialized skill.

Suggested Readings

Anonymous 1981. Indian latitude, longitude and height of important localities. Indian Meterological Department.

Govindakrishnan PM, Khurana SMP, Singh Sarjeet, Chandla VK, Ahmad I, Rawat S, Lal SS and Dua VK (2005) Development of a database for the identification and control of diseases and pests of potato in India. *International Pest Control.* Vol 42 No. 2 78-81.

Govindakrishnan PM, Rawat Shashi, Pandey SK, Singh JP, Lal SS and Dua VK (2011) Computer Aided Advisory System for Potato Crop Scheduling (CAASPS)-A decision support tool for potato planting strategies. *International Journal of Agricultural Stat. Sci.* 7 No. 2 571-577.

Haverkort AJ and Kooman PL (1997) The use of system analysis and modeling of growth and development in potato ideotyping under conditions affecting yields. *Euphytica* **94**: 191-200

Magarey RD, Travis JW, Russo JM, Seem RC and Magarey PA (2002) Decision Support Systems: quenching the thirst. *Plant Disease* **86**: 1-14

Rawat S, Pandey SK, Chakrabarti SK, Khurana, SMP and Kumar Vinod (2004) VarTRAC: A computer software for identifying potato varieties through morphological and molecular markers. CPRI Newsletter-30: 1-2.

Singh J P, Govindakrishnan P M, Lal S S and Aggarwal P K. 2005. Increasing the efficiency of agronomy experiments in potato using INFOCROP-POTATO model. *Potato Research* **48**: 131-52.

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16

FUNGAL DISEASES OF POTATO AND THEIR MANAGEMENT

Sanjeev Sharma

Contents

Introduction

The importance of potato as a food crop was duly recognized soon after its introduction in Europe in the 16th century. This is going to be the future food crop for the millions especially in the third world countries. Potato production and consumption is accelerating in most of the developing countries including India primarily because of increasing industrialization. In fact, potato production in developing countries surpassed that of developed countries. Potatoes in India are grown under varied climatic conditions ranging from tropics, subtropics to temperate highlands. Consequently, the spectrum of insect-pests and diseases is very large. All of them put together have the potential to limit potato production up to 85% depending upon the weather/region. Scope of this chapter is limited to the important fungal diseases of potato, which causes considerable losses to the growers. For the convenience these diseases are grouped into foliar diseases and soil & tuber borne diseases.

Foliar Diseases

Late blight (*Phytophthora infestans* (Mont.) de Bary)

It is one of the most devastating diseases of potato and losses up to 85% have been reported if crop (susceptible cultivar) remains unprotected. Disease appears every year in epiphytotic forms in hills as well as in plains.

Symptoms

Late blight affects all plant parts viz. leaves, stem and tubers. It appears on the leaves as pale green, irregular spots which enlarge into large water soaked lesions. In moist weather the spots enlarge rapidly with central tissue turning necrotic and dark brown or black. Often, the spots have a purplish tinge. On the lower side, white mildew (cottony growth) ring forms around the dead areas. In dry weather the water soaked areas dry up and turn brown.

On stems and petioles light brown elongate lesions develop often encircling the stem/petiole. Under favourable conditions, the whole vine may be killed and blackened and the disease spread rapidly killing the entire crop in a few days.

Tubers are readily infected while in soil by rain borne spores from blighted foliage. Initially the tubers show a shallow, reddish brown dry rot that spreads irregularly from the surface through the flesh. At low storage temperatures, the lesions usually remain firm and frequently show a metallic tinge especially at the border of healthy tissues.

Epidemiology

Tubers carrying the pathogen are the real carriers and serve as the source of the disease in the subsequent season. In the plains, the pathogen over summers through infected seed tubers in cold stores. Infected seed tubers grow into healthy plants but under conditions favourable for the disease (temperature 10-20°C and RH>80%) the resting pathogen develops within the infected seed and affects the stem base/lower leaves. Such infected stems and leaves serve as the primary source of inoculum. The pathogen sporulates on the primary lesions and the sporangia so formed are carried over by wind currents/rain splashes to other plants/fields thereby setting a chain reaction. The sporangia are also washed down to soil with rain water or dew and infect the new tubers.

Appearance and buildup of late blight depend solely on weather conditions. There are specific requirements of temperature and humidity for initiation and further buildup of disease. Temperature requirements are different for pathogen growth (16-20°C), spore production (18-22°C), spore germination (10-20°C) and for infection and disease development (7.2-26.6°C with 18-1°C). Spore germination and infection requires 100 per cent humidity and spores get killed under low humidity (<75%). The spores are produced during the night and are sensitive to light. Cloudiness favours disease development.

Disease Management

Following integrated management schedule is recommended for the management of late blight in the country.

i) Reduction of the primary sources of inoculum is the first step in management of late blight. Control of contaminated sources such as waste heaps, infected tubers, volunteer plants, disease in neighboring fields and re-growth after haulms destruction can help in management of the disease.

ii) Follow sound crop rotation for reducing the risk of soil-borne infections of *P. infestans*.

iii) Grow late blight resistant varieties recommended for the region.

iv) Use disease free seed.

v) Follow high ridging and earthing up.

vi) Stop irrigation under overcast conditions.

vii) Give prophylactic spray (just before the canopy closure) of mancozeb (0.2%) followed by cymoxanil+mancozeb dimethomorph+mancozeb/ fenamidone+mancozeb (0.3%) followed by one more spray of mancozeb.

viii) Kill the haulms and bury them in pits at 75% disease severity.

ix) Harvest the crop 12-15 days after haulms cutting, sort out the late blight infected tubers and store the seed after treating it with boric acid (3%).

Late Blight Forecasting

Development of late blight mainly depends on moisture, temperature and cloudiness. In India, the rains are heavy and the weather is cool and cloudy/foggy during summer in the hills but in plains the weather is generally clear with scanty rains (during autumn or spring) and therefore, the disease epidemic is not a regular feature. The monsoon moves from East to West in the Himalayas. Therefore, the blight occurs early in the eastern Himalayas. Taking weather parameters in account, Bhattacharya *et al.* (1983) developed forecasting models for Shimla, Shillong and Ootacamund i.e. i) if the 7-day moving precipitation (30 mm for Shimla, 28.9 mm for Ootacamund and 38.5 mm for Shillong observed to be critical rainfall lines) associated with mean temperature of 23.9°C or less continues for 7 consecutive days, late blight would appear within 3 weeks and ii) if hourly temperature ranges from 10-20°C associated with high RH (80% or more) for continuous 18 hr for two consecutive days, the blight would appear within a week. Based on these criteria a late blight warning service was started since 1978 for Shimla hills and successful warnings are issued through All India Radio, Shimla every year.

Late blight forecasting in the sub-tropical plains is different to that of temperate highlands. In the hills, environmental conditions (temperature, RH, rainfall) favourable for late blight appearance are assured. There are plenty of rains during the crop season which led to high RH (>80%) for most of the crop season. Temperature remains moderate and congenial throughout. It is therefore, possible to rely on weather parameters like, rainfall, RH and temperature for making disease forecasts. Such situations, however, do not exist in the sub-tropical plains, where there are scanty rains during the crop season. In such a situation, role of micro-climate, fog dew and sunshine becomes critical for the appearance of the disease. Besides, weather data for substantial period is required to develop reliable empirical models.

A late blight forecasting system 'JHULSACAST' has been developed for western Uttar Pradesh using temperature, RH and rainfall data. It consists of two models, one each for rainy and non-rainy years.

Model for rainy years

i) Measurable rains (0.1-0.5 mm) for a minimum of two consecutive days

ii) 5-day moving >85% RH period 50 hrs or more

iii) 5-day moving congenial temperature (7.2-26.6°C) for 105 hrs or more

If above conditions prevail for five consecutive days, blight would appear within 10 days time.

Model for non-rainy years

i) 7-day moving $\geq$ 85% RH period $\geq$ 60 hrs

ii) 7-day moving congenial temperature (7.2-26.6°C) $\geq$ 120 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 10 days time.

Model for Punjab

i) 7-day moving $\geq$ 85% RH period $\geq$ 90 hrs

ii) 7-day moving congenial temperature (7.2-26.6°C) $\geq$ 115 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 10 days time.

Model for Tarai region of Uttarakhand

i) 7-day moving $\geq$ 85% RH period $\geq$ 85 hrs

ii) 7-day moving congenial temperature (7.2-26.6°C) $\geq$ 135 hrs

If above conditions prevail for 7- consecutive days, blight would appear within 14 days time.

Software for this forecasting system has been developed as JHULSACAST and has been successfully validated.

Early blight (*Alternaria solani* (Ell. & Mart.) Jones & Grout)

Early blight occurs in all the potato growing areas but is common in central India and plateau of Bihar/Jharkhand and Maharashtra. The disease has been reported to cause significant losses (up to 20%) in *Kharif* crops in Ranchi and adjoining plateau region. In north-western and north-easten hills and plains, the disease appears regularly but in lesser significant form since late blight takes over.

Symptoms

Initially the symptoms occur on the lower and old leaves in the form of small (1-2 mm), circular to oval, brown spots. These lesions have the tendency to become large and angular at later stage. Characteristic 'target board' concentric rings of raised and depressed necrotic tissue can be observed, often with a chlorotic halo surrounding the lesion. The tuber symptoms comprise brown, circular to irregular and depressed lesions with underneath flesh turning dry, brown and corky. Lesions tend to enlarge during storage and affected tubers later become shriveled.

Epidemiology

The fungus can survive in soil and plant debris particularly in temperate climate. The infected tubers form the primary source of inoculum. The disease is favoured by moderate temperature (17-25°C) and high humidity. Intermittent dry and wet weather is more conducive for early blight.

Phoma leaf spots (*Phoma exigua* Desm., *P. sorghina* Doerema, Doren & Kest.)

Leaf spots caused by *Phoma* spp. also occur widely both in hills and plains. Depending upon the severity, these leaf spots may cause significant yield losses.

Symptoms

Leaf spots due to *P. exigua* are larger (1-2.5 cm) with broad alternate light and dark concentric zones. Affected tubers have grey to greenish black depressed lesions (up to 3cm) on the surface. Leaf spots due to *P. sorghina* are characterized by pin head size spots, which may be oval, circular or irregular (not exceeding 4mm). Infected tubers show grey large lesions (up to 1.7cm).

Epidemiology

These fungi can survive in soil and plant debris and on infected tubers during storage. The infected tubers form the primary source of inoculum. Infection usually appears on the lower leaves near ground level and results in the infection of young immature tubers if not covered by the soil. The disease is favoured by moderate temperature (17-25°C) and high humidity.

Management

The integrated management of early blight and leaf spots is as below:

i) Use disease free tubers for raising the crop.

ii) Removal and burning of haulms of the affected potato crop help in reducing the inoculum in the field.

iii) Cultivation of solanaceous crops, being collateral hosts, nearby potato field must be avoided.

iv) Spray the crop with mancozeb (0.2%), chlorothalonil (0.2%), copper oxychloride (0.3%) and Bordeaux mixture (1.0%).

Soil and Tuber Borne Diseases

Soil and tuber borne diseases are multifaceted in nature. Most of the pathogens have a very long soil phase and also carried through potato tubers. These diseases may cause disfiguring of tubers thereby impairing the quality, tuber rots in storage & transit, and wilts and stem rots in field.

Black scurf (*Rhizoctonia solani* Kuhn)

Symptoms

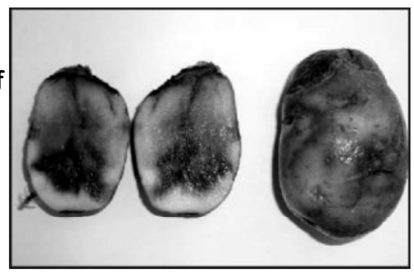
Almost all plant parts are affected. The fungus attacks young sprouts through epidermis and produces dark brown lesions thereby killing the sprout before emergence, which result in gappy germination. Elongated reddish brown lesions develop on the stem at or below soil surface that may girdle the stem. When the girdling is complete the foliage curl and turn pinkish to purplish. Often aerial tubers are formed as a result of interference in starch translocation. Towards the end of the season, the fungus produces numerous hard, small, dark brown to black sclerotia on the surface of mature tubers. These sclerotia when get deposited continuously, form a black encrustations on the tuber surface.

Epidemiology

Seed tubers serve as the main source of the disease. In the hills, the fungus survives in the soil throughout the year and is a potential source of the disease. However, high summer temperatures are not conducive for the production of sclerotia and their survival. Therefore, *R. solani* has to over summer either as saprophytic mycelium or by infecting the crops grown during summer period. The soil temperature governs production of sclerotia on the tuber surface. The optimum temperature for growth of the fungus is 25-30°C and for the germination of sclerotia is 23°C.

Charcoal rot (*Macrophomina phaseolina* (Tassi) Goid

Symptoms



The pathogen produces three types of symptoms i.e. stem blight, charcoal tuber rot and dry tuber rot. The charcoal tuber rot phase is important under Indian conditions. The first visible symptoms are black spots (2 to 8 mm) surrounding the lenticels and eyes. As the disease advances, the tissue underneath the skin becomes uniformly black up to a depth of 2 to 5 mm. No sclerotia are formed.

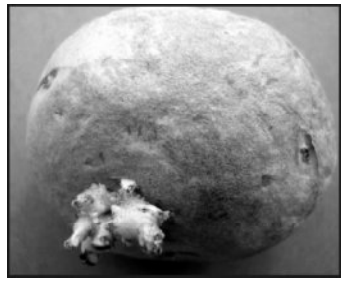
Epidemiology

Both tubers and soil may serve as primary source of inoculum. However, soil is the main inoculum source. Soil temperature at or preceding harvest is the most crucial factor for disease development. Temperature below 28°C almost completely checks the disease. Therefore, in sub-tropics, tuber rottage is less in crop lifted before middle of February. Disease buildup is faster in sandy-to-sandy loam soil as compared to clay soil.

Black dot (*Colletotrichum coccodes* (Wallr.) Hughes (Syn.: *C. atramentarium* {Bek. & Br.} Traub.)

Black dot is commonly found in most potato growing regions. It is generally considered to be a surface blemishing disease of tubers, which downgrades potatoes, destined for table purposes and may affect seed tuber sales due to disease tolerance restrictions. Recent studies indicate that the fungus may be associated with the potato relatively early in the growing season, and with many plants over a wide geographic area. Therefore, yield effects may be more significant than formerly assumed.

Symptoms



Symptoms on leaves are less common than stem or tuber symptoms in the field. Infection of vascular tissue and girdling stem lesions can induce yellowing and wilt like symptoms, which generally progress from plant apices to lower portions of the plant. Wilt symptoms may be confused with those caused by *Fusarium* or *Verticillium*. Small, black, dot-like sclerotia (microsclerotia) are formed abundantly in stem lesions, particularly late in the growing season, and are visible to the naked eye. Sclerotia may form in internal tissues as well.

On roots and stolons silvery brown lesions are formed on which characteristic microsclerotia are readily formed-aiding to diagnosis. Infected remnants of stolons often adhere to tubers at harvest.

Tubers infected with *Colletotrichum* develop dark, grayish lesions which appear similar to silver scurf. However, black dot lesions are more irregular, with undefined margins. They also usually contain microsclerotia which are smaller than those on stolons. Extensive tuber blemishes may increase tuber respiration, resulting in shriveling and tuber shrinkage.

Epidemiology

The pathogen overwinters as microsclerotia occurring free or on colonized plant debris in the soil. The fungus can persist in the soil for at least 8 years. The fungus may also overwinter as sclerotia on infected seed tubers and, therefore, infection of plants may be due to tuber –borne and/or soil borne inoculum. Conidia probably serve as the primary inoculum for infection. Conidia do not germinate at 7^{0}C, the optimum temperature for germination and infection is between 22 & 28^{0}C. Roots are the organs most susceptible to infection; stems generally become diseased only after the fungus is well established on the underground stem of the plant. Black dot is commonly associated with high temperature, poor soil drainage and sandy soils, and low nitrogen levels. Other solanaceous plant species and several weed species also act as hosts for *C. coccodes*. In storage, infection and symptom development are favoured by warm, humid conditions.

Silver Scurf (*Helminthosporium solani* Dur. & Mont.)

It is a common storage disease and occurs wherever potatoes are grown. Now, it has become an economically important disease through reduction in cosmetic quality of washed fresh-packed potatoes. Silver scurf does not usually cause yield loss, but severe seed infection can affect vigour. The disease is also becoming important in potato processing, because crisps made from potatoes with severe silver scurf infection may result in blackened edges, making the product unmarketable. Fresh weight reduction of tubers may also occur due to excessive moisture loss from the tubers through lesions.

Symptoms

There are no above ground symptoms and on roots. However, lesions can be observed on stolons soon after tuber initiation. The most conspicuous symptoms are produced on tuber periderm. The lesions are roughly circular in size, expanding up to several centimeters. The edge of the lesion is regular. The disease gets its name because the lesions are mostly silvery in colour. In soil, established lesions expand rapidly within a few weeks of planting infected seed tubers. Lesions on progeny tubers spread slowly on the surface when in soil. The lesions are usually small at the harvest but enlarge during storage.

Epidemiology

Perpetuation of the disease takes place through soil as well as tuber borne inoculum. Therefore, transmission of silver scurf can occur through infected seed introduced into soil or through conidia present in soil. Conidia produced in storage conditions are released and carried to other tubers via circulating air. Under favourable conditions – moderate to warm temperatures (10-32°C) and very high humidity or free water-conidia germinate on plant tissue by polar germ tubes and cause infection of tubers.

Fusarium wilt and dry rot (*Fusarium* spp.)

Symptoms

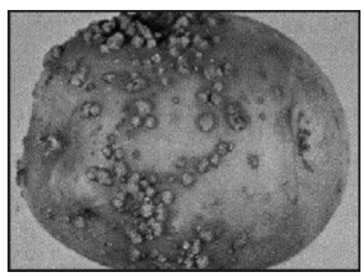
Variety of symptoms is produced on potato including wilt, stem rot and damping off of seedlings. On tuber they produce spots, necrosis, dry rot and seed piece decay. In wilting, lower leaves turn yellow and the affected plant dries off rapidly. Both stems and tubers at stolon end show vascular browning. In some cases wilting may be accompanied by rotting of stem base. It may cause damping off of seedlings if planted early in the season when temperature is high.

Dry rot is a storage disease and does not become evident until 2-3 months of storage. Rot may occur in any part of the tuber but wounded site and stolon end are the most vulnerable. Initially the infected tissue develops slight depression, which increases, and the skin develops wrinkles in the form of irregular concentric circles. Underlying tissue assumes mealy and brown fungal mycelium.

Epidemiology

Infected tubers and soil are the primary source of inoculum. Dry rot development is affected by tuber age, tuber size, storage conditions, tuber damage and degree of curing. Dry rot infection gets aggravated 5-6 months after harvest. Store temperature ranging 20-28°C is congenial for dry rot development. Wilt is mainly affected by soil temperature and relative humidity. High wilt incidence in early planted crop is mainly associated with high soil temperature.

Powdery scab (*Spongospora subterranean* (Wallr.) Lagerh.



Symptoms

The fungus attacks all underground parts of the plant without showing any adverse effect on plant growth. The damage to the tubers is however, more serious. The disease does not affect the potato yields but disfigures tubers, reducing its commercial value and renders them unsuitable for seed purpose. Pimple like spots appears on the surface of young tubers. These spots are circular, smooth and light brown which gradually increase in size and ultimately rupture, exposing a cavity containing a brown powdery mass of spore balls. Deep pustules of powdery scab resemble deep pitted common scab lesions. However, powdery scab pustules are filled with mass of fungal spore ball whereas common scab lesions are empty.

Epidemiology

The fungus over winters through spores in soil and on infected seed tubers. The spores germinate during crop season and produce zoospores in soil, which infect the tubers through lenticels or directly through epidermis. Soil temperature and moisture are the main factors affecting the disease. Low soil temperature (0-15°C) coupled with high soil moisture is ideal for disease development. This disease is a high altitude disease and is seldom noticed below 2500 m amsl and its incidence increases with the increase in altitude.

Wart (*Synchytrium endobioticum* (Schilb) Perc.)

Symptoms

It is a disease of potato tubers and is usually not recognized in the field until the tubers are dug out. The disease is characterized by prominent warty protuberances resembling cauliflower or bunches of 'cocks comb' like proliferated outgrowth on tuber. Sometimes small greenish warty growths on the stalks may be observed near the ground level.

Epidemiology

Wart disease is both soil and tuber borne. Once the soil is contaminated with the resting sporangia, it becomes an important source for the spread of the disease, as winter sporangia are known to remain viable for many years. The chief means by which the disease spreads is through the transportation of material containing resting spores. The disease is worst in wet season. Both winter and summer sporangia can germinate over a wide range of temperature (12-18°C) if the moisture is favourable.

Wilts

Verticillium wilt (*Verticillium alboatrum* Reinke & Berth.)

Symptoms

The infection starts from the roots and the fungus grows into the stem and colonizes the xylem vessels thereby disrupting the water and mineral supply to the aerial parts as a result plants remain stunted, lack vigour, lower leaves tend to droop and there is loss of turgidity. Vascular bundles of stem and tuber become brown. In tuber initial infection is seen as yellowish discolouration at the stolon end. In tuber, initial infection is seen as yellowish discolouration at the stolon end.

Sclerotium wilt (*Sclerotium rolfsii* Sacc.)

Symptoms

Infection starts at the stem base in the form of 1-2 cm dark brown lesions, which gradually enlarge and encircle the stem base resulting in the collapse of plant. The pathogen produces white fungal mat and mustard sized sclerotia on the underground parts within the hyphal mat.

Sclerotinia wilt (*Sclerotinia sclerotiorum* (Lib.) de Bary)

Symptoms

The disease occurs on the stem either at the soil line or at the junction with leaf petioles. Early symptoms on stems are the appearance of water soaked areas on which white fluffy mycelial growth subsequently develops, which gradually enlarge and encircle the stem base resulting in the collapse of plant. Rotting of the stem may extend up to 5 cm above the ground. In the later stages of symptom development, large, dark, compact resting sclerotia are formed in stem pith.

Epidemiology

All the wilt causing fungi survive in the soil and plant debris although infected seed tubers my also act as the primary source of inoculum. *Sclerotium* survives in the soil in mycelial as well as in sclerotial form. The fungus may also survive on collateral hosts. The fungus gets aggravated at high soil temperature (25-30°C) and requires alternate periods of wet and dry soil. Flooding of soil kills *S. rolfsii* thereby reduces the wilt.

Infected tubers and contaminated soil serve as the source of primary inoculum for *Verticillium* wilt. For the perpetuation of the disease the seed surface contamination has been reported to be more important than the internal seed borne inoculum. The pathogen requires comparatively low temperature and therefore, restricted to cooler parts of the country.

S. sclerotiorum overwinters as mycelium in dead or living plants, but primarily in the form of sclerotia. In soil it can remain viable up to 5 years. It also requires comparatively low temperature (10-27°C) and therefore, restricted to cooler regions of the country.

Management of soil and tuber borne diseases

Soil and tuber borne diseases primarily perpetuate through infected seed tubers and soil. Their management therefore, requires elimination or lowering down of the inoculum load on the tubers as well as in soil. Management strategies therefore, have to be many fold for combating these diseases.

Cultural practices

Crop rotations and green manuring: When potato crop is planted year after year in the same field, the survivability of the pathogens and their buildup gradually increases over the years. Although, most of the diseases, which infect the potato crop, have wide host range, it is still possible to keep the pathogens population within manageable limits by practicing suitable crop rotations. It has been found that long-term rotation of maize or sun hemp with potato significantly reduced black scurf and charcoal rot incidence. Sesbania, sunhemp and pearl millet are also effective against black scurf. *Verticillium* wilt can be effectively managed if potato crop is grown after two years of Kulth cultivation. Intercropping of potato with maize, rotated with bean or radish was quite effective in the management of potato wart.

Amendment of oil cakes: Oil cakes have mostly been tried for the management of black scurf and *Fusarium* wilt. Buildup of the *Fusarium* population was least in groundnut cake amended soil followed by mustard cake and cotton seed cake.

Adjustment in planting and harvesting time: Some of the soil and tuber borne diseases are temperature sensitive and can be effectively managed by altering the planting and harvesting dates. By advancing the harvest from February 16 to January 30, the incidence of black scurf was brought down by more than 50 %. Similarly, harvesting of potato tubers before the soil temperature crosses 28°C reduces charcoal rot incidence in endemic areas. By delaying the planting from October 1 to October 30 resulted in 36% reduction in *Fusarium* wilt.

Sanitation: Use of disease free seed, weed control and removal of diseased plants/debris from field are some of the cultural practices that reduce soil and tuber borne inoculum.

Soil solarization: Soil solarization by the use of transparent polyethylene sheet is an effective, simple and ecofriendly way of managing soil borne diseases. This method could be useful in tropical and sub-tropical plains where summer temperatures are very high and is practicised during the hottest period of the year. Solarization was superior to deep summer ploughing as it reduced black scurf incidence by 55.6% and russet scab by 58.4%.

Biological Control

Use of *Bacillus subtilis* (B-5) has been found effective against black scurf, common scab, Fusarium wilt and bacterial wilt. A combination of soil solarization and seed treatment with boric acid or *Trichoderma viride* improved black scurf. A bioformulation developed at Central Potato Research Institute from *T. viride* strain A-7 was found very effective when used as seed treatment before planting potatoes (Arora and Somani 2001). An integrated use of *Trichoderma viride* and boric acid significantly further improves disease control.

Host Resistance

Disease resistant or immune varieties are the best methods to check soil and tuber borne diseases, however, such varieties are available only against few diseases. Varieties immune/resistant to art disease are Kufri, Sherpa, K. Kanchn, K. Jyoti, K. Muthu, K. Bahar, K. Chmatkar, K. Khasigro, K. Kumar, K. Giriraj, K. Chipsona-2, K. Anand, K. Pukhraj, K. Jawahar and K. Sutlej. The early maturing varieties like K. Chndarmukhi nd Up-to-Date are less prone to charcoal rot and may be cultivated in spring. Most of the varieties in India are susceptible to black scurf. However, K. Dewa, K. Bahar and K. Sherpa are comparatively less susceptible.

Chemical Control

Dipping of infected tubers in boric acid (3 %) for 30 minutes or spraying on tubers has been recommended for the management of tuber borne diseases.

Suggested Readings

Khurana, SM Paul. 2000. Diseases and Pests of Potato- a manual. CPRI, Shimla, 66pp.

Singh, BP and GS Shekhawat. 1999. Potato Late Blight. Tech. Bull No. 27 (Revised), CPRI, Shimla, 85pp.

Singh, BP, RK Arora and SM Paul Khurana. 2002. Soil and Tuber Borne Diseases of Potato. Tech. Bull. No. 41 (Revised), CPRI, Shimla, 74pp.

Singh, PH and GS Shekhawat. 2000. Wart Disease of Potato in Darjeeling Hills, India. Tech. Bull. No. 19 (Revised), CPRI, Shimla, 73pp.

Stuart, W, HW Platt and N Cattlin 2008, Disease, Pests and Disorders of Potatoes- A Color Handbook, Manson Publishing Ltd. London.

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BACTERIAL DISEASES AND THEIR MANAGEMENT IN POTATO PRODUCTION

Vinay Sagar and Rahul R Bakade

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Introduction

Potato (*Solanum tuberosum* L.) is the world's fourth most important food crop after wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.), and provides a balanced source of starch, vitamins and minerals to many communities in the global village. Potatoes were first introduced outside the Andes region four centuries ago, and since then have become an integral part of much of the world's cuisine. Potato can produce more food per unit area per unit time than the conventional cereal crops. However, the full potential of the crop can only be realized if diseases and pests are kept under control.

Potato is a vegetatively propagated crop and as a consequence seed tubers suffer from many diseases and pests. Therefore, the availability of good quality planting material is a major constraint in successful production of potatoes. Moreover, successful production of quality potato can be undertaken only in those areas and fields which are free from serious soil borne pathogens like wart, cyst nematode, bacterial wilt, black scurf, and common scab. Suitable strategy to manage bacterial wilt and other diseases may enable quality seed production in such areas. Adoption of management strategy along with innovative seed production technology like micro-propagation may bring breakthrough in quality seed production.

Potato production is seriously compromised due to prevalence of a number of diseases. For example, potato wart restricted seed production and movement from Darjeeling hills and its adjoining area in West Bengal; cyst nematode infestation restricted seed movement from Nilgiri hills. Bacterial wilt is a primary factor restricting seed production in states of West Bengal, Karnataka, Maharashtra, Orissa, NEH Region, and Bihar that constitutes about 50-55% potato area.

Potato is affected by a few bacterial diseases namely, bacterial wilt or brown rot (*Ralstonia solanacearum* (Smith) Yabuuchi *et al.,* soft rot of stem and tubers (*Erwinia carotovora* sub spp., *Bacillus* spp., *Pseudomonas* spp.), ring rot (*Clavibacter michiganensis* subsp. *sepedonicus* (Spieck & Koth) Devis *et al.,* common scab (*Streptomyces* spp.), pink eye (*Pseudomonas* spp.) and leaf spot (*Xanthomonas vesicatoria*). In India ring rot and pink eye do not occur. The leaf spot is a minor disease. Bacterial wilt/brown rot is the most destructive followed by common scab and soft rot.

Bacterial Wilt

Bacterial wilt or brown rot is caused by *Ralstonia solanacearum* (Smith) Yabuuchi *et al.* It is one of the most damaging pathogens on potato worldwide and has been estimated to affect potato crop in 3.75 million acres in approximately 80 countries with global damage estimates exceeding $950 million per year. In India, the disease is prevalent in all potato growing areas except north western plains comprising of Rajasthan, Punjab and Haryana and north central and western part of Uttar Pradesh. Losses up to 75 per cent have been recorded under extreme conditions. With increase in global temperature, the disease is likely to spread to new areas and affect potato cultivation.

The disease causes damage at two stages; (i) killing the standing plants by causing wilt and (ii) causing rot of infected tubers in storage and transit. Another indirect loss is spread of the disease through planting of healthy looking tubers harvested from infested fields. Bacterial wilt poses a serious restriction to seed and processing potato production. Potato breeder seed production cannot by undertaken in those fields having even slightest bacterial wilt incidence. There is nil tolerance to this disease in most international seed certification systems. The infected tubers are not suitable for processing purpose also.

Symptoms

The earliest symptom of the disease is the slight wilting in leaves of top branches during hot sunny clear days. The leaves show drooping due to loss of turgidity followed by total unrecoverable wilt. In advanced stages of wilt, cut end of the stem may show dull white ooze on squeezing. Bacterial wilt in field can be distinguished from any fungal wilt by carrying out a simple test. Obtain 3 to 6 cm long stem pieces from base of the stem, dip the base end in clean water in glass tumbler, and keep it undisturbed for about one to two minutes. Observe for whitish thread like substance coming out from cut end into water. If wilt is due to bacteria, water in tumbler will soon become cloudy and turbid. The same test can also be carried out to see infection in tuber.

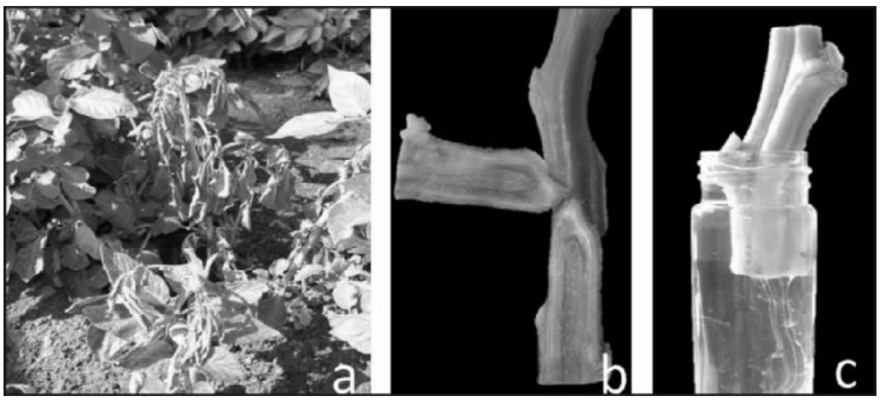

Fig. 1: Symptoms of wilt (a); brown discoloration of vascular tissues in stem (b); and bacterial streaming in clear water from cut end of stem (c) of potato plants infected with *Ralstonia solanacearum*

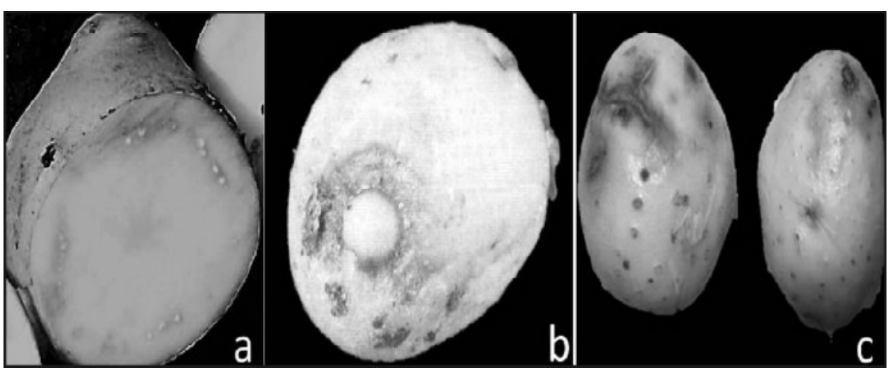

Fig. 2: Vascular browning of tubers with dirty white sticky drops of bacterial ooze (a); dirty white sticky bacterial ooze on tuber eye; and lesions on tuber surface (c) due to *Ralstonia solanacearum* infection

In tubers, two types of symptoms are produced; they are vascular rot and pitted lesion on surface. In vascular rot, the vascular tissues of transversely cut tuber show water soaked brown circles and in about 2-3 minutes, dirty white sticky drops appear in the circle. In advanced stages of wilt, bacterial mass may ooze out from eyes. Such eyes may carry soil glued with the bacterial ooze. Second kind of symptom is the lesions on tuber. The lesions are produced due to infection through lenticels (skin pore). Initially, water soaked spot develop which enlarges in the form of pitted lesion. The tubers may not rot in storage and also may not show vascular browning. These symptoms on tuber surface are more common in north eastern region of India.

Disease Cycle

Infected tubers and plant debris in infested soil are two major sources of inoculum. The pathogen infects roots of healthy plants through wounds. Nematodes such as *Meloidogyne incognita,* which affect potato roots and tubers, increase wilt incidence. Inoculum potential of about 10^7cfu/g soil favours infection which however is dependent on other predisposing factors. Mean soil temperature below 15°C and above 35°C do not favour disease development.

Survival

The pathogen survives through infected seed tubers and in plant debris in soil. Symptom-less plants may harbour the bacterium and transmit it to progeny tubers as latent infection. This could lead to severe disease outbreaks when the tubers are grown at disease free sites. High soil moisture, temperature, oxygen stress and soil type affect the survival of the pathogen. The pathogen population decline gradually in soil devoid of host plants and their debris.

Spread

Transmission of *R. solanacearum* from one area to another occurs through infected seed, irrigation water, and farm implements.

Management

Absolute control of the disease is difficult to achieve due to seed and soil borne nature of the pathogen, however economic losses certainly can be brought down considerably using the following eco-friendly means:

Healthy seed: Use of healthy planting material can take care of almost 80% of bacterial wilt problem. We fortunately have bacterial wilt free areas in western and central Indo-Gangetic plains. Obtain seed from these areas. Do not cut tubers; if the tuber is infected, the cutting knife spread the disease and also cut tubers contact disease from soil easily.

Field sanitation: Where the field is already infested, the best way to minimize the disease is to adopt the following agronomic practices:

Crop rotation: Follow 2-3 years' crop rotation using crop like maize, cereals, garlic, onion, cabbage and sanai. Do not rotate vegetables like brinjal, ginger, chillies and other solanaceous crops. Paddy and sugarcane although are not host, still they carry pathogen and contribute to the disease perpetuation.

Avoid tillage operations: Pathogen enters in plant through root or stolen injuries. Such injuries cannot be avoided during intercultural operations. Therefore, restrict tillage to the minimum and it is advisable to follow full earthing-up at planting.

Off-season management of field: The pathogen perpetuates in the root system of many weeds and crops. Clean the field from weeds and root/foliage remnants and burn them. The pathogen in remnants can be exposed to high temperature above 40 ^{0}C in summer in plains and plateau and low temperature below 5 ^{0}C in hills by giving deep ploughing. This may cause extinction of pathogen from the field.

Chemical control: Application of stable bleaching powder @ 12 kg/ha at the time of potato planting in furrow along with fertiliser reduces pathogen population from field and gives effective control.

Management Based on Agroclimatic Zones of the Country

Based on intensive ecological and epidemiological studies at Central Poteto Research Institute, Shimla, the following management practices are recommended for checking the bacterial wilt in different agro-climatic zones of the country.

Zone I: Gujarat, Maharashtra, north-western and north-central plains. This zone mainly is characterised by hot and dry summer (April-June) with scanty vegetation; temperature can go up to 40-43^{0}C. Bacterial wilt is no more a major problem. Therefore, deep ploughing in summer and use of disease free seed is adequate for the disease control.

***Zone II*:** North-western mid hills (up to 2200 masl), north-eastern hills and the Nilgiris. This zone comprises typical complex, diverse and risks prone areas. It is characterised by mild summer, profuse vegetation and maximum temperature range of 26-30 ^{0}C. Winter temperature may go as low as 3-6 ^{0}C. Many weed hosts can provide perpetual niche for colonisation and survival. The use of disease free seed plus application of stable bleaching powder @ 12kg/ha mixed with fertiliser at planting, ploughing the field in September- October and exposing the soil to winter temperature are adequate for disease control. The application of bleaching powder can be substituted by 2 year crop rotation with crops like wheat, barley, finger millet, cabbage, cauliflower, knol-khol, carrot, onion, garlic etc. Early planting and early harvesting are also recommended.

Zone III: Eastern plains and Deccan plateau. Here crop is cultivated as short day crop during winter months (October-March). Maximum temperature sometimes reaches to 38 °C. Heavy precipitation occurs due to western disturbances. The area is relatively rich in vegetation. Eastern plains and Deccan plateau have many symptomless carriers of the pathogen. Therefore, management of the disease is most difficult. However, the disease can be kept under check with practices like use of disease free seed, application of bleaching powder, blind earthing-up and ploughing in March and leaving the soil exposed to summer temperatures during April- May and crop rotations along with clean cultivation.

Zone IV: Northwestern high hills above 2200 masl (excluding Kumaon hills). This zone has a temperate climate with severe winters; daily temperature ranges from –10 to 5°C during December–January. Snow is common during these months. Bacterial wilt is not endemic and the use of disease free seed alone is adequate.

Soft Rot or Black Leg

Bacterial soft rot can cause significant loss of potato tubers at harvest, transit and storage. Losses under bad handling of the produce, poorly ventilated storage or transit may go up to 100 per cent. Soft rot bacteria usually infect potato tubers which have been damaged by mechanical injury or in the presence of other tuber borne pathogens. Bacterial soft rot develops much faster under warm and humid conditions. The disease also results in blackleg of foliage during the crop growing season.

Sot rot is mainly caused by coliform bacteria called *Pectobacterium atrosepticum* (van Hall) Gardan *et al.*, 2003 (syn. *Erwinia carotovora* subsp. *atroseptica*), *Pectobacterium carotovorum* subsp. *carotovorum* (Jones) Hauben *et al.*, 1998 (syn. *Erwinia carotovora* subsp. *carotovora*), *Dickeya* spp. (including *D. dianthicola*, *D. dadantii, D. zeae*) (syn. *Erwinia chrysanthemi*). Under tropical conditions tubers not only carry *Pectobacterium* (*Erwinia*) but also *Bacillus polymyxa, B. subtillis, Pseudomonas marginalis, P. fluorescens, P. viridiflava, and Flavobacterium* species in lenticels and in vascular tissues. Excessive moisture in field predisposes the tubers to soft rot. It leads to the proliferation of lenticels and create anaerobic conditions. Water film and injury on tubers is must for soft rot bacteria to infect and proliferate. High temperature during harvest predisposes tubers to soft rot.

Tubers which are immature, large, damaged by hail, exposed to late blight or dry rot are more prone to soft rot. Nitrogen fertilisation, particularly ammonium chloride application during cultivation makes tuber more prone to soft rot. High nitrogen dose delays the maturity while chloride ions increase the water content and decrease dry matter in tubers leading to increased soft rot.

Symptoms

Initially a small area of tuber tissue around lenticels or stolon attachment point becomes water soaked and soft. Under low humidity, the initial soft rot lesions may become dry and sunken. Under high humidity, the lesions may enlarge and spread to larger area. Tubers in advanced stages of decay are usually invaded by other organisms and the decaying tissue becomes slimy with foul smell and brown liquid ooze. The tuber skin remains intact and sometimes the rotten tubers are swollen due to gas formation. At harvest, many small rotten tubers with intact skin can be seen. The infected seed tubers rot before emergence resulting in poor stand of the crop. Black-leg caused by *Pectobacterium atrosepticum* phase of the disease is not common in India. It occurs only rarely in the Shimla hills in Himachal Pradesh, the Kumaon hills in Uttarakhand, Ootacamund in Nilgiris and also in Bihar plains. The disease develops from soft rot infected seed tubers and the affected haulms become black at collar region just above the ground. Infected plants develop yellowing, start wilting and die early without producing any tubers.

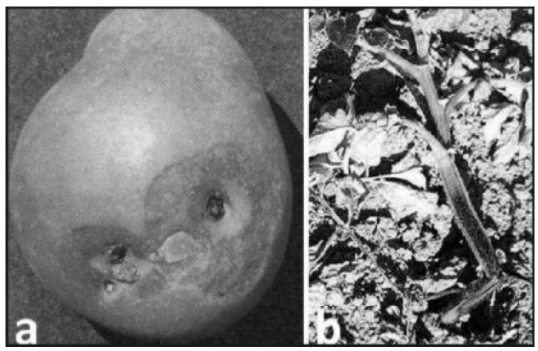

Fig. 3: Soft rot symptoms on tubers (a); black leg symptoms on stem near soil line (b)

Stem and petiole rot due to *Pectobacterium carotovora* subsp. *carotovora* has been observed in Shimla, Jalandhar, Ambala, Panipat, Meerut, Agra, Kanpur, Allahabad, and Burdwan. Water soaked lesions develop on succulent stems, petioles, and leaves. On stem and petioles, the lesions first enlarge into stripes, turn black and then invade the affected parts causing soft rot and toppling of the stem and leaves.

Necrosis of leaf veins and apical buds due to *Bacillus polymyxa* was found in Shimla hills. Veins on lower surface of the leaves become water-soaked and gradually turn necrotic. The entire leaf or leaflets curl downwards. The apical buds become bunchy and stunted. The growth and unfolding of the leaves get delayed. The partly expanded leaves are distorted with necrotic margins.

Disease cycle

Soft rot bacteria may be carried latently in lenticels, wounds and on surface of tubers without any visible symptoms and spread to healthy tubers in stores, during seed cutting, handling and planting. Water film on surface of tuber which cause proliferation of lenticels and creates anaerobic conditions and injury on surface of tuber predispose potatoes to soft rot. From soft rot infected seed tubers bacteria may enter vascular tissues of developing stems and can develop black leg under favourable conditions. From black leg infected plants the pathogen can reach daughter tubers through stolons and initiate tuber decay at the site of tuber attachment. Decaying tubers in soil could serve as source of contamination for healthy tubers. The threshold level for disease development is about 103 cells of *E. carotovora* sub sp. *atroseptica* per tuber (Perombelon, 2000). Tubers harvested in wet soil, poor ventilation in transit and storage promotes the rot.

Survival

Soft rot bacteria may survive in soil, on tuber surface, lenticels, periderm, cortex, ground tissue and vascular tissue. Rotting and decay of infected tubers in fields or stores may cause extensive contamination of adjacent healthy tubers, which serves as the most important source of primary inoculums. Contaminated irrigation water, aerosols of rains, farm implements, soil micro-fauna, nematodes, earthworms, larvae and adults of some insects etc. also help in secondary spread of the disease. Excessive moisture creating anaerobic condition, high temperature, excess nitrogen, tuber injuries and poor ventilation during storage are the important factors helping in disease development.

Spread

In warm climates, where one potato crop follows another or where only short rotation cycles are applied, the bacteria can pass easily from one crop to the next, especially in poorly drained soil. The bacteria can be disseminated in the potato fields by irrigation water, insects, rain or bacterial aerosols. The pathogen may also spread through water during washing of the produce with contaminated water. Soft rot causing bacteria can also spread easily from diseased to healthy tubers during storage, handling and grading. Insects especially maggots of *Hylemyia* species may also transmit the bacteria from one tuber to another.

Management

Pectolytic bacteria causing soft rot are present in soil, water and tubers. Soft rot bacteria are carried deep inside the tuber, in lenticels and surface wounds making it difficult to eradicate. These quiescent bacteria proliferate in high moisture condition and require water film that cause anaerobic conditions leading to disease development. Surface injury predisposes the tubers to soft rot infection. Based on ecology and epidemiology of the disease following management practices have been worked out:

- In field, avoid excess irrigation, provide proper drainage and restrict nitrogen dose to 150 kg/ha.
- Adjust planting time to avoid hot weather during plant emergence. Harvest the crop before soil temperature rises above 28 °C.
- Harvest the crop only when the tuber skin is fully cured.
- Avoid injury to tubers and sort out bruised/injured tubers.
- Treat tubers (for seed purpose) before storage with 3% boric acid for 30 min. and dry under shade.
- Store the produce either in well-ventilated cool stores or cold stores.

Common Scab of Potato

Common scab of potato was first recorded in Patna during 1958. Since then, it has become endemic in various potato growing states. The disease does not cause detectable yield loss but does cause economic losses to the growers as the affected tubers fetch low prices in market due to bad look (pit, lesion and russeting) and is out rightly rejected for seed purposes by seed agencies when incidence is 3-5% or by processing industries as peeling loss is very high in such tubers. Its real impact is felt in state like Punjab and Lahaul valley of Himachal Pradesh where potato production is for seed industry. At least 13 different *Streptomyces* spp. have been found to cause common scab on potato worldwide. The prominent among them are *Streptomyces scabis* (Thaxter) Lambert and Loria, *S. acidiscabies* Bambert and Loria, *S. turgidscabis* Takeunchi, *S. collinus* Lindenbein; *S. griseus* (Krainsky) Waksman & Henria, *S. Longisporoflavus*, *S. cinereus* , *S. violanceoruber*, *S.alborgriseolus*, *S. griseoflavus*, *S. catenulae* and others.

Symptoms

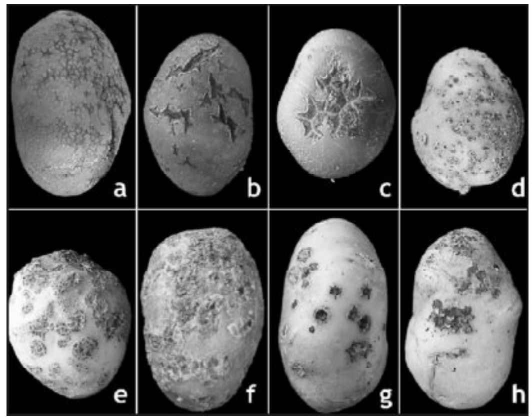

Fig. 4: Various types of scab symptoms caused by *Streptomyces* species on potato tubers

Scab begins as small reddish or brownish spot on the surface of the potato tubers and its initial infection takes place during juvenile period of tuber. Infection takes place mainly through lenticels and surrounding periderm turns brown and rough. Lesion becomes corky due to elongation and division of invaded cells. Under Indian conditions multiple kinds of symptoms have been recorded and they are grouped as (1) a mere brownish roughening or abrasion of tuber skin (2) proliferated lenticels with hard corky deposition, might lead to star shaped lesion (3) raised rough and corky pustules (4) 3-4 mm deep pits surrounded by hard corky tissue (5) concentric series of wrinkled layers of cork around central black core. The last type of symptoms has been attributed to mix infection of scab and *Fusarium oxysporum*.

Disease cycle

Potato is physiologically most susceptible to *Streptomyces* spp. in the period following tuber initiation. *Streptomyces* species infects the newly formed tubers through stomata and immature lenticels. Once the periderm has differentiated, tubers are no longer susceptible to the pathogen. The pathogen is both seed and soil borne. It can survive in soil for several years in plant debris and infested soil. Soil conditions greatly influence the pathogen. Favourable conditions include pH between 5.2 to 8.0 or more, temperature in the range of 20 to 30°C) and low soil moisture. The pathogen is aerobic in nature and maintaining high soil moisture for 10 to 20 days after tuber initiation can help in reducing the common scab.

Survival

The organism is tuber-borne and is well-adapted saprophyte that persists in soil on decaying organic matter and manure for several years. Infected tubers serve as inoculum foci in the field, giving rise to infected progeny tubers.

Spread

The pathogenic *Streptomyces* species are both soil and tuber-borne.

Tuber-borne inoculum is likely to be involved in the distribution of new strains or species.

Disease management

The pathogen is difficult to eradicate because of long survival both on seed tubers and in soils. Therefore, following practices to minimize the inoculum and creating adverse condition for pathogen spread/disease development are recommended.

- Use only disease free seed tubers.
- Give tuber treatment with boric acid (3% for 30 min.) before or after cold storage; dry under shade before storage or planting.
- Irrigate the crop repeatedly to keep the moisture near to field capacity right from tuber initiation until the tubers measure 1 cm in dia.
- Maintain high moisture in ridges at least for a few weeks during the initial tuberization phase.
- Follow crop rotation with wheat, pea, oats, barley, lupin, soybean, sorghum, bajra, and adopt green manuring to keep the disease in check.
- Plough the potato fields in April and leave the soil exposed to high temperatures during May to June in the North Indian plains.

Suggested Reading

Shekhawat, G.S., Gadewar, A.V., and Chakrabarti, S.K. (2000). Potato bacterial wilt in India. *Technical Bulletin No. 38*, (Revised). C.P.R.I., Shimla 45 pp.

Somani, A.K., Khurana , S.M.P., Gadewar, A. V. and Arora, R. K. (2006). Soil and tuber borne diseases of potato and their management in India. In: *Emerging trends in Mycology, Plant Pathology & Microbial Biotechnology* (Eds.G. Bagyanarayana, B. hadraiah, I. K. Kunwar) pp.199-222. B. S. Publications, Hyderabad.

Stevenson, W. R., Loria, R., Franc, G. D., and Weingartner, D. P. (2001).*Compendium of Potato Diseases.* 2nd ed. The American Phytopathological Society, St. Paul, MN.

Stuart, W., Platt, H. W. (Bud) and Cattlin, N. (2008). *Diseases, Pests and Disorders of Potatoes-A Color Handbook.* Manson Publidhing Ltd, London pp 26-27.

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18

VIRAL DISEASES AND THEIR MANAGEMENT IN SEED POTATO PRODUCTION

Ravinder Kumar, A. Jeevalatha and Baswaraj R.

Contents

Introduction:

The potato (*Solanum tuberosum* L.) is an important crop worldwide. Potato production is not an easy task, as potatoes are affected by multiple key pests, including several viruses which contribute to “running out”, or degeneration, of seed stocks. Viral diseases are prevalent throughout the India but are most severe in North-eastern plains and plateaux where population of aphid vectors is high throughout the crop season. *Tomato leaf curl New Delhi virus* (ToLCNDV), *potato leaf roll virus* (PLRV) and potato virus Y (PVY) are the most important viruses in India. Viruses once introduced may persist and spread in agricultural environments and under favourable conditions they may multiply rapidly and cause significant yield loss and economic damage. Therefore, sustainable potato production is possible only if the diseases are kept under check, especially in sub tropics where the weather is highly conducive for common viral diseases. Major potato viruses have been discussed below.

Discription of Major Potato VIruses

1. *Tomato leaf curl New Delhi virus* (ToLCNDV)


Fig 1. Infected potato plants showing symptoms of apical leaf curl disease.

Potato apical leaf curl disease was first reported in northern India by Garg et al. (2001). The association of a geminivirus with this disease has been found by immune electron microscopy using polyclonal antibodies of the Indian cassava mosaic virus and based on symptoms, the virus was named tentatively as Potato apical leaf curl virus (Garg et al., 2001). Later, Usharani et al. (2003) confirmed that this virus is a strain of *Tomato leaf curl New Delhi virus* (ToLCNDV) belonging to the genus *Begomovirus* within the family *Geminiviridae*. Apical leaf curl disease has emerged as a new disease in potato during the last decade in India due to a change in planting date and an increased whitefly population. Its incidence is on the rise threatening the cultivation of potato across the country. The affected plants show curling/crinkling of apical leaves with a conspicuous mosaic symptom. When the infected tubers are used for planting, the entire plant show symptoms with severe stunting due to high virus titre (Fig. 1). The plants recover from symptoms as the maximum temperature falls below 25æ%C. Recently, high prevalence of this disease was recorded in some of the popular high yielding commercial potato varieties from different potato growing regions of the country.

Transmission: The virus is transmitted by whiteflies and the infection is more common in crops planted during October than in November because of the large whitefly population (Chandel et al., 2010). The incidence correlates positively with the whitefly population and the whitefly infestation period of potato crops. Around 40–75% of infections were recorded in the cultivars grown in Indo-Gangetic plains of India (Venkatasalam et al., 2005).

Lakra (2002) reported even upto 100% of infection from the Hisar (Haryana) area of India causing heavy yield losses in susceptible varieties. The primary infection in the field appears within 40–45 days after planting.

2. *Potato leaf roll virus* (PLRV)

It belongs to genus *Polerovirus,* family *Luteoviridae* and causes severe yield loss (up to 90%) as well as in some cultivars a quality reduction due to internal damage to tubers (net necrosis). Single infected plants can have their yield reduced by 50% or more, although neighbouring uninfected plants will compensate. However, where widespread infection is present, severe yield reduction will occur. PLRV is probably the most important potato virus worldwide. One estimate has suggested the virus is responsible for 20 million tonnes yield loss globally. Primary infection, arising from infection in the growing season, appears in the youngest leaves and mostly results in a pale discoloration and in-rolling of leaflets starting at the leaflet base (Fig. 2). Some purple discoloration of affected leaflets may occur. Primary symptoms tend to occur only where infection of the plant occurs early in crop development or in hot climates. Secondary infection, where symptoms develop from infected tubers, is always more severe. Inward rolling of lower leaflets, extending ultimately to the upper leaves, is typical. The leaves become dry and brittle, and if touched the plant makes a characteristic rustling noise. Leaves are chlorotic and often show purple discoloration. Net necrosis may not be apparent at harvest but can develop in store. It can develop in tubers from plants showing both primary and secondary haulm infection (Fig. 3).

Fig. 2. In-rolling of lower leaflets as a result of *PLRV* infection

Fig. 3. Net necrosis of vascular tissue of tubers infected by *PLRV*

Transmission: PLRV can be spread long distances by winged aphids. The virus persists in the aphid throughout its life cycle in a persistent (circulative) way. All instars (stages) of the aphid can transmit the virus, but the nymph stage is more efficient than the adult. The extent of transmission depends on the degree of acquisition of the virus from an infected host and this, in turn, depends on the duration of feeding. Similarly, the transmission to an uninfected host depends on the amount of virus in the aphid and the duration of feeding. Virus accumulates in tubers and, if planted, the virus is transmitted to daughter tubers as well as into the foliage.

3. *Potato virus A* (PVA)

It belongs to genus *Potyvirus,* family *Potyviridae* and cause up to 40% yield reduction. The virus is found wherever potatoes are grown. It consists of flexuous filamentous particles 730 x11 nm. PVA causes mild mosaic symptoms not dissimilar to those caused by PVX (Fig 4). Differences can be difficult to detect visually, but PVA mottles may appear on the veins, and infected leaves look shiny. Infected plants may have a more open habit. Although visually similar to PVX, this virus is related to PVY and is spread by aphids.

Fig 4. Mild mosaic symptoms in a plant affected by *PVA*

Transmission: At least seven aphid species are capable of ransmitting PVA (including *Aphis frangulae, Macrosiphum euphorbiae,* and *Myzus persicae*). The virus is non-persistent and is lost from aphids as they go through their life cycle. As with PVY, the virus can be acquired rapidly from an infected plant (<1 minute) and transmitted equally rapidly.

4. *Potato Virus M* (PVM)

It belongs to genus *Carlavirus* and yield reduction in potatoes is usually low, at worst 15-45%. It consists of slightly curved filamentous particles 650 x 12 nm. Causes mottle, mosaic, crinkling and rolling of leaves (paracrinkle), and stunting of shoots. Symptoms mainly occur in plants infected at very young stage.

Transmission: For most isolates, natural spread is by aphids in a non-persistent manner. Some isolates, however, may be transmitted mechanically (e.g. machinery) including plant to plant contact.

5. *Potato virus S* (PVS)

It belongs to genus *Carlavirus* and the most frequently found virus in potato. Yield reduction is usually low, at worst 10–20%, but might be slightly worse in combination with PVX. It consists of slightly flexuous filamentous particles 660 x 12 nm. PVS is symptomless on the majority of cultivars, with occasional mild leaf symptoms of rugosity, vein deepening and leaf bronzing.

Transmission: Commonly spread mechanically (e.g. machinery) including plant to plant contact. Some isolates are spread in a non-persistent manner by aphids, particularly *Myzus persicae*a and *Aphis nasturtii*.

Fig 5. Mild mosaic symptoms in a plant affected by *PV X*

6. *Potato virus X* (PVX)

It belongs to genus *Potexvirus* and found wherever potatoes are grown. In nature it is largely confined to members of the family Solanaceae. When occasional plants are infected, yield loss is negligible. With more widespread infection, yield losses of 15–20% can occur. However, through effective control, in many countries the virus has become of limited importance. PVX is one of the potato viruses that cause mosaic symptoms. Visually, symptoms range from absent through a faint or fleeting mottle to a severe necrotic streak (Fig. 5). Only occasionally does leaf distortion, rugosity, necrotic spotting or stunting occur. More severe symptoms can occur when PVX is present with other viruses. In combination with PVA or PVY it causes leaf distortion and crinkle.

Transmission: Transmission is by contact, either plant to plant or by humans, animals or machinery passing through a crop. PVX is highly contagious, and once attached to a surface such as clothing the virus can remain infective for many hours provided the surface remains wet. Consequently, a virus picked up from an infected plant can be transmitted to many other plants when moving through a crop. The virus accumulates in tubers, and the process of cutting seed tubers can spread the virus from one tuber to another. PVX is not transmitted by true seed or by aphids.

7. *Potato virus Y* (PVY)

It belongs to genus *Potyvirus, family potyviridae.* It consists of flexuous, long filamentous particles 740 x 11 nm. PVY^{O} is one of the most damaging potato viruses in terms of yield loss. In combination with PVX, it causes an even more destructive disease known as rugose mosaic. PVY contains strain groups which cause different symptoms in potato and other Solanaceous crops. Primary symptoms of common strain (PVY^{O}) are necrosis, mottling, yellowing of leaflets, leaf drops and premature death of plants (Fig. 6). Necrosis of foliage is a hypersensitive-type of reaction and generally starts at a veinal point on foliage and may result in spots or rings. Affected leaves may drop (leafdrop streaks) or remain clinging to the stem. These symptoms may be restricted to a few leaves or to a single shoot. Secondary symptoms result in a dwarf plant with mottled or crinkled foliage (Fig. 7).

Fig 6. Comparison of healthy leaf (right) and leaf with *PVY* infection (left)

Fig 7. Severe mosaic–PVY^{O} symptoms

Transmission: The main sources of PVY inoculum are infected seed tubers. Aphids feeding on plants emerging from infected tubers acquire PVY within a few seconds and also inoculate the virus to healthy plants within seconds. Thus, aphids probing on potato plant are potential vectors of PVY. The peach potato aphid, *Myzus persicae* is the most efficient vector in many areas.

8. *Potato spindle tuber viroid* (PSTVd)

Viroids are the smallest-known infectious agents causing diseases in higher plants. They consists of small (241–399 nucleotides), single-stranded circular RNAs. Aerial symptoms develop in warmer conditions but are masked in cooler ones. Primary haulm symptoms are seldom evident in potato plants. Stem and blossom pedicels are slender, longer than normal, and remain erect. Leaflets are slightly reduced with fluted margins, tend to curve inward and overlap the terminal leaflet. As the season advances, diseased plants are restricted in growth (Fig. 8) and become harder to identify because of intertwining with neighbouring healthy plants. Tubers may be reduced in size and may be misshapen with spindling and conspicuous eyes (Fig. 9).

Fig 8. Stunted plant infected with PSTVd

Transmission: The viroid is highly contagious and readily transmitted to plants by contaminated cultivating and seed cutting tools. The viroid is transmitted through pollen and true potato seed; therefore, breeding and release of new cultivars can be one of the sources of its introduction to fields.

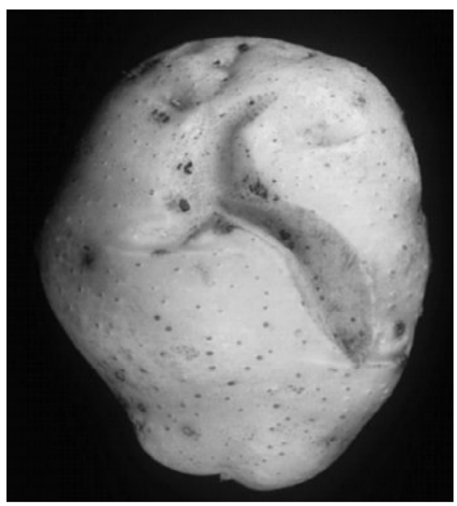

Fig 9. Surface cracking as a result of PSTVd

Persistent and Non-persistent Viruses: Potato viruses are transmitted by aphids in two basic ways. The virus is either non-persistent (stylet-borne) or persistent and circulative (they are ingested and persist in the aphid throughout its life). The most common persistent and circulative virus affecting potatoes in India is *potato leaf roll* (PLRV). Common non-persistent or stylet-borne viruses are PVY, PVA, PVS and PVM. Because the aphid has to feed for more than several minutes to transmit persistent-circulative viruses, control by insecticides is highly effective, whereas with a stylet-borne virus the virus is transmitted as soon as the aphid stylet penetrates the epidermal cells of the leaf- too soon for any insecticide to kill the aphid and prevent virus transmission.

Integrated management of viruses

Viral diseases of plants cause enormous economic losses particularly in the tropics and semi tropics which provide ideal conditions for the perpetuation of viruses and their vectors. Intensive agricultural practices necessitated by the ever-increasing demands of the rapidly growing population and the introduction of new genotypes, cropping patterns and crops have further aggravated the problem of viral diseases. Many diverse approaches have been tried to minimize the losses caused by these diseases. The approaches are mainly based on avoidance of sources of infection; avoidance or control of vectors; modification of cultural practices; use of resistant varieties obtained though conventional breeding procedures; cross protection; systemic acquired resistance; and use of transgenic plants containing alien genes that impart resistance to viruses. Although the use of resistant varieties has been found to be the most economical and practical, for effective management of viral diseases an integrated approach is essential in sustainable agriculture. Development of integrated management practices also requires correct identification of the causative viruses, because symptoms can be misleading, and adequate understanding of the ecology of viruses and their vectors. Control of viruses involves a number of general cultural techniques to reduce inoculum. Most seed lots originate in tissue culture to remove all pathogens. The resulting disease-free plantlets are used to produce minitubers in the greenhouse, which in turn go to the field to produce several generations of seed potato. In the field, general practices of sanitation reduce viruses- destroying cull piles to prevent sprouting, and roguing and removing infected plants from the field. Our certified seed program that starts with virus free planting stock, 100% testing of nuclear stocks, field inspection with virus testing winter testing, requiring that all seed planted for certification have less than 0.5% virus infection and a “flush out” requirement after G4 has minimized our virus problem and is the basis for a virus management program. Insecticides will reduce numbers of both potato colonizing and non colonizing aphids. Seed growers should select insecticides that alter aphid feeding behavior and that do not agitate aphids causing them to move. No gap insecticide protection from emergence till vines are dead is important. It should be remembered at the time of vine-kill potatoes are often the only green things around and are thus highly attractive to flying aphids. Since most growers use one of the neonicotinoid products (imidacloprid-based products-Admire Pro, Gaucho, Nuprid, Mana Alias, etc. To avoid aphid or other insect insecticide resistance, growers should never use the same class of insecticide in successive applications.

Suggested Readings

Chandel, R.S., Banyal, D.K., Singh, B.P., Kamlesh Malik Lakra, B.S., 2010. Integrated management of whitefly *Bemisia tabaci* (Gennadius) and *Potato Apical Leaf Curl Virus* in India. Potato Res. 53, 129–139.

Garg, I.D., Paul-Khurana, S.M., Kumar, S., Lakra, B.S., 2001. Association of a geminivirus with *potato apical leaf curl* in India and its immuno-electron microscopic detection. J. Indian Potato Assoc. 28, 227–232.

Lakra, B.S., 2002. Leaf curl: a threat to potato crop in Haryana. J. Mycol. Plant Pathol.32, 367.

Usharani, K.S., Surendranath, B., Paul-Khurana, S.M., Garg, I.D., Malathi, V.G., 2003.Potato leaf curl – a new disease of potato in northern India caused by a strain ofTomato leaf curl New Delhi virus. New Dis. Rep. 8, 2.

Venkatasalam, E.P., Singh, S., Gawande, S.J., Malathi, V.G., 2005. Detection of white fly transmitted geminivirus associated with *potato apical leaf curl* by serological and molecular tools. In: Proceedings of the Annual Meeting of Indian Society of Plant Pathologists and Centenary Symposium on Plant Pathology, 7/8 April, Central Potato Research Institute, Shimla, p. 18.

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ELECTRON MICROSCOPIC TECHNIQUES FOR VIRUS DETECTION

Baswaraj Raigond, Tarvinder Kochar, Jeevalatha A. and Ravinder Kumar

Contents

Introduction

Electron microscope is one of the most powerful scientific tools for carrying out detail structural studies of biological materials. In general, the purpose of any microscope is to form magnified image of a specimen so as to observe its maximum structural details (resolution). Resolution is a measure of capability of an image - forming system to produce separate images of adjacent objects.

Historically, electrons have been discovered by J.J. Thomson in 1897, and revealed to possess wave like motion by Lou's de Broglie, in 1924. The electromagnetic lens that converged a beam of moving electrons was designed by H. Busch in 1926, leading to the first design of an EM by M. Knoll and E. Ruska in 1932. Electron Microscope were developed due to limitations of Light Microscopes, which are limited by the physics of light to 500x or 1000x magnification and a resolution of 0.2 micrometers. In the early 1930s this theoretical limit had been reached and there was a scientific desire to see the fine details of the interior structures of organic cells. This required 10,000X plus magnification, which was just not possible using light microscope. An EM, in which the image is formed by electron transmitted through a specimen, is known as Transmission Electron microscope (TEM). An EM uses a beam of fast moving electron for the formation of a magnified image of the specimen.

Principle

In TEM, electron beam is used as a source of illumination where extremely small negatively charged electrons given off by a heated tungsten filament can be accelerated by high voltage to produce a coherent electron beam and can be focused by an electric field. The electric field of a doughnut-shaped electromagnet surrounding the electron beam acts just like the glass lens, which focuses the light beam on the specimen. A similar electromagnet is used as the objective lens to form a highly magnified image of the specimen; and one or two electromagnetic lenses further magnify and project the image onto a fluorescent viewing screen or light sensitive sensor such as a CCD (charge-coupled device) camera. The image detected by the CCD may be displayed in real time on a computer monitor. Both particles and ultrathin sections are held in the electron beam on carbon-coated grids. These grids are thin enough to be transparent to the electrons. The grid is held in a movable holder for observation in the TEM.

Viruses infect plants cause significant economic losses in potato production. These viruses have to be reliably detected since the concentration of the viruses would be very low in infected plant tissues. Therefore, there is a need to develop an accurate, sensitive and reliable detection technique for detection of viruses in suspected samples.

In general viral diseases can be detected or diagnosed by mosaic patterns on leaves, stunting of the plant, leaf malformations, and tuber malformations. To be specific, different techniques such as electron microscopy (EM), Immuno sorbent electron microscopy (ISEM), serology (ELISA), nucleic acid based hybridization and polymerase chain reaction (PCR) methods are used to detect the viruses. Almost all the above diagnostic techniques like biological, serological and molecular gives an indirect evidence of the causal agent (etiology) whereas, Transmission Electron Microscope (TEM) gives a direct access to see the causal agent.

TEM is one of the most powerful scientific tools for carrying out detail structural studies of biological materials.

Methods of detection

In TEM studies, negative staining made it easy for detection of viruses from liquid samples. This led to the widespread application of TEM in the field of basics of virology and rapid diagnosis of viruses (Brenner and Horne, 1959). Negative staining also provides morphological information about symmetry and capsomer arrangement of the viruses (Philippe, 2008) and hence provides a rapid and accurate identification of viral diseases (Wild 2008; Bernd and Gunther 2009). Due to the advancement of the science, electron-opaque gold nano particles labelled immunoglobulin (IgG) complexes were used successfully for electron microscopic detection of plant viruses at the ultra-structural level.

Immune-gold electron microscopic technique is also known as GLAD *i.e.,* gold-labelled antibody decoration which has been coined by Pares and Whitecross (1982). Lin and Langenberg (1982) used colloidal gold-labelled IgG for localization of *Barley stripe mosaic virus* (BSMV) in ultrathin sections of wheat cells. Later on Lin (1984) described the use of gold-labelled IgG complexes for rapid and highly specific detection of *Barley stripe mosaic virus* (BSMV) in wheat, *Tobacco mosaic virus* (TMV) in tobacco, *Wheat streak mosaic virus* (WSMV) in wheat, *Cowpea mosaic virus* (CPMV) in cowpea, Brome mosaic virus (BMV) in barley, *Potato leafroll virus* (PLRV) in potato and *Barley yellow*

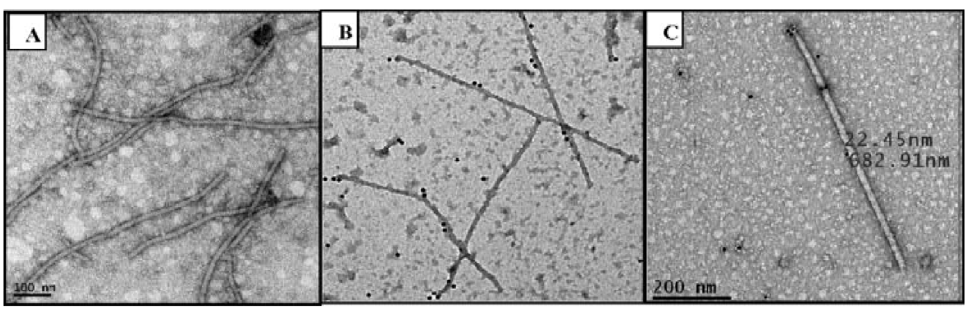

Fig 1: Electron microscopic detection of *Potato virus A* by direct leaf dip method (A) and immune-gold electron microscopic based detection of *Potato virus M* (B & C).

dwarf virus (BYDV) in oats by simple leaf dip method. Similarly Raigond *et al.* (2013 and 2015) developed immno gold electron microscopic technique for clear delection of potato viruses in suspected potato leaf samples (Fig 1).

Here visualization of the antigen-antibody reaction is achieved by using colloidal gold (CG) labelled antibodies. Therefore, this technique is more sensitive in comparison with classical direct electron microscopy and immune electron microscopy. At the same time it has the advantage of being highly specific and can detect the viruses under low concentration in infected tissues.

Negative staining also provides morphological information about symmetry and capsomer arrangement of the viruses and hence provides a rapid and accurate identification of viral diseases (Berned and Gunther 2009.)

Conclusion

TEM is a useful technology which enables rapid and clear identification of the plant viruses. Leaf-dip and the immune-gold electron microscopic technique were found to be one of the best techniques, as it is coupled with serological reactions which can be visualized under TEM. Therefore, this technique can be used for rapid and specific detection of viruses in plants.

Suggested Readings

Abouzid AM, Barth A, and Jeske H (1998) Immunogold labeling of the abutilon mosaic virus in ultrathin sections of epoxy resin embedded leaf tissue. *J Ultra Mol Struct Res* **99**: 38–47

Baswaraj Raigond, A Jevalatha, BP Singh and Tarvinder Kochhar (2013) Electron Microscopic detection of *Potato virus A* using gold nano particles. Potato J (2013) 40 (2): 104-108.

Baswaraj Raigond, Jeevalatha A, Ravinder Kumar, Tarvinder Kochhar, Priyanka Kaundal, Shivani Roach, Rajender Kumar and BP Singh (2015) Development of immune gold electron microscopic technique for detection of *Potato virus M* by using gold nanoparticles. *News letter* (Central Potato Research Institute), 59.

Bernd Zechmann and Gunther Zellnig (2009) Rapid diagnosis of plant virus diseases by transmission electron microscopy. *J Virol Methods* **162:** 163–69

Brenner S and Horne RW (1959) A negative staining method for high resolution microscopy of viruses. *Biochim Biophys Acta* 34: 103-10

Garg ID, Shiv Kumar and Paul Khurana SM (2003) Immuno electron microscopic diagnosis of Potato virus M. *J of Indian Potato Assoc* **30** (3-4): 241-45

Lin NS (1984) Gold-IgG complexes improve the detection and identification of viruses in leaf dip preparations. *J Virol Methods* **8**: 181-90

Lin NS and Langenberg WG (1982) Localization of barley stripe mosaic virus (BSMV) in ultrathin sections with colloidal gold-labelled IgG. *Phytopathol* **72**: 938

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DETECTION OF POTATO VIRUSES THROUGH MOLECULAR TECHNIQUES

A. Jeevalatha, Ravinder Kumar and Baswaraj R

Contents

Introduction

In vegetatively propagated crop like potato, the use of healthy (virus free) plant propagation material is among the most effective approaches for virus management in farmer's fields. One of the elements essential for successful certification programs to produce such propagation material is the availability of sensitive detection methods. Recent advances in biotechnology and molecular biology have played a significant role in the development of rapid, specific and sensitive tests. They are either serology based (ELISA & LFIA) or nucleic acid based (NASH, PCR, real time PCR and Micro or macro array) techniques. Sensitivity of serology based techniques is poor compared to nucleic acid based techniques. Moreover, reliability of those techniques is dependent on requirement of polyclonal or monoclonal antibody sera specific for each virus of interest that does not cross-react with plant proteins.

Initially, critical visual inspection of disease symptoms constituted a major step in virus detection. However, disease symptoms alone had the limitation as similar symptoms could be produced by certain nutrient deficiencies or other abiotic or biotic factors. Sometimes no perceptible symptoms may be visible in case of infection by PVA, PVX, PVM and PVS in certain varieties. This was overcome with use of indicator hosts. The technique of virus detection using indicator hosts, however, required more time, labour and space. Therefore, techniques based on serology and histochemical tests were standardized for detection of viruses and phytoplasma diseases during 1960s through 1970s. The most commonly used serological tests were the precipitin and chloroplast agglutination. These tests were effectively used in detecting PVX, PVS and PVM. Since large volume of antisera was required for testing all the clones under breeder seed production, the institute started mass production of antisera by the year 1972. Chloroplast agglutination test was the standard method used for indexing potato clones till 1984. The technique suffered the following drawbacks namely requirement of large quantities of antisera, its applicability to only high titred viruses like PVX, PVS and PVM and a low sensitivity (detection had only about 60% reliability or confidence level). These limitations of chloroplast agglutination were overcome when CPRI introduced the use of ELISA (enzyme-linked immunosorbent assay) in 1984. The subsequent use of the serological and molecular techniques for potato virus detection is described here.

Enzyme Linked Immuno sorbent assay (ELISA)

The technique utilizes the ability of antibodies raised in animals to recognize proteins, usually the coat protein, of the virus of interest. Antibodies are fixed to the surface of a well within a microtitre plate, and a sap extract from the plant is added to the well. If the virus of interest is present in the plant, it will bind to the antibodies fixed on the surface. Any unbound extract is washed-off before a secondary antibody that recognizes the first antibody is added. The secondary antibody allows for indirect detection of the virus because it has a reporter molecule attached to it, usually an enzyme that acts on a substrate that changes colour, which is detected visually by a calibrated microtitre plate spectrophotometer. CPRI started producing its own ELISA kits for potato viruses by 1990. Presently, CPRI produces ELISA reagents for PVA, PVM, PVS, PVX, PLRV and PVY. ELISA is reasonably sensitive and highly amenable to high throughput automation. Hence, it is suitable for large scale screening of samples.

Lateral flow immuno assay

Mass express diagnosis of viral infections for virus-free plant culture industry or individual use requires inexpensive, rapid, and simple technologies that make possible analysis without special skill and equipment even under field conditions. One of the promising solutions for overcoming this challenge is lateral flow immuno assay (LFIA), based on the interaction between the target virus and immunoreagents (antibodies and their conjugates with colored colloidal particles) applied on the membrane carriers (lateral flow test strips). When the test strip is dipped into the sample being analyzed, the sample liquid flows through membranes and triggers immunochemical interactions resulting in visible coloration in test and reference lines (Fig. 1). Test strips were developed for detection of five plant

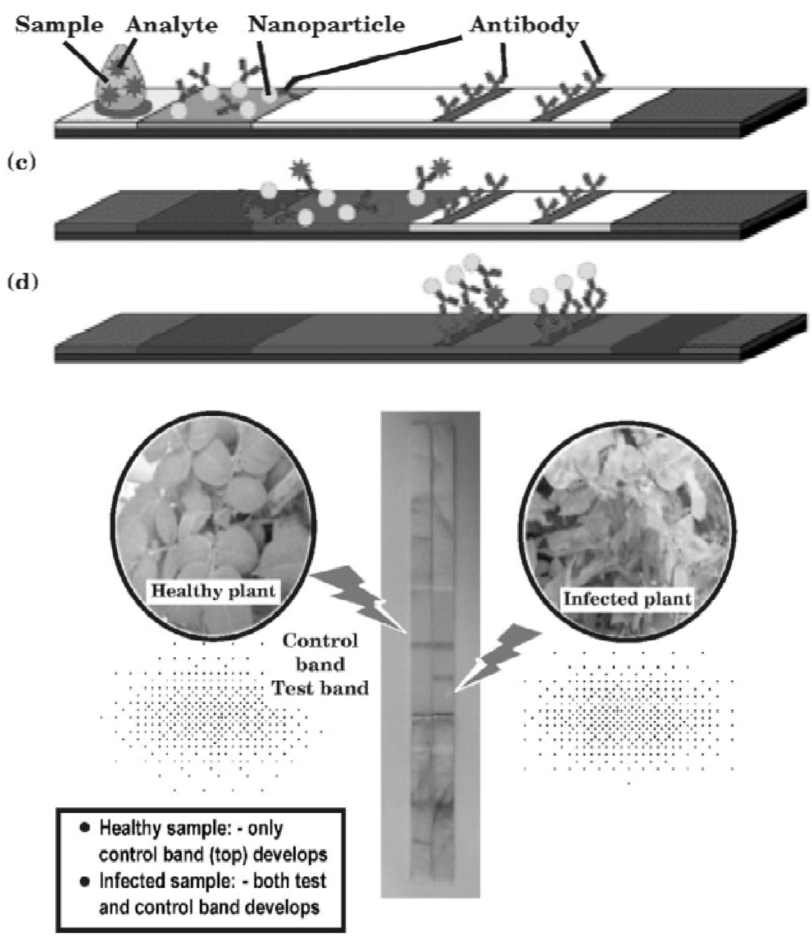
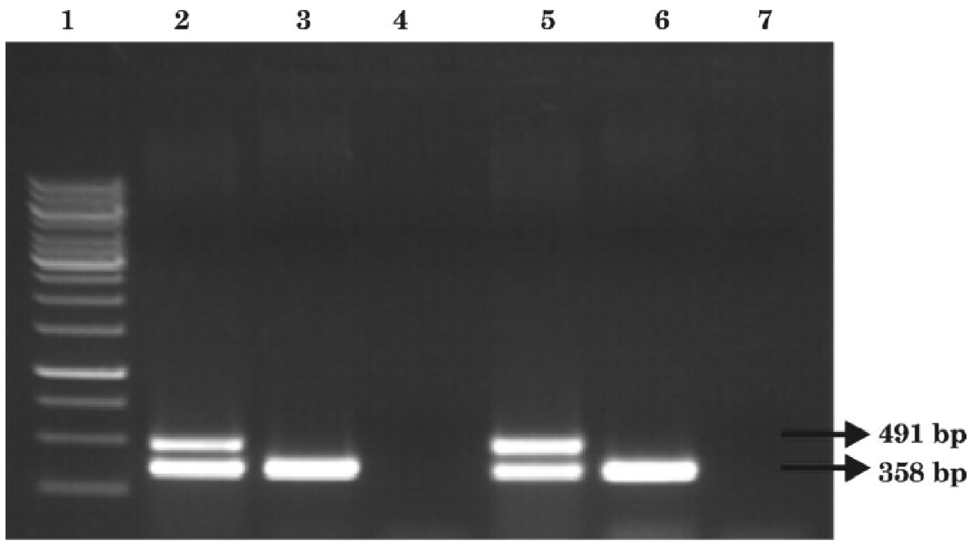


Fig. 1 Working principle of LFIA and interpretation results

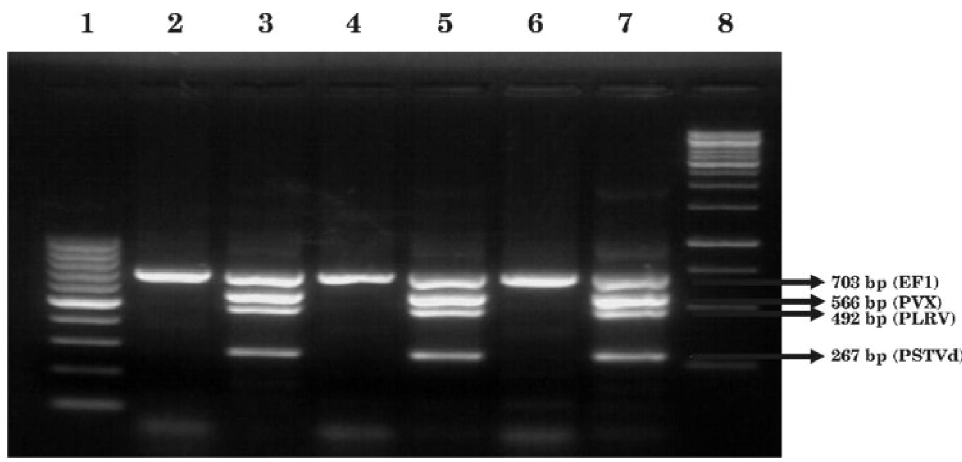
viruses varying in shape and size of virions: spherical carnation mottle virus, bean mild mosaic virus, rod shaped tobacco mosaic virus, and filamentous potato viruses X and Y by Byzova *et al.*, (2009). CPRI has developed LFIA kits for the detection of five viruses *viz.*, PVX, PVA, PVS, PVM and PVY either individually or in combination of two viruses viz., PVA & PVX, PVA & PVS, and PVY & PVM using a single strip.

Polymerase chain reaction

RT–PCR and PCR are popular techniques for detection and identification of RNA and DNA plant viruses respectively. The procedures are extremely sensitive, fairly inexpensive and require minimal skill to perform. In the case of RNA viruses, a cDNA strand complementary to the virus is made with reverse transcriptase (RT). Oligonucleotide primers, flanking part of the genome of the virus, are extended by a thermostable DNA polymerase in a series of denaturation and extension steps that exponentially increase the target DNA. For DNA viruses, the RT step is unnecessary. PCR-based methods can be adapted to high-throughput applications. In addition to detection of the virus, an additional advantage of the method is that the amplicon can be sequenced to provide further data about strain types. Possible drawbacks of the method are the need for a thermocycler, which can be expensive, and sequence information for design of primers. With databases containing ever-growing numbers of virus sequences, access to sequence information for many viruses is possible. Careful primer design is crucial, whether to detect only a single strain, or all the members of a genus. The sensitivity of the method is its major advantage. High sensitivity, however, can easily lead to false positive results from contamination; so adequate controls are essential. RT-PCR protocols for detection of major potato viruses have been standardized that can detect very low level of virus inoculums (Singh and Nie, 2003, Lorenzen *et al.*, 2006). Several variations of RT-PCR like Immuno Capture PCR (IC-PCR), nested PCR and multiplex RT-PCR have been standardized for detection of potato viruses or to differentiate strain variation of a particular virus. Multiplex RT-PCR is a time- and reagent-saving amplification technique in which multiple primer sets are used to amplify multiple specific targets simultaneously from the same sample. CPRI has designed primers and developed protocols for the uniplex and multiplex detection of PVX, PVY, PVA, PVS, PLRV, ToLCNDV-potato (Fig. 2) and Stem Necrosis and are routinely used to screen mother plants which meant for breeder seed production.



Lane 1.1 kb ladder Lane 2, 5-Infected sample Land 3, 6-Healthy sample, Lane 4, 7 Water control



Land 1. 100 bp ladder, Lane 2, 4 and 6 Healthy sample, Lane 3, 5 and 7. Infected sample, Lane 8.1 kb ladder

Fig. 2. Detection of potato viruses through duplex PCR (a) and multiplex RT-PCR (b)

Real time PCR or quantitative PCR

Real time PCR allows quantification of the target DNA as it is amplified. Real time RT-PCR protocols are now being standardized for potato viruses in several international laboratories (Agindotan et al., 2007, Mortimer-Jones et al., 2009). For potato viruses, TaqMan® duplex RT-PCR have been used for the detection of *Tobacco rattle virus* (TRV) and *Potato mottle top virus* and for PLRV and PVY. Agindotan et al., 2007 reported an assay where four common potato-infecting viruses, *Potato leafroll virus*, *Potato virus A*, *Potato virus X* and *Potato virus Y*, were detected simultaneously from total RNA and saps of dormant potato tubers in a quadruplex real-time RT-PCR. A single tube real time RT-PCR was reported by Mortimer-Jones et al., 2009 to detect single infections of PLRV, PVX, PVS and TSWV simultaneously in a single assay from bulked samples equivalent to 300 dormant tubers. Real time PCR protocols for detection of very low level of virus inoculums in nucleus seed stocks and mericlones have been standardized for all common potato viruses at CPRI (Fig. 3).

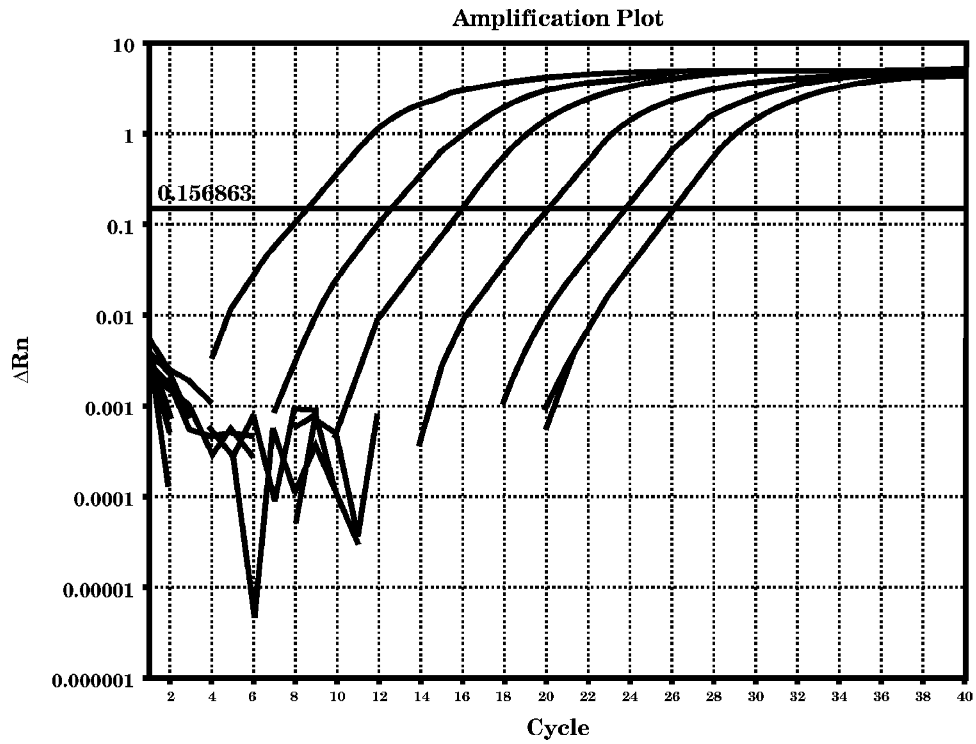


Fig. 3. Taqman probe based real time RT-PCR detection of *Potato virus Y*

Nucleic acid spot hybridization

Nucleic acid hybridization techniques have also been standardized for detection of many potato viruses. Nucleic acid hybridization of DNA or RNA probes has the advantage of being able to detect the nucleic acid of the virus in both forms, single-stranded and double-stranded. cRNA probes can be labelled with isotopes or nonradioactive probes. cRNA probes are preferable to cDNA probes when used to detect RNA viruses, because RNA/RNA hybrids are more stable than DNA/RNA hybrids. An RNA extraction from infected tissue is blotted onto a membrane and the probe hybridized to it and detected. Polyprobe for the simultaneous detection of several viruses can be designed utilizing the sequence information of all the target viruses.

Micro and Macroarrays

Microarrays are one of the new emerging methods in plant virology currently being developed by various laboratories. The principle of microarrays is the hybridization of fluorescently labeled sequences (targets) to their complementary sequences spotted on a solid surface, acting as probes. The main advantage of this method is the opportunity to detect many pathogens simultaneously. Microarrays are high-density arrays with spot sizes smaller than 150 microns. A typical microarray slide can contain up to 30,000 spots. Arrays printed with probes corresponding to a large number of virus species (or indeed, any type of pathogen) can be utilized to simultaneously detect all those viruses within the tissue of an infected host. Bystricka et al., 2005 described a microchip using short synthetic single-stranded oligomers (40 nt) instead of PCR products as capture probes for detection of PVA, PVS, PVM, PVX, PVY and PLRV, in both single and mixed infections. Sip et al., 2010 reported oligonucleotide microarray for the detection of mixed infections of PVA, PVS^{O}, PVM, PVX, PVY^{O}, PVY^{N}, PVY^{NTN} and PLRV.

Macroarrays are generally membrane-based with spot sizes of greater than 300 microns. Agindotan and Perry, 2007 reported a macroarray sytem using 70-mer oligonucleotide probes immobilized on nylon membrane for the detection of CMV, PVY and PLRV. Sugiyama et al.,2008 used convenient, cost-effective macroarray and microtube hybridization (MTH) system in which cDNA probes immobilized on nylon membrane, target viruses were amplified and labelled with biotin and then hybridization was carried in hybridization oven and colorimetrically detected using nitro blue tetrazolium (NBT)/bromo-4-chloro-3-indolyl phosphate (BCIP) reagent (Fig. 4).

Viral RNAs in total RNA from lily roots were multiply reverse-transcribed with the chimeric T7/virus-specific primers to synthesize cDNAs containing the T7 promoter sequence. Second strand cDNA synthesis converts the single-stranded cDNA into the double-stranded DNA template for

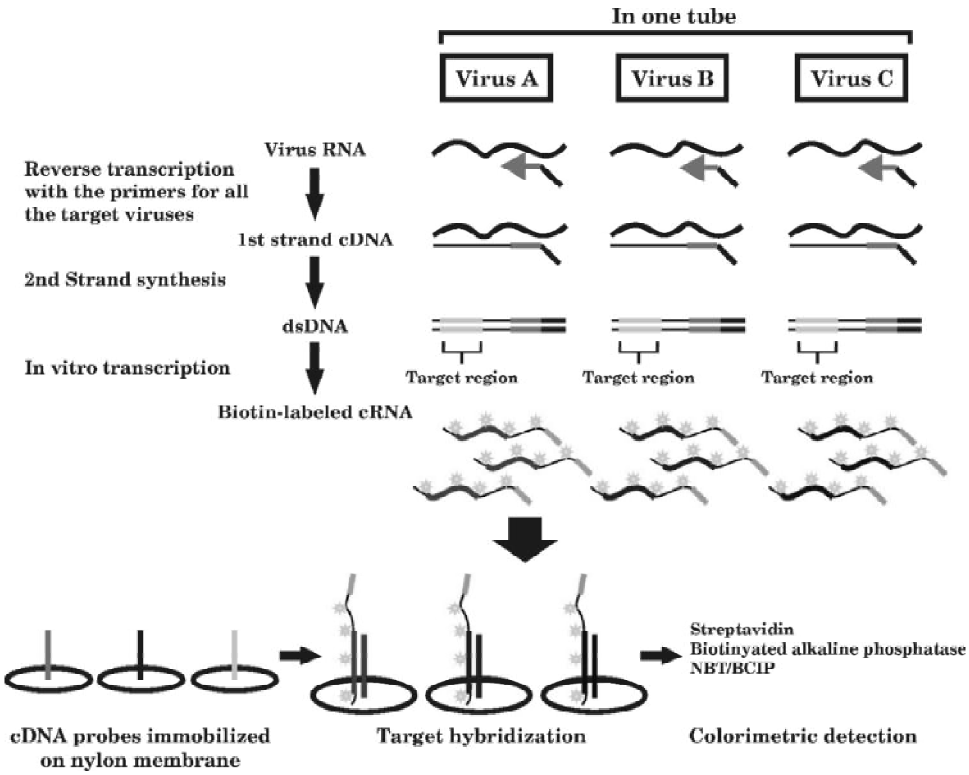


Fig. 4. cRNA preparation for macroarray hybridization

transcription. In vitro transcription generates multiple copies of biotinylated cRNA from the double-stranded cDNA templates. The biotin-labeled cRNAs react on a cDNA macroarray. Because the cDNA probes on the membrane were designed fromthe region that does not include a reverse transcription primer sequence, the nonspecific cRNAs generated by mispriming of the primer theoretically never mishybridize to the array.

Suggested Readings

Agindotan, B., and Perry, K. L. 2007. Macroarray detection of plant RNA viruses using randomly primed and amplified complementary DNAs from infected plants. Phytopathology. 97:119-127.

Agindotan, B.O., Shiel, P.J., Berger, P.H., 2007. Simultaneous detection of potato viruses, PLRV, PVA, PVX and PVY from dormant potato tubers by taqman real-time RT-PCR. Journal of Virological Methods, 142: 1–9.

Bystricka, D., Lenz, O., Mraz, I., Piherova, L., Kmoch, S., Sip, M. 2005. Oligonucleotide-based microarray: A new improvement in microarray detection of plant viruses. Journal of Virological Methods. 128: 176–182.

Byzova, N.A., Safenkova, I.V., Chirkov, S.N., Zherdev, A.V., Blintsov, A.N., Dzantiev, B.B., and Atabekov, I.G. 2009. Development of Immunochromatographic Test Systems for Express Detection of Plant Viruses. Applied Biochemistry and Microbiology, 45(2): 204–209.

Lorenzen, J.H., Piche. L.M., Gudmestad, N.C., Meacham. T., Shiel, P. 2006. A multiplex PCR assay to characterize Potato virus Y isolates and identify strain mixtures. Plant Disease, 90: 935-940.

Mortimer-Jones, S.M., Jones, M.G.K., Jones, R.A.C., Thomson G., Dwyer, G.I. 2009. A single tube, quantitative real-time RT-PCR assay that detects four potato viruses simultaneously. Journal of virological methods, 161: 289-296.

Singh, R. P. and X. Nie. 2003. Multiple virus and viroid detection and strain separation *via* multiplex reverse transcription- polymerase chain reaction. Canadian Journal of Plant Pathology. 25:127-134.

Sip, M., Bystricka, D., Kmoch, S., Noskova, L., Hartmannova,H., Dedic, P., 2010. Detection of viral infections by an oligonucleotide microarray. Journal of Virological Methods. 165 :64–70.

Sugiyamaa S., Masuta, C., Sekiguchic, H., Ueharad, T., Shimura, H., Marutaa, Y. 2008. A simple, sensitive, specific detection of mixed infection of multiple plant viruses using macroarray and microtube hybridization. Journal of Virological Methods, 153: 241–244.

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PEST MANAGEMENT FOR HEALTHY POTATO PRODUCTION

Vallepu Venkateswarlu, Sridhar Jandrajupalli, M Nagesh and Kamlesh Malik

Contents

Introduction

Potato is the third most important food crop in the world after rice and wheat with a record global production of 347 million tons of which India contributes 45.00 million tones with an average productivity of 22.72 t/ha from 1.86 mha area. India is the second largest producer of potato in the world after China. Estimated domestic demand of potatoes in India is projected to be 55 and 122 million tons by 2025 and 2050 respectively. However, the potato production is often limited by number of biotic and abiotic factors including insect pests of economic importance. Insects cause direct damage to leaves and tubers, and indirect damage by transmitting the viruses which reduces the yield and quality. The major insect pests infesting potato crop are aphids, whiteflies, leaf hoppers, thrips, white grubs, cutworms, potato tuber moth and mites. These pests are polyphagous in nature and are not specific to potato alone. The economic importance, nature of damage and management practices for these pests are presented below.

Aphids

Green peach aphid - *Myzus persicae* Sulzer (Aphididae: Hemiptera)

Aphids are small (1-2 mm) soft bodied insects which are usually green in colour (fig. 1). In India, it was found that more than 13 species of aphids infest potato of which *M. persicae* and *Aphis gossypii* are predominant. *M. persicae* is polyphagous and colonizes hundreds of plants belonging to more than 40 families. Aphids travelling from plant to plant are efficient vectors of economically important potato viruses.

Biology

Fig.1. Aphids on potato leaf

Aphids have complex life cycles. Aphids that colonize potato are mainly heteroecious and holocyclic. Aphids use the practice of host alternation; they live on primary host during winter, then migrate to secondary host during rest of the period and again come back to primary host. Their life cycles include an overwintering phase, during which fertilized eggs constitute the resistant form during periods of cold temperatures. Because potato is seasonal plant, its colonizing aphids are heteroecious. Aphids molt four times, with the mean number of offspring per wingless aphid ranging from 60 to 75. Optimum temperature for reproduction is around 21°C. There may be several generations on a primary host, but eventually winged adults (spring migrants) develop and fly away to colonize “secondary”, often herbaceous, host plants.

Other Species

- *Cotton aphid, Aphis gossypii*
- *Green citrus aphid, Aphis spiraecola*
- *Oleander aphid, Aphis neerii*
- *Black bean aphid, Aphis fabae*
- *Coriander aphid, Hydaphis coriandri*
- *Foxglove aphid, Aulacorthum solani*
- *Plum aphid, Brachycaudus helichrysi*
- *Cabbage aphid, Brevicoryne brassicae*
- *Rice root aphid, Rophalosiphum rufiabdominalis*
- *Potato aphid, Macrosiphum euphorbiae*
- *Mustard aphid, Lypaphis erysimi*
- *Groundnut aphid, Aphis craccivora*
- *Grass root aphid - Rhopalosiphum rufiabdominalis*

Nature and symptoms of damage

Aphid colonies can be easily identified in potato plant terminals and on the underside of leaves in the field. Both nymphs and adults suck plant sap from the underside of the leaf during which virus acquisition and transmission takes place. Aphids are economically important polyphagous insect pests known to cause damage directly by sucking the plant sap and indirectly by transmitting the infectious plant viruses (PLRV, PVY, PVA, PVM and PVS) affecting both quality and yield of potato.

Management

1. Avoid aphid attack by adjusting planting dates as mentioned below
   a. 15th Oct: North-Western Plains
   b. 25th Oct: Central Plains
   c. 5th Nov: North-Eastern Plains

2. Different predatory and parasitoid insects (such as coccinellid beetles and the *Aphidius sp.*) also feed on aphids. Fungi such as *Entomophthora sp.* Is effective against aphids.

3. Remove haulms when aphids reach 20 aphids per 100 compound leaves in case of seed production.

4. Installation of yellow sticky traps @ 60/ha.

5. Spraying of imidacloprid @ 0.03% to manage the aphids at 15 days interval.

6. Seed treatment of sprouted potatoes with imidacloprid (17.8 SL) @0.04% (4 ml/10 lit) for 10 minute before planting.

7. First foliar spray with imidacloprid 17.8 SL @ 0.03% (3 ml/10 lit.) at the time of earthing up.

8. Second foliar spray with Thiamethoxam 25 WG@ 0.05% (5 g/10 lit) after 15 days of first spray.

Whiteflies

Whitefly- *Bemisia tabaci* (Gennadius)(Aleyrodidae: Hemiptera)

Green house whitefly- *Trialeurodes vaporariorum*

Fig.2. Whiteflies on potato leaf

Several species of the Aleyrodidae family generally known as whiteflies(fig.2), although they are not actually flies, but causes severe damage to number of agricultural and horticultural crops acting as vector for many viruses. *B. tabaci* is a pest of more than 600 host plants including vegetables, fibre crops, spices, ornamentals plants, and many weed plant species. It acts as serious vector for *Tomato leaf curl New Delhi virus* ToLCNDV-potato in potato. The small adult whiteflies (fig. 2) can be easily seen on the underside of the leaves and they will quickly start fluttering at the slightest movement of the leaves.

Biology

Whiteflies have six life stages viz, egg, four instars and the adult. The elongate oval shaped eggs are white in colour. The distal end of the egg is acute and the basal portion is usually broad, with a pedicel or stalk of varying length by which the female attaches to the host. The female can lay up to 300 eggs singly on the underside of the leaf. The first instar known as the crawler, has legs and is the only mobile instar that moves to look for feeding sites. The other instars are sessile and they complete their lifecycle on the same leaf. It can take 14-60 days, but typically *Bemisia* spp. takes 20 days at 25±2°C. The whiteflies can complete 11-15 generations in year depending upon the weather conditions (temperature and humidity) and plant species. These species reproduce parthenogenetically. A black fungus that grows on the honeydew produced by the nymphs will cover the plant.

Nature and symptoms of damage

Both nymphs and adults settle on underside of potato leaves and suck plant sap from phloem vessels. Whiteflies transmit *Tomato leaf curl New Delhi virus*-potato causing potato apical leaf curl disease.

Management

1. Sticky yellow traps can be used for population monitoring and mass trapping. Application of oxy demeton methyl@ 1.2ml/lit water and imidacloprid @ 0.03% water for management of whiteflies at 15 days interval.

2. Seed treatment of well sprouted potatoes with Imidacloprid (200 SL)@0.04% (4 ml/10 lit) for 10 minute before planting.

3. First foliar spray with imidacloprid 17.8 SL @ 0.03% (3 ml/10 lit.) at the time of earthing up.

4. Second foliar spray with Thiamethoxam 25 WG@ 0.05% (5 g/10 lit) after 15 days of first spray.

Leafhoppers

Leafhopper: *Empoasca fabae* (Cicadellidae:Hemiptera)

Leafhoppers are polyphagous pests distributed all over countries in the world. In India, the leaf hoppers are distributed in all potato growing regions of Indo-Gangetic plains.

Biology

Leafhopper lays eggs in veins and petioles. These are transparent and pale yellow. They hatch in about 10 days and the total life cycle of the leaf hopper is completed in about 30 days. The nymph is also yellow in colour and adults are pale green in colour, have piercing and sucking type of mouth parts. These can be easily identified as they move back and forth. The lower and upper temperature thresholds limits of leaf hoppers have been estimated to be 8.4^{0}C and 29^{0}C.

Nature and symptoms of damage

The nymphs and adults of the leafhoppers suck the sap from lower side of the leaves causing extensive damage by direct feeding of the plants and also inject a toxin into the plant, which causes yellowing, browning, curling and drying of leaves results in hopper burn. The adults and nymphs are wedge-shaped with heads that are slightly broader than the rest of their bodies. They move diagonally when disturbed. The severely infested field gives a burnt look appearing in a circular ring commonly known as "hoper burn"

Management

1. Delay in planting to 25th September for early crop and to middle of October for the main crop would reduce the leafhopper incidence.
2. In seed crop, granular systemic insecticide (Phorate10G@10.0kg/ha) can be applied at the time of planting or at the time of earthing up.
3. Dimethoate 30EC @2.5 ml/lit water and oxy demeton methyl 25 EC@1.2 ml/lit water spraying in the evening can help in control of leafhoppers.

Thrips

Thrips- *Thrips palmi* Karny(Thripidae:Thysanoptera)

Thrips are small and minute insects (1-2 mm long) distributed in most potato growing regions of Indian plains.

Biology

Eggs are colourless to pale white in colour, bean-shaped and are deposited in leaf tissue by a slit cut by the female. Larvae resemble the adults except wings and size. These are tiny, slender, fragile insects, with adults having heavily fringed wings. The females have extremely slender wings with a fringe of long hairs around their margins. Life cycle is completed in about 20 days at 30°C.

Nature and symptoms of damage

All the nymphs feed in groups along the midrib and veins of older leaves. Adults are tend to feed and prefer to hide in young plant parts (new leaves). These are the vectors of *Tospovirus* which cause stem necrosis disease in potato. Pale or brown nymphs and darker adults can be observed on the underside of leaves, where silver spots appear.

Other species: *Scirthothrips dorsalis, Frankliniella* spp.

Management

1. Thrips populations increase in number under dry conditions

2. Frequent irrigation to crop field is an effective method to check the thrips population

3. Thrips can also be controlled with the systemic insecticide i.e. Imidacloprid 17.8SL@ 0.03%.

Mites

Mites: *Polyphagotarsonemus latus* (Tarsonemidae:Acarina)

Mites are extremely small, almost microscopic, and feed on the cellular matter of leaves. Mites are widely distributed throughout India. The broad mite, *Polyphagotarsonemus latus* is very serious during kharif season (Maharashtra and Karnataka) and rabi (Western UP and Punjab).

Biology

The mites have four stages namely egg, nymph, pupa and adult. The spherical, shiny white and translucent eggs are laid singly on underside of the leaves often near the veins. The eggs hatch in 2-3 days. The newly emerged nymphs are dirty white and these become protonymph in 2 days. Protonymph develops into deutonymph which lasts for 1-3 days and sex of the mite is determined at this stage. The pupal stage lasts for 2 days and the adults live up to 10-13 days. The dry and humid conditions are favourable for mite's multiplication and cause huge damage to potato.

Nature and symptoms of damage

Mites are usually found on the upper part of the plant. They feed on apical shoots and on abaxial side of young leaves. Mites suck the cell sap from leaves and young plant tissues using chelicerae. The typical mite infestation symptoms are bronzing, curling and discolouration of leaves. The webbing of leaves, sepals and petals are the symptoms produced under severe infestation. The leaf injury produced by mites is often confused with diseases and phyto-toxicity. The pest is known to cause 12-60% yield loss under severe infestation.

Other species: *Tetranychus* spp.

Management

1. Crop rotation using non-host crops like wheat is helpful in reducing mites.
2. Delay in planting to last week of September for early crop and during middle of October for the main crop reduces the mite incidence and damage.
3. Spray Dicofol 18.5 EC @ 2.0 lit/ha or wettable sulphur 80% @ 2.5 kg/ha or Abamectin 1.9EC @ 1.2ml/lit will help in promising control of mite.
4. The natural enemies like Phytoseiid mite, *Neioseiulus longispinosus*, anthocorid bug, *Orius* sp. reduce the mite population under field condition.

Potato Tuber Moth (PTM)

PTM: *Phthorimaea operculella* (Zeller) (Gelechiidae:Lepidoptera)

The potato tuber moth is the most significant insect pest of the potato. It has been reported from more than 90 countries worldwide. The PTM is principally a post-harvest pest damaging potatoes kept in farm stores but it can be an important field pest as well. In India, the damage has been reported from Maharashtra, Bihar, Madhya Pradesh, Himachal Pradesh (Kangra), Tamil Nadu, North Eastern hill states, plateau region and Karnataka. The range of infestation could be 30 to 70% in farm stored potato.

Biology

The freshly laid eggs are small and white in colour (deposited singly or in groups on underside of leaves or tubers). Freshly hatched larva is 1mm long. The larva (Fig. 3) feeding on leaves is purple to green in colour while on tuber whitish purple (fig .3). Maximum population growth of PTM occurs at temperature range of 20-25^{0}C. Life cycle of PTM is completed in 21-30 days at 27-35°C. Upper and lower threshold limit of temperatures for PTM are 40°C and 5°C. The male and female moths are brownish grey in colour and wings are folded to form a roof like structure. In addition to temperature, precipitation also influences development and abundance of *P. opercullela*. The damage is severe under low rainfall and high temperature conditions.

Other species- Andean PTM, *Symmetrischema tangolias,* Guatemalan potato tuber moth, *Tecia solanivora*

Nature and symptoms of damage

The young larvae penetrate the leaves and feed within them. Larvae also bore into stems of the plant causing wilting of plants. The larvae enter into the tubers and feed on them causing mines. The activity of larvae in tubers, placed in heaps, result in production of heat which promotes significant rotting of the produce. In country stores, 18-83% tuber damage due to PTM has been reported in the NEH hills.

Fig. 3: Potato tuber moth larvae feeding on tubers

Management

1. Installation of pheromone traps to capture and monitor field populations of PTM
2. Store clean and healthy tubers only
3. Deep planting and covering with soil to prevent the expose of the tubers.
4. Use of bioagents like *Bacillus thuringiensis* @0.05% and Granulosis virus @4LE/lit
5. *Apanteles subandinus* and *Copidosoma koehleri* are being widely used in classical biological control of *P. opercullela* in different parts of the world.
6. Use of sex pheromone traps @ 4 traps/100 m^3 of storage space for effective mass trapping
7. Dusting of cypermethrin @250g/quintal seed tuber or spray of quinolphos 25EC @ 2 ml/lit. water gives good control of PTM in seed stocks but such potatoes should not be used for consumption.
8. Covering the heaps of potato with thick layer of chopped dried leaves (2.5 cm) of lantana or eucalyptus.
9. Spraying of chloropyriphos 20 EC @ 2.5 ml/lit. when pest appears on the crop.

Cutworms

Cutworm: *Agrotis ipsilon* (Noctuidae: Lepidoptera)

Fig.4. Cutworm larva

Cutworms are polyphagous, cosmopolitan and most destructive insect pests throughout the world. In India, cutworms (Fig. 4)are more serious in northern region. *Agrotis segetum* is commonly found in hills and *A. ipsilon* is common in plains. Peak activity of cutworms occurs during May-

June in Shimla hills, in August in peninsular India and in March- April in Bihar and Punjab. In Bihar the tuber infestation up to 12.7% and in Himachal Pradesh 9.0-16.0% has been reported.

Biology

Moth lays eggs singly or in clusters between 600 and 800 eggs on vegetation, on moist ground or in cracks in the soil. Eggs hatch in 10 to 28 days. Young caterpillars are smooth, stout, cylindrical with a blackish brown dorsally and greyish green laterally. Older caterpillars have a plump body; fully-grown caterpillars are 4 to 5 cm long. Newly hatched caterpillars feed on the leaves and later on the stems. They commonly hide under the soil or litter by day. Older caterpillars feed at the base of plants or on roots or stems underground. They are nocturnal and hide in the soil or under stones and plant debris during the day. At night they move up to the soil surface to feed. Caterpillars (Fig.4) construct burrows or tunnels in the soil about 2.5 to 5 cm deep near the host plant. They pupate in an earthen cell in the soil. Adults are dark grey, black or brown coloured medium sized moths with markings on the front wings. The forewings are greyish-brown with black lines or kidney-shaped markings along the side margins. The hind wings are pearly white with dark brownish margins and veins. They are active at night. The life cycle can be completed in 6 weeks under warm conditions.

Other species: *Agrotis flammatra, Agrotis spinnifera, Agrotis interacta, Agrotis segatum*

Nature and symptoms of damage

Crop is damaged by the caterpillar stage only. The young larvae cause damage by feeding on leaves, stems/seedlings at ground level and making irregular holes in the tubers. They feed at night on young shoots or underground tubers and hide themselves during day time in the soil near to the stem. After tuber formation, they starts feeding on tubers and roots results in holes of different sizes resulting in reduction in tuber yield and its market value.

Management

1. Deep summer ploughing of the land in plains and hills before the planting to expose immature stages to hot weather and for predation by birds.

2. Flooding of the field for few days before planting can also kill cutworm caterpillars in the soil.

3. Use of insecticides like Chlorpyriphos 20 EC (2.5 ml/lit.) @ 0.04% for spraying the foliage and drenching the ridges.

White Grubs

White grubs (Scarabaeidae: Coleoptera)

White grubs are relatively large in size and are called as June beetles. *Lachnosterna longipennis* (Blanchard) and *Lachnosterna coracea* (Hope) are the predominant species damaging potato in the hills.

Biology

In summer, overwintering May beetles emerge from the ground at dusk, feed on the leaves of trees, and mate during the night. At dawn, they return to the ground, where the females lay 15 to 20 eggs in earthen cells several centimeters below the surface. Most of the beetles lay eggs in grassy surface. Eggs hatch 3 to 4 weeks later. The young grubs (fig.5) feed on plant roots throughout the summer; in the monsoon, they burrow below the frost line (to a depth of 1.5 meters) and hibernate. Larvae characteristically curl up in a C-shape when disturbed and only one generation per year is produced, the following summer, they return near the soil surface to feed and grow. In monsoon, the grubs again migrate downward to overwinter. The third summer, they move upward to feed on plant roots and are completely grown. These large grubs form earthen cells and pupate. The usual length of time for one complete generation (adult to adult) is 2 to 4 years depending upon latitude. The larvae live and pupate in soil, after which the emerging adults may move to new feeding sites. Adults are present year round in low numbers, but peaks are found in October-December and then again in March-April.

The beetles start coming out of soil at dusk soon after pre monsoon showers generally in May end or early June and settle on nearby trees namely *Acacia spp.*, roses, peach, plum, pear, apricot, apple (in hills) and neem trees (in plains) for mating and feeding. The beetles after feeding on host foliage return to burrows in the soil early in the morning for egg laying.

Other species: *Lachnosterna seticollis* Moser, *Anomala dimidiate* Hope and *Melolontha indica*

Nature and symptoms of damage

The adult emerges with the first shower of rain in May in hills. The damage is done by second and third instar grub which feeds on underground part of the plant such as roots and rootlets, by making large shallow and circular holes in the tubers. The grub stage is creamy white in colour with dark brown head and it becomes curved when disturbed. Economic damage results from the deep holes larvae make in the tubers underground. Severe damage occurs when potato field near to pastures or grazing fields.

Fig.5. White grubs feeding on potato tubers

Management

1. Potato should not be planted directly in pasture or grass fields.
2. Deep summer ploughing the fields repeatedly before monsoon to expose white grubs to harsh weather and predatory birds.
3. Flooding the fields wherever possible and adopt the crop rotation.
4. Installation of light traps for mass collection of beetles and killing them in kerosene/chemical treated water.
5. Drenching the ridges with Chloripyriphos 20 EC (2.5 ml/lit.) @ 0.04% near the base of the potato plants.
6. Apply phorate 10G @ 1 kg ai/ha or carbofuran 3G@ 3kg ai/ha in furrows at planting or near plant base at earthing up time.
7. *Metarrhizium anisopliae, Beauveria bassiana*, EPN like *Steirnernema carpocapsae* and *Heterorhabditis indica* have been reported to be effective in management of white grubs in mid and higher hills of HP.

Suggested Reading

Alyokhin, A., Vincent, C., Saint-Jean-sur-Richelieu, Giordanengo, P. and Antipolis, S. (2012) *Insect Pests of Potato: Global Perspectives on Biology and Management.*1-616.

Boiteau, G. (2010). Insect pest control on potato: harmonization of alternative and conventional control methods. *Am. J. Pot Res.* **87**: 412–419.

Chandel, R. S., Chandla, V. K. and Singh, B. P. (2005) Potato tuber moth *Phthorimaea operculella* (Zeller). Technical Bulletin No. 65. ICAR-CPRI, Shimla.

Chandel, R.S., Chandla, V.K., Verma, K.S. and Pathania, M. (2013) Insect pests of potato in India: biology and management. *In*: (eds) Giordanengo P., Alyokhin, A. and Vincent. C., Insect pests of potato. Global perspectives on biology and management. Elsevier, Waltham, MA, USA, 227-265 pp.

De Barro, P.J., Liu, S.S., Boykin, L.M. and Dinsdale, A.B. (2011). *Bemisia tabaci*: a statement of species status. *Annual Review of Entomology,* **56**: 1–19.

Khurana, S. M. P. (2000) Diseases and pests of potato-a manual. ICAR-CPRI, Shimla.

Malik, K. and Singh, B.P. (2007) Studies on *Bemisia tabaci* and its management. *Potato Journal* 34 (1-2): 91-92.

Misra, S. S. and Chandel, R. S. (2003) Potato white grubs in India. Technical Bulletin No. 60. ICAR-CPRI, Shimla.

Pushkarnath (1976) Potato in Subtropics. Orient Longman, New Delhi: 289p.

Rondon, S. I. (2010). The Potato Tuber worm: A literature review of its biology, ecology, and control. *Am. J. Pot Res.* **87**: 149–166.

Sharma, S., Thakur, M., Chandla, V. K., Singh, B. P. and Chakrabarti, S. K. (2012) Integrated management of potato pests. Technical Bulletin No. 96. ICAR-CPRI, Shimla.

Stuart Wale, H.W. and Cattlin, P.N. (2008). *Diseases, pests and disorders of potato.* 1-172.

Verma, K. D. and Chandla, V. K. (1990) Potato aphids and their management. Technical Bulletin No. 26 (Revised). ICAR-CPRI, Shimla.

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POTATO STORAGE AND PHYSIOLOGY OF SEED

Brajesh Singh and Ashiv Mehta

Contents

Introduction

Potato contains approximately 80% water and is a semi-perishable commodity because it is not as perishable as fresh vegetables like tomato, but is more perishable than cereal grains. About 90% of the potatoes produced in our country are grown in the Indo-gangetic plains and are harvested during January to March, the beginning of the long hot summer. This makes it very difficult to store the harvested potatoes, as under these conditions potatoes cannot be stored without refrigeration for more than 3-4 months after harvest because of enormous losses due to rottage, shrinkage, sprouting and attack of microorganisms. Therefore, in India potatoes are stored in cold store and used for both seed and table purposes. Seed potatoes are best stored in cold store maintained at 2-4°C and at about 95% relative humidity. But cold stored potatoes are not suitable for table and processing purposes. Potatoes stored in cold store accumulated sugars and become sweet in taste and are therefore, less suitable for consumption. Because of high accumulation of reducing sugars, these potatoes produce dark coloured chips which are unacceptable both colour-wise and taste-wise. Thus, the storage requirements of potatoes should be in accordance with the purpose for which potatoes are stored. It is suggested that cold stores maintained at 2-4°C should be used exclusively for the storage of seed potatoes. Table and processing potatoes should be stored at 10-12°C, after treating the potatoes with a sprout suppressant for long-term storage. For short-term storage of table and processing potatoes, non-refrigerated storage methods like evaporatively cooled potato store and traditional, on-farm potato storage methods like heaps and pits can be used profitably.

Storage of Seed Potatoes

Refrigerated stores: Seed potatoes are best stored at 2-4°C and 90-95% RH in cold stores, because at this temperature, sprouting does not occur and weight loss is minimum. The farmers have to pay the rent for storing potatoes in these cold stores and they take out these potatoes at the time of planting in the next potato season. The only problem regarding the storage of seed potatoes in cold stores is the uneven distribution of these cold stores over locations and non-regulatory storage charges.

***Non-refrigerated stores*:** In the northern hills, potatoes are planted in April/May and harvested in September/October. Seed potatoes harvested in

Fig. 1: A traditional cold storage and stack of potatoes inside the store

October are stored during cold winter months until they are planted in next April. Under these conditions, non-refrigerated diffused light storage systems work efficiently as the sprout growth in potatoes is reduced to desired level and seed vigour is retained in potatoes. Though diffused light storages are suitable for hills, they cannot work in plains because of high temperatures during summer months and there is heavy loss of seed vigour as well.

Fig. 2: Diffused light potato store and sprouted tubers

Storage of Table and Processing Potatoes

The potatoes to be used for table and processing purposes have different storage requirement than the seed potatoes. Essentially storage for table and processing potatoes may be divided in to two categories viz. Non-refrigerated storage systems and refrigerated storage systems as discussed below.

Non-refrigerated storage systems for table and processing potatoes

These are the storage systems where no artificial refrigeration is used. These storage methods can be used to store potatoes for 3-4 months (i.e. up to June) after harvest in February/March. However, once the monsoon begins, potatoes cannot be stored in a non-refrigerated store because it works only under dry conditions. Short-term storage of potatoes for 3-4 months is good enough because it helps avoid distress sale immediately after harvest and the farmer can get better returns by selling the potatoes in May or June, when potato prices start rising. It is relatively easy to store potatoes under non-refrigerated conditions when they are dormant. Indian potato varieties have a dormancy period of 6-8 weeks. Once the dormancy period is over, sprouting begins. Weight loss in potatoes during storage is mainly due to water loss from the tubers and the weight loss is much more in sprouted tubers. The extent of rotting is high under non-refrigerated storage systems as the temperature and humidity conditions are favourable for aggravating the infection. Non-refrigerated storage systems may be either traditional on farm systems as practiced by farmers or may be a modified system like evaporatively cooled potato store (ECPS).

Fig. 3: A potato heap

Refrigerated storage for table and processing potatoes

Fresh potatoes are available for consumption only for a few months, after the harvest. For a major part of the year, potatoes from cold stores are consumed. Though cold storage facility was developed primarily for the storage of seed potatoes, they have been used for the storage of table potatoes as well. But, 2-4°C is not the ideal storage temperature for table and processing potatoes as at this temperature, potatoes become sweet due to sugar accumulation and are not preferred for consumption. Further, cold stored potatoes do not keep well once they are taken out of the store. Therefore, storage of table and processing potatoes is suggested at 10-12°C. This method of potato storage is comparatively new to our country, but a good number of cold stores are now storing potatoes by this technology. When potatoes are stored at this temperature, accumulation of reducing sugars is minimum and potatoes do not become sweet. Depending on the variety stored, potatoes are suitable for processing as well up to about five months. However, at this storage temperature, potatoes sprout. Therefore, it is necessary to treat the stored potatoes with a sprout suppressant like CIPC (Isopropyl N-(3-chlorophenyl) carbamate). The treatment is made in the cold stores in chambers where only table and processing potatoes are kept. The treatment is done through an inlet made on the wall of the chamber and after the treatment; store is kept airtight for 24-48 hours. The first fogging is done at the first sign of sprout growth and second 45 days after first fogging. The treatment helps in checking sprout growth in potatoes and also helps in reducing the weight loss. The treated potatoes are safe for consumption after 3-4 weeks of treatment. Storage of potatoes by this method is very suitable for table potatoes because the potatoes do not give sweet taste and are preferred by most of the consumers. Besides, this kind of storage is helpful in providing the processing quality tubers to the processing industry for a longer period of the year.

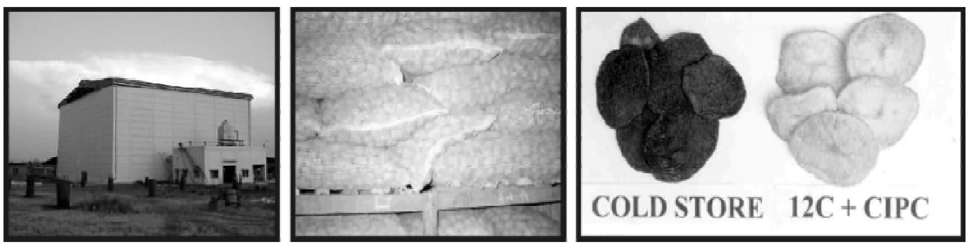

Fig. 4: A commercial cold store using 10-12°C storage technology, potatoes stored in leno bags and comparison of chip colour from two refrigerated storages.

Seed Physiology

Dormancy: Dormancy is a state in which tubers will not sprout even when placed under conditions ideal for sprout growth (18-20°C, 90% RH and darkness). Duration of dormancy is normally counted from the date of harvest. Another method of determining duration of dormancy is from the date of detaching the tubers from the plant i.e. Dehaulming and this method is both practical and convenient. Tuber dormancy is influenced by genotype, by the growth conditions of the crop and by the storage environment. The dormancy duration in Indian potato cultivars varies between 65 to 86 days and have been grouped into three categories, *viz.*, short dormant (less than 71 days dormancy), medium dormant (71-80 days dormancy) and long dormant (having dormancy of more than 80 days). The period of endodormancy is normally not as long as the required period of storage for seed and therefore, the cultivars having medium to long dormancy are desirable for long duration storage. The seed tubers are stored in cold stores (2-4°C) till the next planting season in most parts of the country. Similarly, for round the year supply of table and processing potatoes in the market, the dormancy has to be enforced by low temperature or chemical treatment. In hilly areas, cold storage facility has never been developed for storing seed potatoes, therefore, the seed is stored at ambient temperatures inside closed structures resulting in high storage losses and excessive sprouting. Central Potato Research Institute developed diffused light potato seed storage technology for the hilly areas. Seed tubers stored in these stores have healthy sprouts leading to a vigorous crop.

Factors affecting dormancy

Cultivar: Based on the dormancy duration from the date of harvesting (it is assumed that harvesting is done 10-15 days after dehaulming) in the plains, Indian potato cultivars can be divided into three categories.

i) Short dormancy: < 71 days. e.g. Kufri Bahar.

ii) Medium dormancy: 71-80 days. e.g. Kufri Jyoti.

iii) Long dormancy: >80 days. e.g. Kufri Sindhuri.

Even within a cultivar, dormancy duration can be affected by growth conditions and tuber weight. Dormancy duration is not related to the crop duration of a cultivar. In other words, it is not necessary that a late cultivar should have long dormancy.

Growth conditions: Soil and environmental conditions during crop growth have a strong influence on the dormancy duration. Cold and wet weather is known to increase the dormancy duration while dry and warm weather reduces it. Potato grown under short-day conditions (plains) have shorter dormancy duration than those grown under long-day conditions (hills). For example the dormancy duration in Kufri Jyoti, Kufri Chipsona-1 and Kufri Chipsona-2 was 55, 47 and 40 days, respectively when grown in the northern plains under short day conditions and 126, 84 and 91 days, respectively when grown in the northern hills under long day conditions. Season (year) to season variation in the duration of dormancy can also be considerable due to variation in the environmental conditions during crop growth.

Storage environment: Storage temperature has a strong influence on the dormancy duration. Higher storage temperature hastens dormancy release, while storage at a temperature of 4°C and below prolongs dormancy by preventing sprout growth. Exposure to light during storage also affects dormancy duration but its effect is much less compared to temperature effect. RH in the storage atmosphere has very little effect on dormancy duration. Concentration of gases in the storage atmosphere also affects dormancy duration. Lower concentration of oxygen (O_2) and higher concentration of carbon-di-oxide (CO_2) hasten the release of dormancy and stimulate sprout growth.

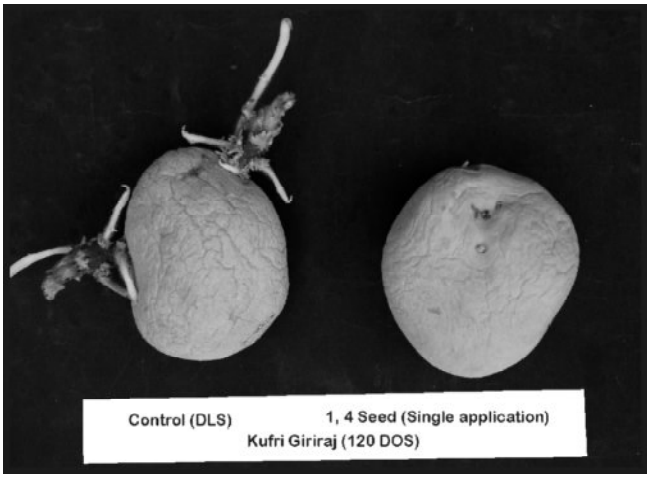

Fig. 5: A dormant and a sprouted tuber

Breaking of dormancy

In places where more than one potato crop is grown in a year, it becomes necessary to break the dormancy artificially. For example when seed tubers from northern hills harvested in September are planted in October in northern plains. Dormancy breaking is also practised in those places where two successive crops are grown and the seed for the second crop comes from the first crop. In the North-western plains, tubers harvested from the autumn crop are used as seed for the spring crop. In the Nilgiris hills, tubers harvested from the summer crop are used as seed for the autumn crop. In the above cases, the dormancy has to be broken artificially by treating the tubers with chemicals. Dormancy breaking treatment helps in faster emergence and a better crop stand. Several methods are being practised in India for breaking dormancy. Generally gibberellic acid (GA) + thiourea treatment is given for breaking dormancy. Whereas, in the Nilgiris carbon-di-sulphide is used for breaking dormancy. Though this treatment has been found effective in the Nilgiris hills, it has not worked in other places. Treatment with GA and thiourea has been found effective and useful for breaking tuber dormancy. In this treatment dormancy is broken by soaking seed tubers in a solution of 1ppm GA and 1% thiourea for 1 hour. After the treatment, the tubers should be dried in the shade and then planted. If whole tubers are to be treated, they have to be given incisions (two or three superficial cuts given in such a way that the eye is not injured). Higher concentration of CO_2 is also known to hasten the release of dormancy. Studies carried out at the Central Potato Research Institute (CPRI) have shown that when seed potatoes were stored at 15% CO_2 (20°C and 90% RH), dormancy release was observed after 24 days whereas in control tubers, it was observed after 67 days.

Dormancy release appears to be a gradual process. The biochemical and physiological changes associated with dormancy release are complex. The only clear picture that has emerged is that dormancy release is associated with an increase in gibberellins (growth promoter) and decrease in abscisic acid (ABA) (growth inhibitor).

Suggested Readings

Burton WG (1989) The potato, 2nd Edn. Longman, Essex. 742 pp.

Burton WG, van Es A and Hartmans KJ (1992) The physics and physiology of storage. In, The potato crop, 2nd Edn. Harris PM (ed.), Chapman and Hall, London. 608-727.

Ezekiel R, Mehta A, Kumar D and Das M (2003) Potato storage. In, The Potato-Production and Utilization in Sub-tropics. Khurana SMP et al., (eds.), Mehta Publishers, New Delhi. 323-335.

Sukumaran NP and Verma SC (1993) Storage and processing. In, Advances in Horticulture. Vol. 7-Potato, Chadha KL and Grewal JS (eds.), Malhotra Publishing House, New Delhi. 701-732,

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HEAT AND DROUGHT TOLERANCE IN POTATO PRODUCTION

JS Minhas, Devendra Kumar, Som Dutt and Brajesh Singh

Contents

Introduction

Although cultivated potatoes originated in highlands of South America, it is in the temperate countries where the full potential of the crop was first exploited as a result of organised breeding work. From these countries, potato was introduced to the tropical and subtropical areas of the world. However, the yield of potatoes in the tropical and subtropical parts of the world is less than one third compared to the temperate zones. Although poor cultural practices and high incidence of diseases and pests are responsible for the low yields, yet environmental factors like high temperatures and limited moisture availability are other major factors affecting the crop growth and yield adversely.

Drought stress

Some researchers consider drought to be the main limiting factor for yield influencing negatively not only yield but also tuber quality. Insufficient water supply may occur almost anywhere, where potatoes are grown. In arid regions (e.g. sub-tropics), where potato production is only possible with irrigation, short periods of drought often arise because of inadequate irrigation techniques or shortage of water. Even with good irrigation practices, water stress may occur because of high transpiration rates especially during mid-day, when root system can not completely meet the water requirements of the plant, leading to increased water potential and consequent reduction in the rate of photosynthesis. In the temperate climatic zones both short and long periods of drought may occur in most years due to irregular rainfall, particularly on soils with low water holding capacity. Taking into account production conditions and the present yield levels, it is estimated that the average potato yield in the world could be increased by at least 50% if the water supply to the crop could be optimised. Breeding for drought tolerance should therefore receive high priority.

Effect of drought on potato growth and production

Drought may affect potato growth and production in three ways: 1) by reducing the amount of productive foliage, 2) by decreasing the rate of photosynthesis per unit of leaf area and 3) by shortening the vegetative period. Drought after planting may delay or even inhibit germination. Drought after planting is generally experienced by the potato crop in the Northern hills of India where the crop is generally taken under rain-fed conditions. Water stress has caused reduction in leaf growth in eight cultivars tested in an experiment, although the extent of reduction varied within the varieties. Insufficient water supply in the period between emergence and the beginning of tuber bulking may therefore lead to a small growth rate of foliage and to small leaves and small plants. As a consequence soil cover with green foliage will often be incomplete and yields will be below optimum. This can cause loss in priductivity.

Potato plant is highly sensitive to water stress as the decline in photosynthesis is fast and substantial even at relatively low water potentials of –3 to –5 bars. Even in the irrigated crop, plants experience water stress during the mid-day as the roots are not able to meet the transpirational demands of the plants fully. Mid-day depression in the rate of photosynthesis in irrigated crop was also reported. Plants respond to water stress by closing their stomata thus shutting out the supply of CO_2. Sugar concentration within the leaf tissue increases to increase the osmotic potential of the plant, thus leading to feed back inhibition of photosynthesis. Sensitivity of the potato crop to water stress varies with the developmental stage of the crop. It has showed that stolon initiation stage of the crop is most sensitive to water stress.

Water stress during the tuber bulking stage causes a reduction in the leaf expansion rate, but to a lesser extent, as compared to plants before tuber initiation. Presence of the tubers probably increased the water capacitance of the plants. Apart from reduction in leaf growth, water stress at this stage encourages plant senescence resulting in decreased LAI. At first lower leaves start to wilt and drop off, simultaneously drought inhibits the development of new leaves.

Drought and tuber quality

Tuber quality characteristics such as shape, dry matter content and content of reducing sugars can be influenced by water stress during the vegetative period. Shape defects such as dumb-bell shaped, knobby or pointed end tubers can be caused by short stress periods during the tuber bulking stage. Misshapen tubers can also occur due to secondary growth, which is especially likely to occur in dry soils where temperature can go high. This phenomenon may also result in poor cooking quality (glassiness) among some of the tubers or jelly end or translucent end tubers. All these tubers have high content of reducing sugars, which causes difficulties for the processing industry. Tubers of water stressed plants often have higher content of total sugars than well irrigated plants. Dry matter content is often higher in tubers from water stressed plants than in well watered plants. It has been found that the dry matter content of potato tubers of four varieties grown under low soil moisture was much higher than the well watered plants.

Drought tolerance

Drought tolerance can be the result of drought avoidance (e.g. closure of stomata, large root system) or drought tolerance (capacity for osmotic adjustment, rapid resumption of photosynthesis activity). Aspects of drought tolerance that are considered important and should be taken into account in breeding programme are: 1) the effect of short periods of stress on productivity and tuber quality, 2) survival and recovery of the plants after water stress and 3) water use efficiency.

The first aspect has already been discussed. Regarding the survival and recovery after water stress, two factors are important: 1) limited loss of soil cover by green leaves and 2) recovery of expansion growth and of the photosynthetic rate. Regarding the second factor, there are indications that the potato is well able to regain its photosynthesis rate after a drought stress. Researchers have found that after "permanently wilted" potato plants were re-watered, the rate of photosynthesis recovered fully even after three days of "permanent wilting". A study was done to see the recovery of leaf growth after a period of water stress in eight potato cultivars and it was found that based on the recovery potato cultivars can be placed in three groups. Group A was characterised by minimum growth reduction under stress and rapid recovery on re-watering with final increase in the leaf length exceeding that of the unstressed controls. In group B plants, stress created moderate reduction in growth and on recovery the increase in leaf length became comparable to that of controls. Group C was characterised by large reduction in growth and re-watering did not result in final leaf length increase comparable to that of controls.

Indicators of drought stress or drought tolerance

The plants water status can be described by leaf water potential (LWP) indicating the energy status of water in the plant and the relative water content (RWC). Since these parameters are related to leaf growth and photosynthesis rates, they can provide information on drought tolerance. Further, direct or indirect indications of drought tolerance can be obtained by measuring:

- photosynthesis rate
- water retention of excised leaves
- depth and extension of the root system
- anatomical structure of the leaf
- yield under dry growing conditions in the field
- the extent of wilting and recovery after severe drought stress
- Water use efficiency and transpiration rate

Relation between stress parameters

When plants are exposed to water stress, reduced water uptake leads to reduction in RWC and LWP, increased stomatal resistance due to closure of stomata and consequently reduction in the rate of photosynthesis. It has been found that under controlled conditions the photosynthesis rate of potatoes was reduced by 17% at an LWP of –4 bars and by 50% at –11 bars. Both passive and active osmotic adjustment of the cell sap allows the plant to maintain the photosynthetic rate at lower LWP. When RWC of a leaf decreases, the osmotic value of the cell sap will increase passively. However, it is not clear whether active osmotic adjustment takes place in potato plant or not.

Varietal differences in sensitivity to water stress

It is well known that varieties of many field crops including potato respond differently to water stress with respect to various growth parameters and yield. The varietal differences in response to stress can be due to variation in one or more of the following factors:

- leaf longevity
- harvest index
- root factors
- anatomical structure of the leaf
- stomatal behaviour

- leaf water potential, osmotic potential and relative water content
- photosynthesis rate
- water retention by the leaves
- wilting and recovery after a long water stress period
- water use efficiency
- yield determinations on a soil profile with varying depths
- Water use efficiency and transpiration rate

Screening clones for drought tolerance

All the above listed parameters can serve as a basis for screening clones for tolerance against drought but most of them are not easy to apply or are not sufficiently reliable, so that it could be used to screen a large number of clones. The most promising method seems to be estimating water use efficiency and transpiration rate based on isotope ratio of carbon and oxygen by isotope ratio mass spectrometer. This instrument can measure time averaged rate of water use efficiency based on ratio of carbon isotopes and transpiration based on ratio of oxygen isotopes. Ninety eight germplasm lines were screened for water use efficiency and transpiration rate by isotope ratio and good variation was found in the potato germplasm. Highly water use efficient and high transpiration rate lines were selected and used in breeding for combining both these characters to develop drought tolerant potato varieties.

Heat stress

The potato has long been considered a crop for cool, temperature climates. 17^{o} C has been define as an optimum mean temperature for good yield in potatoes. Higher temperature may inhibit yield by overall reduction of plant development due to heat stress or by reduced partitioning of assimilates to tubers. Minimum night temperature is very important for potato crop. Whether or not potato will tuberise, depends largely on the minimum night temperature and not on the average daily temperature. Tuberisation is reduced by night temperature of 20^{o} C and there may not be any tuberisation at night temperature of 25^{o} C and above, even though potato plants can tolerate day temperature of about 35^{o} C without much deleterious effect.

Potato produces highest dry matter, edible energy and proteins per unit area per unit time among all the major food crops. Because of the potential of this crop to feed the ever increasing population, the concentration of potato production is now shifting from Europe to Asia and other parts of the developing world where population density is high. Developing countries today produce 37% of world's potatoes. Since these areas lie in tropical and subtropical part of the globe, potato yields are low because of prevailing high day and night temperatures. Imparting heat tolerance to potatoes will greatly help in the establishment of potato as an important food crop in these areas.

Effect of heat stress on potato growth and production

High temperature induces development of plants with thin stems, small leaves, long stolons, increase in the number if inter-nodes, inhibition of tuber development and a decrease in the ratio of tuber fresh weight to total fresh weight. High temperature increases the rate of dark respiration in plants. When the rate of night respiration was measured in potato plants at different temperatures, doubling of respiration with every 10^{o} C increase in temperature was observed. So, as the temperature increases, more and more carbohydrates are used up as respiratory substrate and less and less are available for translocation to the tubers. Chlorophyll fluorescence studies conducted at this Institute showed that photosynthetic apparatus in potato is stable up to 38^{o} C but beyond that there is a drastic reduction in photosynthetic efficiency. The most important effect of high temperature is on the partitioning of assimilated carbon between leaves and tubers. On studying the partitioning of ^{14}C at 32/22, 32/12, 27/22, 27/12 and 22/12, total plant productivity was not affected by temperatures, nor was export of carbon from the source leaf. More of assimilated carbon was partitioned to vegetative parts at high temperature while at lower night temperature most of the assimilated carbon was partitioned to the tubers. They concluded that the main effect of high temperature is on assimilate partitioning and not total plant productivity. Another study on the partitioning of assimilated carbon within the source leaves into starch and sucrose in three heat tolerant and three heat susceptible varieties showed that in heat tolerant varieties 20-25% of the current assimilates was converted to sucrose and 40-45% into starch. Whereas in heat susceptible varieties only about 5% of the current assimilates were converted to sucrose while 80-85% were converted to starch.

Exposure of potato plants to heat stress alters the hormonal balance between roots and shoots and thus alters tuberisation and bulking. When potato plants are exposed to high temperature, gibberellin content in the leaves increases thus promoting haulm growth and higher concentration of gibberellins inhibit tuberisation. Gibberellins and abscisic acid concentrations in heat tolerant and susceptible genotypes were also studied and it was found that GA/ABA ratio was low in shoots of heat tolerant genotypes. GA like substances decreased in the shoots and tended to accumulate in the roots of heat sensitive genotypes during tuber bulking stage, whereas substantial amounts of GA like substances remained in the shoots of heat tolerant genotypes. It was suggested that tuberisation at high temperature may be related with high levels of ABA like inhibitors in the shoots during tuber induction.

Heat tolerance

In potato plants high night temperatures are much more deleterious to the formation of yield than day temperature. Potato can give good yield even at day temperatures of 30-35^{o} C provided nights are below 18^{o} C. But if night temperature go beyond 22^{o} C there is very little tuberisation even when the day temperature is 25-27^{o} C. So heat tolerance in potatoes is concerned more with the minimum night temperature than the maximum day temperature. Aspects of heat tolerance that are considered important and should be taken into account in breeding programme are: 1) ability of the plants to tuberise at night temperature of 22^{o} C and above, 2) low shoot/root ratio at high night temperature and 3) early maturity of the crop. There is genetic variability with respect to tuberisation at high temperature. At International Potato Centre, 6000 commercial varieties and breeding lines were evaluated for yield at high temperature and 34 gave reasonably good yields. The genetic studies with these genotypes showed that a higher level of heterozygosity at the population level would confer a greater capacity to adapt to divergent environments. The best performing genotypes had genes from different species of *Solanum* like *tuberosum, andigena* and *phureja*. High temperature induces senescence in plants and shortens the crop duration. So genotypes which has early tuberisation and fast bulking rate perform better under such conditions.

A leaf bud cutting is a model system to study effect of temperature on tuberisation in potato. Single leaf cuttings are placed in the soil/sand medium so that the leaf bud is buried in the soil. These cuttings are exposed to various temperatures and leaf buds are examined for tuberisation after three weeks.

The presence of tubers, stolons or tubers on long stolons give good indication of the heat tolerance of the plant from which leaf bus cuttings were taken.

Fig. 1: Tuberization in leaf buds in response to night temperature showing formation of more tubers at 18C than 24C.

Indicators of heat tolerance

Tall plants with elongated inter-nodes and small leaves indicate heat stress. Further, direct or indirect indications of heat tolerance can be obtained by measuring:

- photosynthesis rate
- chlorophyll fluorescence
- thermostability of the membranes
- chlorophyll stability
- rate of inter-node elongation
- yield under high temperature conditions in the field

Relation between stress parameters

The optimum temperature for photosynthesis is about 25^{O} C. Above this temperature, the rate of photosynthesis decreases due to non stomatal factors. Three respiratory processes, viz., photorespiration, growth respiration and maintenance of respiration change as a function of temperature along with the rate of photosynthesis. The effect of temperature on these processes is not necessarily to the same extent. This implies that low night temperature should result in less respiratory loss of photosynthate, thus making more photosynthate available for translocation to the developing tubers. Chlorophyll fluorescence studies conducted in our laboratory indicated that PS-II remained intact up to 38°C. At temperatures higher than 38°C PS-II activity was irreversibly reduced due to chloroplast membrane disorganisation.

Another reliable measure of heat tolerance of a genotype is the thermostability of the cell membranes measured by electrolyte leakage after exposing the leaf discs to 50°C for 30 minutes. Heat tolerant genotypes show lower electrical conductivity compared to susceptible genotypes. Similarly chlorophyll of heat tolerant genotypes exhibit higher stability after short term exposure to high temperature. Heat tolerant genotypes show higher inter-node elongation on exposure to higher temperature as compared to heat susceptible genotypes.

Varietal differences in sensitivity to heat stress

Variability is the essence of life. Potato genotypes also show variability with respect to their performance when grown under heat stress. The varietal differences in response to heat stress can be due to variation in one or more of the following factors:

- Harvest index
- Tuber initiation and rate of bulking
- Rate of inter-nodal elongation
- Tuberisation in the leaf bud cuttings
- Hormonal distribution
- Carbon partitioning
- Membrane stability
- Chlorophyll stability
- Photosynthesis rate
- Respiration rates

Screening clones for heat tolerance

All the above listed parameters can serve as a basis for screening clones for heat tolerance but most of them are not easy to apply or are not sufficiently reliable, so that it could be used to screen a large number of clones. The most promising methods are tuberisation in leaf bud cuttings at elevated temperatures, inter-nodal elongation, and tuberisation in the seedlings grown under high temperature conditions. Using these methods CPRI has released the first heat tolerant variety Kufri Surya in 2006. This variety is suitable for early planting in north western plains as well as in peninsular India. It was proves under controlled environment conditions that this variety possess good degree of heat tolerance and can tuberize normally up to 20^{o} C night temperature and up to 80% at 22^{o} C night temperature.

Suggested Readings

Basu PS and Minhas JS (1991) Heat tolerance and assimilate transport in different potato genotypes. *Journal of Experimental Botany* 42: 861-866

Burton WG (1989) The Potato. Longman Scientific and Technical, New York, USA: 742p

Ewing EE (1981) Heat stress and tuberisation stimulus. *American Potato Journal* 58: 31-49

Harris PM (1992) The Potato Crop. Chapman and Hall, London, UK: 909p

Kumar D, Minhas JS and Singh B (2003) Abiotic stress and potato production. In, The Potato-Production and Utilization in Sub-tropics. Khurana SMP, Minhas JS, Pandey SK (eds), Mehta Publishers, New Delhi: 314-322

Li PH (1985) Potato Physiology. Academic Press, London, UK: 586p

Minhas JS and Singh B (2003) Physiology of crop growth, development and yield. In, The Potato-Production and Utilization in Sub-tropics. Khurana SMP, Minhas JS, Pandey SK (eds), Mehta Publishers, New Delhi: 292-300

Struik PC and Ewing EE (1995) Crop physiology of potato: responses to photoperiod and temperature relevant to crop modeling. In, Potato Ecology and Modeling of Crops under Conditions Limiting Growth. Haverkort AJ and Mackrron DKL (eds), Kluwer Academic Publishers, The Netherlands: 19-40

van Loon CD (1986) Drought, a major constraint in potato production and possibilities of screening for drought resistance. In, Potato Research of Tomorrow. Pudoc, Wageningen, The Netherlands: 3-55

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QUALITY PROCESSING PARAMETERS AND VALUE ADDED PRODUCTS OF POTATO

Pinky Raigond, Alka Joshi, Bandana, Brajesh Singh

Contents

Introduction

Potato processing is gaining importance in our country in view of the rising employment of women in cities leading to growing demand for processed products and the general increase in demand for processed foods in urban areas due to liking of people particularly youngsters for such products. The increase in number of fast food outlets in the metros and even smaller cities is also contributing towards this. Processing helps in reducing demand for storage space and also provides better returns to the growers. Potatoes can be processed into a number of value added products like chips, French fries, flakes, granules, dice and canned potatoes on a commercial scale. In addition industrially useful products like potato flour and potato starch can also be produced on a large scale. Village level processing of potatoes can also be done to prepare dehydrated products like dehydrated chips, *papads,* etc. Two major factors, which determine the quality of end products, are: suitability of the variety for processing and the area where potatoes have been grown. Products from potatoes are quite popular in our country. Many ready to eat products can be prepared by utilizing potatoes. Units based on potato products can easily be established in potato growing areas and the market for these products can be exploited in urban and semi-urban areas.

Quality requirements

The raw material requirements vary with the kind of processed product. Both morphological and biochemical characters of potato tubers have to be considered for this. The important morphological characters are tuber shape, size and depth of eyes and the important biochemical characters are dry matter and reducing sugar content. Fleet eyes are preferred since deep eyes result in higher peeling losses. Large, round or oval tubers are preferred for chips and oval or oblong tubers are preferred for French fries. Tubers with dry matter content of 20% and above and reducing sugars content of less than 150 mg/100 g f. wt. are preferred for processing. Based on the morphological and biochemical quality parameters following varieties released by CPRI have been found suitable for processing purposes:

Important characters of some Indian potato varieties determining processing quality

Variety	Shape/Size	Dry matter (%)	Reducing sugars (mg/100g f. wt)
Kufri Chipsona-1	Oval/Large	21-24	45-100
Kufri Chipsona-2	Round/Large	21-25	44-93
Kufri Chipsona-3	Round/oval/Medium	22-24	30-50
Kufri Frysona	Oblong/large	22-23	<100
Kufri Himsona	Oval/Medium	20-25	<50
Kufri Jyoti	Oval/Large	18-21	106-275
Kufri Lauvkar	Round/Large	18-20	200-250
Kufri Chandramukhi	Oval/large	18-20	250-324

These varieties are expected to reach to the farmers in coming years and become part of raw material for the processing industries.

Value Added Products

Potato chips

Potato chips production by the organized sector has increased rapidly after the introduction of the liberalization policy of the government of India and the total requirement of raw material for producing potato chips by the organized sector in the country reached to about 3,50,000 tonnes during 2005-06, whereas, in the unorganized sector it is still higher. Showing thereby that the demand for potato chips is likely to increase further, because of its increasing popularity as a convenient fast food especially in urban areas.

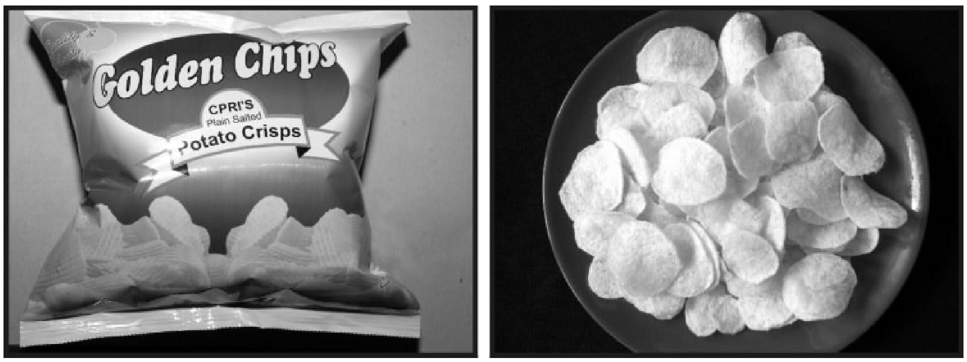

Fig. 1: A packet of chips of CPRI and potato chips

Chip colour, crispiness and taste determine the quality of potato chips. Light or light golden yellow colour is preferred while brown or black chips are considered undesirable. For chips to be acceptable, besides being light in colour, they should be crispy. Not all potatoes are suitable for chipping. For producing good quality chips, potatoes should meet certain quality requirements. They should be round to round-oval in shape with fleet eyes. The size preferred is 40-60 mm. Besides, the potatoes should possess a dry matter content of more than 20% and a reducing sugar level of less than 150 mg per 100g of tuber fresh weight. Higher dry matter content of potatoes results in higher yield of chips and lower consumption of the frying medium. The keeping quality of chips will also be better since they will contain lesser amount of oil. Amongst the cultivated potato varieties, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Jyoti and Kufri Lauvkar when grown in warmer areas, possess higher dry matter and lower reducing sugar content. Therefore, mostly, the potato processing industry in India, for producing potato chips, is using these varieties.

Potato chips can be prepared on a small scale following the procedure given below and the steps involve peeling, trimming, slicing, blanching and frying.

Peeling: Potatoes are washed thoroughly with clean water and then peeled using a peeler. Generally batch type abrasive peelers are used in small scale processing units.

Trimming: Peeled and washed potatoes are trimmed manually during this process residual skin, eyes and green portions are removed.

Slicing: Peeled potatoes are sliced and generally the slice thickness is 2mm. Slices should have uniform thickness and smooth surface. Slices are washed to remove surface starch. Batch type slicers are available in the market.

Blanching: Washed slices are blanched to improve the chip colour especially when sugar level in potatoes is high. Blanching is done by dipping slices in hot water (60-80°C) for 2-3 minutes. After blanching slices are partially dried to remove excess moisture. A spin dryer can be used for this purpose.

Frying: Slices are fried at 180-190°C using a batch type fryer. Normally electrically heated fryers are used in which temperature is indicated. Temperature control is needed for maintaining uniform quality of chips.

Fried potato chips can be consumed as plain, salted chips or can be consumed after mixing with spices.

French fries

French fries are very popular in the developed countries. In India the quantity of French fries consumed is much less compared to potato chips. However, the demand for French fries is increasing gradually. Generally, frozen French fries (par-fries) are prepared and sold. These are finish fried in deep fat. Potatoes are peeled, trimmed and cut into sticks. The cross section can range from 7 to 12 mm and is generally 10 mm. The length of sticks again varies and is normally 5 to 7 cm. The French fry sticks are blanched, par-fried and frozen. Finish frying is done for about 2 minutes at 180°C and served hot. French fries can also be prepared from fresh potatoes at home and restaurants by frying them in deep fat in two stages. Kufri Frysona variety has been developed for production of high quality french fries and is being utilised by the industries for this purpose.

Fig. 2: French fries at frying and as sold from CPRI

Potato Flour

Potato flour can be used in combination with other cereal and pulse flours for preparation of a number of products as per the desired taste. Some products like biscuits, cake, *bhujia, paratha,* etc. can be made.

Method for preparation of potato flour

Take 1kg potatoes in a container, add 2 litre water, add 10g of potassium metabisulphite, boil the potatoes, peel the potatoes, mash the potatoes after cooling and spread on a plate or tray, dry in an oven at 80°C until dry, grind to get a fine powder, sieve and store. 1 kg potatoes will yield about 200 g flour.

Potato Starch

Potato starch is superior to cereal starches in many ways. It has large granule size (5-100um), its lipid content is low, it has higher water binding capacity and high solubility, besides having low protein content and it helps in avoiding foam building and colour formation. It also has higher phosphorus content and higher swelling volume.

Method for preparation of potato starch

Take 1kg of potatoes, peel and cut into small pieces, put in 1 litre water containing 5g potassium metabisulphite, grind in a grinder, pass the slurry through muslin cloth and collect in a tub, wash 3 times with sufficient water (2-3 litre), let the starch settle down in the tub, decant and wash 2-3 times with water till the water is clear, dry the starch in oven at 80°C/ sunlight on tray till fully dry, grind to get fine powder. Sieve and store in an airtight container. 1 kg of potatoes will yield 70-100 g of starch.

Potato starch may be utilized in several industries. In food industry it may be used as thickener in sauces, gravy, puddings, soups, etc., as softening agents in cakes, breads, biscuits and cookies and as ingredient in custard, cream, candies and chewing gums. In textile industry it gives the finished cloth a smooth surface and better feel and hence is preferred in warp sizing. In paper industry, it is useful in coating smooth white paper because of its unusually strong binding power for white pigments and clays. In pharmaceutical industry it is used for preparation of dextrins, adhesives, glues, drugs, dressing materials, binder for tablets, etc.

Dehydrated potato products

Preservation of foods by drying is perhaps the oldest method known to man. Drying results in the lowering of moisture content leading to lesser chances of microbial growth. As a result, the product has a longer shelf life. The reduction in moisture content is accompanied by a reduced bulk, which facilitates storage, transportation and packaging. Even today, solar dehydration is quite common in Gujarat and Maharashtra. Sun drying of potatoes in the form of 2-3 mm thick slices, shreds and *papads* is quite common in several parts of the country.

Dried potato slices

Dried potato slices are also known as raw chips. This is the most popular dehydrated product of potato. Raw chips are consumed after frying and salting. Raw chips are prepared at home by housewives and also by small scale manufacturers. The housewives simply hand peel the potatoes, cut them into slices and then boil the slices in water for 5-8 minutes. The

Fig. 3: Dehydrated chips

slices are dried in the sun till they become brittle. Small scale food processors generally use electrically operated peelers and slicers to make 1-2.5 mm thick slices of potatoes. These slices are washed in cold water to remove adhering starch. The slices are then blanched in hot water (80-90ºC) containing potassium metabisulphite. The blanched slices are then dried in the open, on polythene.

Conclusions

A number of processed products may be prepared from potatoes. Potato strips and dice can be produced by simple methods. Potato flakes and granules can also be prepared. Potato flour is another important product from potato, which can be used in baking industry, baby foods and as thickener and flavouring agent in soups and sauces. Potatoes can be processed into French fries, which is the most popular processed potato product in the world. Next to French fries, potato chips are consumed in large quantities throughout the world. In India, potato chips are the most common and popular processed product of potato. With the increase in demand for processed products in the country especially in the urban areas, more emphasis needs to be given on quality aspects of the processed products. More varieties having still better quality for processing need to be developed by CPRI. At present the cost of processed products seem to be on the higher side and sometimes the products are beyond the reach of common population, therefore, in future it would be desirable that industries try to reduce the cost of production/ marketing so as to make the products cheaper and more popular. Increased emphasis on village level processing is needed. Production of dehydrated potato products, which can be reconstituted needs more emphasis. More importantly, development of proper storage facilities for the storage of potatoes meant for processing at 10-12ºC needs to be given utmost priority.

Suggested Readings

Marwaha RS, Uppal DS, Kumar D and Sandhu SK (2003) Potato Processing. In, The Potato-Production and Utilization in Sub-tropics. Khurana SMP et al., (eds.), Mehta Publishers, New Delhi. 336-346.

Rana RK (2011) The Indian potato processing industry: Global comparison and business prospects. Outlook on Agriculture. 40 (3): 237-243.

Talburt WF and Smith O (1987) Potato processing, 4th Edn. Van Nostrand Reinhold, New York. 796 pp.

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NUTRITIONAL VALUE OF POTATOES

Bandana, Pinky Raigond, Alka Joshi, Brajesh Singh

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Introduction

Potato (*Solanum tuberosum*) is an economical food as they provide a cheap source of available energy irrespective of every age's human diet. Potato does better than rice and wheat as edible energy source. Consuming potatoes just once or twice each day lowers high blood pressure almost the same as oats without resulting in increase in weight. Besides potatoes have more in store than just those unwanted calories, ensuring staying healthy. It is a staple component of the diet in many human cultures and source of many essential nutrients and is available all year round moreover may be cooked with various means (e.g. boiling, baking, and frying) prior to consumption.

Carbohydrates

Carbohydrate is almost universally the major dietary source of metabolic energy. The main energy-providing nutrient in potatoes is carbohydrate, in the form of starch. Potatoes contain both carbohydrate types i.e. simple and complex carbohydrates that provide primary source of energy for the body and supply at least half of calories for the day. Sucrose, fructose and glucose are the main sugars present in potatoes. The advantage of getting carbohydrates from potatoes is that one can get a considerable amount of few micronutrients as well. Although, potato starches are less completely digested when fed raw but their digestibility is similar to that of the cereal starches after cooking.

Fat

When boiled or baked, potatoes are a virtually fat-free food and average fat content of potato is 0.1%. The little fat present in tuber gives palatability. About 60-80% of the fatty acid content is composed of unsaturated fatty acids (linoleic acid).

Protein

Proteins are important constituents of cellular membranes as well as various cytoplasmic structures. Also the enzymes present in potatoes are made up of proteins. The essential nitrogen fraction in a potato tuber is protein nitrogen. Potatoes are commonly perceived as a carbohydrate source only, but they do contain high quality protein. On a fresh weight basis they contain only about 2% protein; the value increases to about 6-8% on a dry weight basis that makes potatoes comparable to cereals, such as rice or wheat. In countries, where potato consumption is high potatoes can make a significant contribution to health as a protein source. Potato proteins comprise 18-20 amino acids present in varying quantities. More than two-third of the non-protein nitrogen present in potatoes is present as free amino acids. A number of different amino acids are present in highest quantities in potatoes viz. lysine, aspartic acid, glutamic acid and valine.

Vitamins

Of all the vitamins, potatoes contain vitamin C in the highest amount. Vitamin C is water-soluble and its main component is ascorbic acid. However, dehydroascorbic acid has properties similar to vitamin C if it is reduced to ascorbic acid in the organism. It acts as an antioxidant stabilizing free radicals, thus helping prevent cellular damage. It aids in collagen production; assists with iron absorption and help support the body's immune system. Potatoes are a good source of vitamin B6, a water soluble vitamin that plays important roles in carbohydrate and protein metabolism. It helps the body by making amino acids that is later used to manufacture various proteins. There are several different B group vitamins, and potatoes are a source of some of these. A medium serving of boiled potatoes (180 g) contains more than one sixth of the adult daily requirements for vitamins B_1, B_6 and folate. These B group vitamins have many functions in the body including being essential components in the metabolism of carbohydrates to provide energy, and maintaining a healthy skin and nervous system. Folate is needed for cell growth and development.

Minerals

Various important minerals and trace elements are present in potato. Potatoes are among the top sources of potassium. In fact, potatoes have more potassium per serving than any other vegetable or fruit, including bananas, oranges, or mushrooms. Diets rich in potassium and low in sodium (which together with chloride forms salt) reduces the risk of hypertension and stroke and help lowering blood pressure. Potatoes are a rich source of iron and this, coupled with the presence of high vitamin C content, helps in its absorption. It is also a good source of potassium, phosphorus and magnesium. Zinc is an important trace element found in potato. Because of low phytic acid content of potato zinc availability is very high.

Phytochemicals

Phenolic acids and flavonoids are the most prominent phytochemical groups present in the potato. Bioactive compounds or phytochemicals are secondary plant metabolites found in the potato have been the subject of interest for researchers due to their promising role as health-modulators. Potatoes due to its high consumption is considered as the third largest source of phenolic compounds in the human diet after oranges and apples, thus potatoes can act as 'delivery mechanism' for bioactive compounds. Colored-flesh potatoes are gaining popularity due to the potential health benefits of anthocyanins. Numerous health benefits such as antioxidant activity, anti-cancer and anti-inflammatory properties, have been attributed to consumption of anthocyanin-rich foods.

Dietary fibre

Potatoes are a good source of fibre, which contributes to the feeling of fullness, and supports healthy digestive functions. A 180 g portion of boiled potato provides about 3 grams of fibre, which equates to more than 10% of the daily recommended intake of fibre. Dietary fiber has been shown to have numerous health benefits, including improving lowering the risk of heart disease, diabetes, and obesity, and increasing feelings of fullness, which may help with weight management. Some people enjoy the stronger taste of eating cooked potatoes with skins on, and in this form they contain even more fibre. A small amount of the starch in potatoes resists digestion (this is called 'resistant starch'). Amount of starch depends upon the time and temperature during processing or cooking and amount of added water. Resistant starch acts in the body in a similar way to fibre, and too aids in the control of blood glucose and blood lipid levels.

Potatoes! awesome for good health

Potatoes are a very popular food source for human health. Food ranking system qualified potatoes as a good source of vitamin B6 (involved in more than 100 reactions), vitamin C, copper, potassium, manganese, and dietary fiber. Besides that, potatoes also contain a variety of phytonutrients that have antioxidant activity. Among these important health-promoting compounds are carotenoids, flavonoids, and caffeic acid, as well as unique tuber storage proteins, such as patatin, which exhibit activity against free radicals. UK scientists at the Institute for Food Research have identified blood pressure-lowering compounds called kukoamines in potatoes. Potatoes are gluten-free and therefore can be consumed freely by people who need to avoid gluten (so cannot eat many common foods including bread, most breakfast cereals). It is a protein which is found in wheat and rye. Therefore, potatoes can be served as very important food for them.

Misconceptions

There are numerous misconceptions about the nutritional value of the potato. It is often believed that the potato is a high-energy food that provides little else in the way of nutrients. Most people eat potatoes in the form of French fries or potato chips. Preparation and serving potatoes with high-fat ingredients raises the caloric value of the dish. Such treatment can make even baked potatoes a potential contributor towards fattening. Potatoes are not contributing towards fattening because potato itself contains very low quantity of fat (0.1%) and it is absorbing oil only when deep fried.

Nutritional value of potato processed products

Demand for processed potato products is increasing and potato products are liked well worldwide. Since potatoes need to be baked, boiled, fried, or otherwise cooked before consumption, it is of interest to determine to what extent exposure to heat affects nutritive value of the potatoes. Losses during chipping and canning are considerable but appear to be minor during boiling and frying. Processing up to some extent, have deleterious effect on nutrients. Because during cooking and processing diffusion of nutrients from the tuber make them low in concentrations. But it does not mean that processed potato products become low source of nutrients. For example, vitamin C concentrations of French fried potatoes can sometimes be as high as in raw potatoes, and thiamine is well retained in fried potato products as well as in fried pork meat. The table listed below indicate the major nutrients present in potato products.

Composition of processed form of potatoes (per 100g)

Form of potato	Total carbohy-drates (g)	Dietary fibre (g)	Protein (g)	Fat (g)	Energy (kcal)
Raw	18.5	1.5	2.1	0.1	80
Chips	49.7	11.9	5.8	37.9	551
Frozen French fries	29.0	3.2	3.0	18.9	291

Flakes	14.5	0.3	1.9	3.2	93
Potato flour	79.9	1.6	8.0	0.8	351
Granules	14.4	0.2	2.0	3.6	96

Conclusion

Potato is a starchy tuberous crop and is an essential food item in the recipes of many countries around the world. While no vegetable dish is complete without the presence of potatoes and there are several countries where only potato is the principal food and is an excellent source of energy-rich diet. Potato is very easy to digest as well as contains mild roughage. The vitamin C content in potatoes is far better than most of the vegetables and fruits and is helpful for preventing the dreaded deficiency disease scurvy and frequent viral infections. Well, the fact is that potatoes are filling and non-fattening, contradictory to the popular belief. Potato is such a wholesome food that one can live by eating potato alone.

Suggested Readings

Ezekiel, R., Khurana, S.M.P. (2003) Nutritional and medicinal value of potatoes. Extension Bulletin no. 35. CPRI, Shimla, pp:14.

Ezekiel, R., Sukumaran, N.P., Shekhawat, G.S. (1999) Potato: A wholesome food. Tach. Bull 49. CPRI.

FAO (2008) The state of food insecurity in the world 2008. Economic and Social Development Department, Food and Agriculture Organization of the UN. Rome.

Pandey, S.K., Charabarti, S.K. (2008) Twenty steps towards hidden treasure; technologies that triggered potato revolution in India. Pp281.

Singh, B.P., Rana, R.K. (2013) Potato for food and nutritional security in India. Indian Farming. 63(7): 37-43.

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TECHNIQUES FOR HIGH-TECH SEED POTATO PRODUCTION

K. K. Pandey, Tanuja Buckseth and B.P. Singh

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Introuction

Potato is one of the world's most important non-cereal high yielding horticultural crops. India has taken a giant leap in terms of potato area (1.97 mha) and production (41.55 million tons) in 2013-14 (NHB) as compared to 1949-50, the year of establishment of CPRI, when the total production was 1.54 million tones from an area of 0.234 million ha. Currently, the national average productivity of potato is 21.1 tons/ha with maximum of 30.8 t/ha in Gujarat. In terms of area, India ranks third in world after China and Russian Federation and second in production after China. As of now, country is well placed to meet the emerging challenges for diversifying the potato production and stabilizing its market. At present, the country has an area of approximately 1.97 million ha under potato and requires about 4.97 million tones of quality seed at the uniform seed rate of 2.5 t/ha on 100 seed replacement rate. However, as per desirable seed replacement rate of 25% in potato, only 1.24 million tons seed potato is required. The correct information for certified/ quality seed potato production in country is not available. However, about 0.7 million tons seed potato is being estimated for production comprising public and private agencies. In potato cultivation, potato seed is most expensive input accounting for 40 to 50 percent of the production cost. Moreover, a high rate of degeneration causes the seed to deteriorate after a few multiplications.

Potato being a vegetatively propagated crop is subjected to large number of seed-borne diseases responsible for degeneration of seed stocks over the years. It is therefore imperative to use good quality seed for economic production. Till 1935, the seed potato was being imported from various European countries on yearly basis, but during Second World War, European countries put a blanket ban on the export of potato seed to India. Therefore, Imperial Agriculture Research Institute started potato breeder seed production scheme at Shimla and Kufri during 1935. It was the beginning of seed potato industry in the country. The seed potato from the hills used to be dormant for planting in the plains, therefore, either the dormancy was broken artificially or the system of late planting, somewhere in last week of December, was adopted to grow late winter or spring crop of potato. The spring crop was exposed to high population of aphids leading to very high viral infestation resulting in poor productivity in the subsequent generations. In addition to this, the area under potato was quite marginal in the hills. It was therefore not possible to feed large area in the plains. Therefore, intensive survey was made in the plains to find out vector free period/low vector suitable for potato seed production. This laid the foundation of development of "seed plot technique" in 1959 which helped production of good quality seed in the plains so as to meet the bulk seed requirement for ware potato production in the sub-tropical plains. This technique drastically improved the health standard of seeds produced in plains. During the first three decades (1958-59, 1968-69 and 1978-79) a linear increase in area, production and productivity could be achieved largely because of the seed plot technique and improved varieties. The seed technology research and innovative quality seed production programme by public and private sector has played a vital role in potato revolution in the country. All neighboring countries viz., Pakistan, Bangladesh, Nepal and Sri Lanka are importing seed from Holland, paying very high price. Seed Plot Technique not only benefited our farmers, our country also saved millions of rupees on foreign exchange which would have gone for purchase of costly seed from foreign countries.

The varieties released before 1963 ran out quickly because small quantities of seed were released to State Departments and progressive farmers, without them linking with the production of disease-free seed stock at the field level. It happened primarily because of low multiplication rate of potato seed, which is as low as 1:5 per generation. Because of high seed rate (25-30 q/ha) and low seed multiplication rate, newly released potato varieties took very long period for reaching to the farmers' field. This necessitated a technology for quick production of healthy breeder seed of the released varieties in sufficient quantity. Moreover, very strict control was needed to maintain the health status of the vegetatively propagated crop.

Therefore, a well organized scientific strategy of breeder seed production was envisaged in 1962-63 through clonal selection, tuber indexing and stage-wise field multiplication of healthy indexed tubers in subsequent four generations. Indexing of tubers against contagious and insect transmitted viruses is done by ELISA against PVX, PVS, PVM, PVA, PVY and PLRV while PALCV and PSTVd by PCR. Crop inspection, roguing of diseased plants and immune diagnosis are the regular features of the programme to improve the seed quality. The breeder seed produced by CPRI is supplied to various state Govt. organizations for further multiplication in three more cycles' viz., Foundation-1, Foundation-2 and Certified seed under strict health standards. However, the current status of breeder seed multiplication by the state government is not as per the desired seed multiplication chain. There is a huge shortage of certified seed in the country. The conventional system has the following limitations;

i) Low rate of multiplication.

ii) Requires more number of disease free propagules in the initial stage.

iii) Development of 100% healthy seed stock from infected material is slow and time taking.

iv) Progressive accumulation of degenerative viral diseases is there in each field exposure.

v) Require several field Multiplications of initial disease-free material (7 years).

The only way-out to overcome the above said limitations is augmentation of seed production through hi-tech system to improve the quality and to reduce the field exposure. Therefore, Central Potato Research Institute is gradually shifting from conventional system of seed production to hi-tech seed production system. Potato has readily responded to the totipotent nature of plant tissues in micropropagation and it has become easy to export/import disease free planting material in tissue culture form without any risk of importation of deadly diseases. The process of micropropagation has become much more important in the case of potato for the purpose of production of disease-free plants from infected one. There is a tremendous scope to increase healthy seed production vertically by adopting aeroponic technology where increase in multiplication rate from 5:1 to 50:1 can be achieved. We do not need any excess area for aeroponic based healthy seed production. Only one percent of conventional water usage is required which is basically recycled water. It is the ideal technology for cost-effective production of quality seed in the present era. The adoption of high-tech seed production technologies developed by the Institute has led to opening of more than 20 tissue culture labs throughout the country. Several private seed companies had been taking virus-free *in vitro* plantlets since last several years from ICAR-CPRI, Shimla of important released varieties for further multiplication in their seed production programme.

Advantages of hi-tech seed production system

i) Tropical states which do not have isolated and virus-free potato growing areas can also produce quality seed.

ii) Early supply of nucleus seed to commercial growers can be done by reducing the field exposure time.

iii) Improved tuber quality and reducing the load of degenerative diseases.

iv) Utilize the resources and trained manpower round the year.

v) Vertical growth and reduction in pressure on land.

Seed production through hi-tech system has been started by Central Potato Research Institute Shimla in the recent past. Under this system, there are three different sub-systems viz., i). Microplant based seed production system, ii). Microtuber based seed production system and, iii). Aeroponic based seed production system.

Under hi-tech seed production system, nucleus planting material is produced in the laboratory under controlled aseptic conditions. The virus-free plants will be used as mother plant for micropropagation. The microplants/microtubers will be planted in net-house conditions for production of mini-tubers (G-0). The minitubers produced in generation-0 will be multiplied in generation-I at a spacing of 60 x 15 cm. The produce of generation-I is further multiplied in generation-II. The produce of stage-IV and generation-II is called breeder and supplied to public and private organization for further multiplication in three clonal cycles viz. Foundation-1, Foundation-2 and Certified Seed

Development of healthy mother plants for micropropagation

Availability of pathogen free starting material is a pre-requisite for any micropropagation program. Produced using meristem culture, the pathogen free plants can be maintained indefinitely in tissue culture and a constant flow of disease-free plants for micropropagation becomes available from this stock. However, for confirmation and maintenance of clonal identity, such *in vitro* stock needs to be subjected to grow-out tests regularly, at least once in a year.

Identification of healthy mother plants is done either through use of serological techniques (ELISA, NASH, ISEM, PCR, RTPCR) or meristem tip culture alone or in combination of thermo & chemotherapy, subsequently mass multiplication of healthy mericlones through *in vitro* micropropagation and use for microtuber production, minituber production directly under protected conditions followed by field multiplication up to two field exposures for production of pre-basic and basic seed potatoes are the components of hi-tech seed potato production.

Indexing for virus freedom

After the varietal release, 10-20 healthy tubers are selected and planted under controlled conditions in the pots in poly/net house. The ideal temperature for plant growth and virus multiplication is 20-25°C. Plants are tested for virus freedom through ELISA after 6 to 7 weeks planting or 6 to 8 leaf stage. Infected plants during ELISA testing are discarded and only the healthy plants are retained. PCR testing of healthy plants is done and the infected plants are discarded. Finally healthy plants obtained during series of testing will be used as mother plant for micropropagation.

Development of healthy mother plants through meristem tip culture

Sometime we may not be getting even a single plant completely free from viruses after releasing of the variety. In such situation, meristem tip culture coupled with thermotherapy has become a powerful and successful tool for virus elimination from infected plants and has been successfully applied in potato for development of virus-free plants. The meristem culture technique for virus elimination is essentially based on the principle that many viruses are unable to infect the apical/axillary meristems of a growing plant and that a virus-free plant can be produced if a small (0.1-0.3 mm) piece of meristematic tissue is propagated. However, despite the phenomenal success of meristem culture in elimination of plant viruses, it remains still unclear as to why the apical/ axillary meristems contain little or no virus? Some of the explanations are: (i) vascular system through which virus particles are spread is not developed in the meristematic region; (ii) chromosome replication during mitosis and high auxin content in the meristem may inhibit virus multiplication through interference with viral nucleic acid metabolism; and (iii) existence of a virus- inactivating system with greater activity in the apical region than elsewhere.

Selection and testing of plants/tubers

- Select apparently healthy plants from the field or sample tubers.
- Test these plants/tubers for freedom from viruses using enzyme-linked immunosorbent assay (ELISA) or any other method.
- If no plant/tuber is found free from all viruses then one has to resort to meristem culture.
- Select a plant/tuber that is infected with minimum viruses for use in meristem culture.

Establishment of *in vitro* cultures

a) **From infected plant:** Excise nodal stem segments from the third and fourth nodes from the stem apex. Each nodal cutting should be 1-2 cm long, and the leaves should be detached. Such single node cuttings (SNCs) are used to initiate *in vitro* cultures.

b) **From infected tuber:** Treat the freshly harvested tubers with a fungicide for 15 min and dry them. If not required for immediate use, the tubers can be stored at 4 °C till dormancy breaking. For immediate use, give dormancy breaking treatment and allow the tubers to sprout in dark at 24 °C. Harvest sprouts measuring about 2-3 cm long.

c) In the laminar flow clean air work station, surface sterilize the SNCs/ sprouts for 8-10 min in 20% of commercial sodium hypochlorite solution (4% w/v available chlorine), rinse in sterile distilled water three times, trim both ends of the explants by a scalpel and place the explants inside culture tubes (25 x 150 mm) each containing 13 ml of semisolid propagation medium. The propagation medium is based on MS (Murashige and Skoog, 1962) basal nutrients supplemented with D-calcium pantothenate (2 mg/ l), gibberellic acid (0.1 mg/l), a-naphthaleneacetic acid (0.01 mg/l) and 30 g/l sucrose. The medium is solidified with 7.0 g/l agar.

d) Incubate the cultures under a 16 h photoperiod using cool white fluorescent lights (50-60 µE/m2/s light intensity) at 24 °C.

e) Using stereomicroscope, excise the apical/axillary meristem (0.2 to 0.3 mm) from *in vitro* plants aseptically with the help of sterile scalpel, needle and blade.

f) Grow the excised meristem in the test tubes containing MS medium without growth regulators and incubate the culture tubes at 25°C and 16 h photo period (120-200 µmol/m^2/s^{-1}) in the culture room until attaining 4-5 cm height.

In vitro multiplication of mericlones

a) Multiply disease-free stock plants obtained through meristem culture using nodal cuttings. Cuttings with 1-2 nodes each are cultured in tubes (25 x 150 mm) on semisolid propagation medium. To economize on inputs, use of high quality commercial sugar in place of sucrose and 3 nodal cuttings in each tube are recommended.

b) Incubate the cultures at 24 °C under a 16 h photoperiod using cool white fluorescent lights (50-60 µE/m2/s light intensity).

c) Sub-culture plants after every 20-25 days depending on growth response.

d) Large number of *in vitro* plants produced by this method are used for microtuber/ minituber production.

Microplant based seed production system

Minituber is an intermediate stage of potato seed production between laboratory micropropagation and field multiplication. The simplest method of producing minitubers from in vitro plants particularly suited to North Indian plains has been described by Naik (2005). In this method, 15-20 day old cultures are kept in glasshouse or polyhouse for 8-10 days for hardening without removing culture tube plugs or lids of magenta boxes. The hardened *in vitro* plants are removed from culture vessels with the help of forceps, washed to remove adhering medium and cut into two pieces after cutting out the root zone. The lower portion (about 0.5 cm) of the cuttings is dipped in rooting hormone powder (soft wood grade) and planted in pre-prepared nursery beds (soil: FYM: sand 1:1:1 v/v) at plant to plant and row to row distance of 10 cm in a vector-free net house. It is beneficial to drench nursery beds with fungicide solution before planting. Three to four water sprays are given daily with a sprayer to keep the soil moist and maintain humidity for initial one week. If available, mist irrigation is also suitable. Once the plants establish and start giving normal irrigation with a watering can or any other means can be followed. With progressive growth of the plants, additional soil substrate is added on the nursery beds to bury lower leaves. This is important to optimize minituber production from buried axillary buds. The crop is allowed to mature on the nursery bed and minitubers are harvested. The minitubers are cold stored and used as planting material in the next crop season. In general, 80-90% cuttings establish and produce about 8-12 minitubers per plant of average. The seed tubers thus produced are minitubers. Curing is done by keeping the seed tubers in heap for about 15 to 20 days in a cool shady place. After curing, the seed tuber should be graded into >2 g and treat with 3 per cent boric acid solution for 10-15 minutes to prevent surface borne pathogen inoculum. Minitubers harvested from microplants (Generation-0) are called as nucleus seed. Store the minitubers in country store in hills while cold store at 3-4°C in the plains. Minitubers weighing >2 g will be planted in Generation-I in the field during next season.

Microtuber based seed production system

Microtubers are miniature tubers developed *in vitro* under tuber inducing conditions. They are very small (average weight 100-150 mg) and convenient for handling, storage and long distance transportation. Microtuber production technology involves: (i) mass multiplication of *in vitro* plantlets in liquid medium, (ii) production of microtubers, and (iii) harvesting and storage. The microplants are tested for virus freedom before initiating microtuber production. The virus-free stock plants are mass multiplied through nodal cuttings on semisolid MS medium in culture tubes (25 x 150 mm) following the standard procedure upto 10 cycles. 3-4 weeks old explants are transferred into 250 ml conical flasks or culture bottles containing 25-35 ml liquid MS medium without agar. The culture tubes are incubated at 25°C and 16 h photoperiod (120-200 µmol/m^2/s^{-1}) in the culture room. After 3-4 weeks of incubation, the unutilized liquid propagation medium is decant from the conical flask/culture bottle under aseptic conditions and 30 ml of microtuber induction medium is poured into it. The microtuber induction medium is based on MS basal media supplemented with 10 mgl^{-1} N6-benzyladenine (BAP) and 80 gl^{-1} sucrose/ commercial sugar. After adding induction medium, the cultures are incubated under complete dark condition at 15°C for 60 to 90 days depending on the genotype. Microtubers develop epigeally at the apical as well as auxiliary buds of the shoots. In general, 15 to 20 microtubers weighing 50-300 mg are produced in each flask/culture bottles. Before harvesting, greening of the microtubers is done in the culture room by incubating microtuber induced cultures under 16 h photoperiod (approximately 30 µmol m^{-2} s^{-1} light intensity) at 22-24°C for 10 to 15 days. Then carefully remove the cultures along with microtubers from conical flasks or culture bottles and manually harvest the green microtubers. Avoid damaging the microtubers, especially the thin periderm during harvest. The harvested microtubers are then washed and treated with 0.25% mancozeb for 10 minutes, and allowed to dry in the dark at 20°C for 2 days. Grading of microtubers in <4mm, 4-6mm and >6 mm should be done while packing. Pack the treated microtubers in perforated polythene covers and store in a refrigerator for 4-5 months until planting. Take out the microtubers from the refrigerator after about one month before planting for breaking the dormancy and proper sprouting. Microtuber production technology is evolving rapidly. Fermentors (containers in which plant material is in contact with nutrient solution continuously or at intervals) and bioreactors (vessels containing plants on screens or porous substrate subjected to nutrient mist and aeration cycles of varying durations) have been described for commercial scale rapid and synchronous microtuberization. Aseptic production and possibility of reducing costs through automation are important factors that are likely to promote use of microtubers in potato seed production world over. Further, any breakthrough technology that increases microtuber size will eliminate intermediary step of minituber production.

Aeroponic seed production system

The conventional system is quite effective but it has low multiplication rate and higher field exposure increases the risk of viral infection. Keeping this in view, tissue culture based system of quality seed production was integrated with breeder seed production programme. The traditional way of producing potato minitubers through micro propagation is to multiply *in vitro* material in insect proof net houses. The conventional method uses substrate made of soil and mixture of various components. This method usually produces 10-12 minitubers per plant depending on cultivar. The aeroponic system developed by CPRI offers the potential to increase production in terms of number of minitubers per plant from three to four times. Aeroponics is the process of growing plants in an air mist environment without the use of soil or an aggregate medium. Water is used to transmit nutrients to the plants. In aeroponics, plants growth is facilitated by suspending them in air, in an enclosed environment, and providing necessary nutrients by spraying on roots. The nutrient solution is continuously re-circulated through the system and monitored for pH and EC and amended whenever necessary. The top portion of the plant is exposed to the open air and a light source. There is a tremendous scope to increase healthy seed production vertically by adopting aeroponic technology of seed system where increase in multiplication rate upto 1:50 can be achieved. We do not need any excess/extra area for aeroponic based healthy seed production. Only one percent of conventional water usage is required which is basically recycled water. The aeroponic seed production system has very high productivity. It prevents exposure to unfavorable soil conditions and the minitubers harvested from this system will be free from all soil-borne pathogens. Desired size of minitubers can be harvested sequentially and this could reduce the cost of minituber production.

Aeroponic technology at CPRI

Aeroponic system mainly consists of an electrical unit, growth chambers, nutrient chamber, high pressure pump, filters and nozzles. Growth chambers are covered with black lining inside to avoid any admittance of light to the root zone of plants. Aeroponic unit can be placed under insect-proof net house under natural conditions or under controlled environment conditions. For aeroponics, *in vitro* grown 15-21 days old microplants are required to be hardened before shifting to this system. For hardening, microplants are transplanted in portrays containing peat moss, vermiculite or sand and hardened for 15 days at about 27°C in hardening chamber. These hardened plantlets of about 15 cm height are planted in the holes made in the roof of the grow boxes of the aeroponic unit. All essential nutrient elements required for the plant growth are dissolved in water in nutrient tank. With the help of an automatically operated pump, the nutrient solution is regularly sprayed inside the chamber for desired duration of on/off time. Misting interval and duration was increased or decreased depending on the weather, relative humidity, and plant growth stage. By misting the solution round the clock 100% relative humidity is maintained inside the root zone. Rooting started in a week and developed inside the growth chamber. Stolon and tuber formation initiated at different intervals depending upon cultivar. Sequential picking was done at regular interval. Tubers are harvested when they attain the desired size of 2-4g. Roots, stolons and tubers develop inside the chamber and leaves are exposed to light. Nutrient solution is replenished from time to time and desired pH of 5.6-6.0 of the solution is maintained. The minitubers are sequentially cured at decreasing humidity and increasing temperature for about one week and stored at 2-4°C and used for planting in the next generation.

Aeroponic minituber based seed potato production is increasing in India due to more number of minituber per unit area and time as well desired temperature manipulation through controlled conditions round the year. Aeroponic technology for potato seed production was standardized and commercialized by Central Potato Research Institute, Shimla for plains during 2009-10. Later on, it became functional in the month of October, 2012 for first time at Shimla under hill conditions. Long day, short day and day neutral varieties of potato are being grown through this technique. There are several other added advantages of aeroponic system like avoid soil and tuber-borne diseases, easy inspection and desired size harvesting at periodical interval, limited space requirement with vertical growth. The planting at 15 x 15 cm of hardened plants in portrays has been used in plains and the best 3 days harvesting interval is reported. Aeroponic technology can be used for the disease-free quality seed production of potato, tomato, pepper, cucumber, gourds, leafy vegetables, strawberry, flowering plants and many other horticultural crops. Information has been generated on time of planting, varietal response, yield performance, survival, weight loss, sprouting; bulk packing material, training system and post storage behavior of aeroponic minituber of different varieties. However, refinement in various production technologies is going on particularly for date of planting, method of planting and nutrient solution to take round the year production of aeroponic minituber for long day as well short as day condition using most of the important varieties under seed production. This technology has been transferred by ICAR-CPRI, Shimla to various private firms under MoU for commercialization.

Aeroponics seems to have lot of scope for augmenting existing seed production system. Since aeroponics is a relatively new technique for seed potato production. For optimization of seed potato production through aeroponics, several factors need to be addressed. Each potato cultivar may have different optimum nutrient requirement, which needs to be determined. In vitro plants of appropriate age and size are preferred but there is need to determine and compare other planting material such as cuttings and sprouts. Besides this, conventional method of pest and disease control may not be applicable to aeroponics thus new methods need to be developed. The post harvest storage behavior, physiology and field performance of aeroponically produced minitubers has to be thoroughly investigated in different climatic conditions.

Suggested Readings

CIP 2010. International Potato Centre. Quality Seed Potato Production Using Aeroponics. Lima. Peru.

Naik, P.S. 2005. Achieving self sufficiency in quality seed production in roots and tuber crops with special reference to potato. In: K.L. Chadha, B.S. Ahloowalia, K.V. Prasad and S.K. Singh (Eds.) Crop Improvement and Production Technology of Horticultural Crops, Vol. I. The Horticultural Society of India, New Delhi. pp. 243-255.

Naik, P.S. and Karihaloo, J.L. 2007. Micropropagation for Production of Quality Potato Seed in Asia-Pacific. Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi, India. p. 47+viii.

Naik, P.S. and S.M. Paul Khurana. 2003. Micropropagation in potato seed production: need to revise seed certification standards. J. Indian Potato Assoc. 30: 123-132.

Singh Vinay, K.K. Pandey, Shukhwinder Singh, Dhruv Kumar and B.P. Singh. 2012. Aeroponics: An Innovative Method of Potato Seed Production. In: National consultation on potato research and development: Way forward. OAU&T, Bhubaneswar 26th September. 2012, pp 45-49.

Singh Vinay, Sukhvinder Singh, Dhruv Kumar and B.P. Singh. 2011. Soil less production of potato minitubers. In: Production of disease-free quality planting material propagated through tuber and rhizomes. CPRIC, Modipuram pp: 151-155.

Singh, B.P., K.K. Pandey, R, Muthuraj, Shukhwinder Singh, E.P.Venketsalam, Vinay Singh, A.K. Sharma, Sumita Sharma and K.P. Singh 2013. Aeroponic seed production system at Shimla. CPRI Newsletter, 53 July-September pp 2-3.

Sukhwinder Singh, Vinay Singh, Singh, B.P. and S.K. Pandey. 2010. Aeroponic for potato seed production. ICAR News- A Science and Technology Newsletter, New Delhi 16 (2):1-2.

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PRACTICES FOR QUALITY SEED POTATO PRODUCTION

Ashwani Sharma

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Introduction

Potato is mainly a vegetatively propagated crop. Due to this, the perpetuation of viral, mycoplasmal and other soil borne pathogens brings down the quality of seed stocks resulting in poor yields during subsequent multiplication of such seeds. Improving potato productivity had been a continuous process since 17th century, but it remained in introductory phase till 1931. During this period, potato established itself as an important cool season crop in hills. Therefore, initially hills were the major source of healthy seeds of potato on account of natural befitting conditions available for seed production. The seed stocks in hills were harvested in September and due to dormancy could not be planted in plains immediately. Therefore, they were planted late in season (spring crop) and the produce was preserved in cold stores or farm houses for next crop season (early or main crop). Spring produce of plains were highly degenerated due to heavy pressure of aphids and other vectors during the crop season.

Keeping in view the problems of hills grown seed and the limited area available for healthy seed production in hills, efforts were made to produce healthy seed in plains. Surveys were conducted in important potato growing areas of the country by CPRI from 1952 onwards. During the survey a remarkable consistency in the aphid build up was found. In north-western and central Indo-Gangetic plains, the aphid population remained very low during October to December months. Taking full advantage of very low aphid population coupled with the use of improved cultural practices; it was made possible to produce healthy seed in plains also (Seed Plot Technique).

During the last five decades, seed production has shown spectacular progress in technology development and production strategies. The improvement in seed quality and quantity is commendable. At present, 94% of the total quantity of seed is produced in sub-tropical plains and remaining 6% in hilly areas. India is the only leading country in Asia which has developed scientific seed production technology for sub-tropics by taking advantage of low aphid period and absence of soil borne diseases and insect-pest.

Basic requirement for seed production

Basic requirements like suitable areas, soils, fertilizers, manures and suitable varieties etc. play a vital role in a successful seed production programme. A quality seed can be produced in areas and fields which are free from serious soil borne pathogens and pests. High hills above 7000' msl are suitable for nucleus and breeders seed potato production. Indo-Gangetic plains of Punjab, Haryana, North-Western parts of Uttar Pradesh, Madhya Pradesh and Bihar are suitable for seed production under low aphid period from October to March and are the primary source of high quality seed. Parts of North-western Uttar Pradesh, Madhya Pradesh, Bihar and entire West Bengal, Odisha, Rajasthan and Gujarat are only secondary source of seed production due to brown rot and aphids. There are two seasons for seed production *i.e.* summer and autumn. In summer, seed is produced under long days and rain fed conditions in high hills from March to October, whereas, in autumn, the seed is produced in sub-tropical plains under short days and irrigated conditions from October to March. The optimum temperature for foliar growth is 18-22^{o}C and 10-16^{o}C is good for tuberization.

Selection of field: For raising a potato seed crop, soil should be free from perennial weeds and soil-borne pathogens such as scabs, brown rot, wart and black scurf and pests like cut worm (*Agrotis ipsilon*). For minimizing the perpetuation of soil-borne diseases, it is desirable to adopt 2-3 years crop rotations preferably with cereals. As far as possible, the seed crop should be grown in a field where potato has not been grown for last two years. A well-drained, light textured sandy loam soil with neutral to slightly alkaline soil pH is preferred.

Hot weather cultivation: In the Indo- Gangetic plains, opening the soil by deep tillage and keeping it exposed to extreme high temperatures during hot summers reduces the incidence of soil-borne diseases and controls weeds and cutworms. Deep ploughing the field in April end and keeping it open in May and June with one or two more ploughings serve the purpose of hot weather cultivation.

Green manuring: Raising and ploughing under the 45-55 days old green manuring crops of sunhemp (*Crotalaria juncea*) or dhaincha (*Sesbania aculeate*) during rainy season at least one month before potato planting in the plains and growing of French bean or other leguminous crops or oats in the hills as green manure is beneficial in reducing pest and disease incidence. Green manuring improves the soil fertility and water holding capacity to benefit growth and yield of potato.

Tillage: Potato seed production demands minimal mechanical interference in the standing crop to check spread of viruses through physical contact. Therefore, field should be cleaned of stubble and perennial weeds by adequate tillage operation before planting. If the field is relatively free from weeds, minimum tillage can be practiced to save on the fuel, time and money to reduce cost of cultivation. Minimum tillage combined with chemical weed control is best suited for seed production as it ensures minimum interference in standing crop. 2-3 ploughings followed by plankings make the soil loose and friable suited for potato planting.

Isolation of seed plots: The seed crop should be separated from crops meant for ware purpose by a distance of at least 25 meters to avoid mixture and spread of viral diseases. Isolation is also required between different varieties of the seed crop.

Varieties: Zone-specific varieties and crop period for seed production are as under:

Zones	Crop Period	Varieties
North-Western hills	Summer(15th April–October)	Kufri Jyoti, Kufri Chandramukhi, Kufri Giriraj, Kufri Shailja, K. Himalini, K. Girdhari
North-Western plains	Autumn (1st week October – March)	Kufri Jyoti, K. Chandra-mukhi, K. Badshah, K. Pukhraj, K. Khyati, K. Pushkar, K. Surya
North Central plains (MP)	Autumn (3rd week October – March)	Kufri Jyoti, K. Chandra-mukhi, K. Sindhuri, K. Lauvkar, K. Chipsona I & III, K. Arun
North Central plains (UP)	Autumn (2nd week October – March)	K. Bahar, K. Sadabahar, K. Badshah, K. Anand, K. Surya,K. Chipsona I, III &IV, K. Frysona, K. Gaurav, K. Khyati,
North-Eastern plains	Autumn (4th week October – March)	K. Jyoti, K. Chandra-mukhi, K. Kanchan, K. Sindhuri, K. Lalima, K. Ashoka, K. Pukhraj, K. Surya, K. Arun, K. Chipsona I & III

Seed Plot Technique (SPT)

The technique of growing seed potato crop in Indo-Gangetic plains during low aphid period with healthy seed from October to first week of January coupled with the use of insecticides, roguing and dehaulming in the last week of December or up to second week of January, was developed by the CPRI, Shimla in 1959 and is called as “Seed Plot Technique”. Quality seed production was possible under this technique in sub tropical plains by advancing the date of planting from December end to first week of October.

Characteristic features of Seed Plot Technique

- There should be a low aphid or aphid free period of 75 days after the planting of crop.

- Adopt 2-3 years crop rotation to take care of soil borne pathogens.
- Seed crop should be grown in isolation of 25 meters from ware crop.
- Seed should be procured from reliable sources and must be free from viruses and soil born pathogens. Cold stored seed of right physiological age should be used.
- Crop should be planted by 10th October in Punjab, 25th October in Haryana, Rajasthan, Western Uttar Pradesh and 5th November in Eastern Uttar Pradesh, Bihar, West Bengal and Odisha.
- Systemic insecticide such as Thimet 10G to be applied in split doses of 10 kg/ha at the time of planting and earthing up against sucking insects.
- Pre-sprouted seed with multiple sprouts may be used, which ensures quick, uniform and early germination.
- Inspect the seed crop thrice at 45, 60 & 75 days during growing season to remove off type and diseased plants.
- Spray the crop with mancozeb @ 2.5 kg/ha at 10 days intervals from 3rd week of November and spray Curzate M-8 @ 3.0 kg/ha as and when late blight is observed.
- Spray the crop with Rogor (1.25 L/ha) or Imidacloprid 17.8%SL (0.4L/ha) alternatively at 15 days interval from 1st week of December to control the insect vectors.
- Irrigation should be with held in 3rd week of December i.e. 7-10 days before haulms killing in north-western plains and 1st week of January in north-eastern plains.
- Haulms killing to be done in the end of December in Punjab, Haryana, Western Uttar Pradesh; by 10th January in Central Uttar Pradesh, Madhya Pradesh and by 15th January in eastern Uttar Pradesh, Bihar, West Bengal and Odisha.
- Harvest the crop 15-20 days after haulms killing when the fields are in workable condition and tuber skin is hardened. Cure the crop in heaps in a cool shady place for about 15-20 days.
- Treat the produce with commercial grade Boric Acid 3% solution for 25 minutes to prevent surface borne pathogens. Dry in shade and fill in bags, sealed and labeled properly and cold store.

Seed source: For on farm multiplication of quality seed by the farmers, it is essential to obtain healthy, disease free, true-to-type and treated seed from reliable source, preferably from a government agency. The foundation or certified seed tubers should be used to start with and stocks should be replaced every 3-4 years.

Pre-sprouting: The pre-sprouting treatment of the seed tubers before planting ensures multiple, stout and healthy sprouts, which helps in quick emergence, weed suppression, uniform stand and early maturity of the crop. It also improves yield, number of tubers and proportion of seed-sized tubers in the produce. For pre-sprouting, withdraw the seed tubers from cold store 10 days before planting. Keep it in pre-cooling chamber of cold store for 24 hours.

Whereas, in the hills, take out the tubers from country stores during first fortnight of March. Spread the seed tuber in thin layer preferably on cemented or pucca floor in a ventilated room under diffused light. If tubers are already over-sprouted due to malfunctioning of cold store or any other reason remove such sprouts. It helps in checking apical dominance. Sort out the blind, hairy sprouted, rotten and diseased tubers. Transfer the well-sprouted tubers in the trays to the field for planting. While transferring the sprouted tubers to the trays and at planting, care should be taken to avoid damage to the sprouts.

Planting method: Use of cut tubers is prohibited and only whole tubers are used for seed crop. In the plains inter-row spacing for planting seed crop manually, bullock and tractor drawn implements may be kept at 40-45, 50-55 and 60cm, respectively. Planting of seed-sized tubers of 30-40g at 60cm inter and 20cm intra-row spacing is best for seed potato production. Plant the large size tubers by increasing the intra-row spacing from 20 to 30 cm depending upon the size of seed tubers. Small-sized tubers are planted at reduced intra-row spacing. The approximate intra-row spacing for <25, 25-60, 60-100 and >100g seed size is 15, 20, 25 and 30 cm with inter-row spacing of 60cm, respectively. Seed tubers are placed at a depth of 5-7 cm from top of the ridges made manually or by tractor drawn implements.

Manure and fertilizers: Application of well rotten farmyard manure (FYM) @ 20-25 t/ha in absence of green manuring is beneficial for seed crop. It improves soil physical condition, soil fertility and water holding capacity of the soil. The FYM should be incorporated into the soil 20-25 days before planting. Nitrogen needs of seed crop are 25-30% lower than the ware crop. Excess N increases the yield of undesirable extra large size tubers and produces dark green foliage masking the symptoms of viral and mycoplasmal diseases and detection of infected plants becomes difficult during roguing. In the plains, the crop requires a basal dose of 75kg N, 60-80kg P_2O_5 and 100-120 kg K_2O/ha at planting, whereas, 100 Kg each of N, P_2O_5 and K_2O is the recommended basal dose for the hills. Top dressing of 75 kg N/ha at earthing up in plains and 20 kg N/ha in the hills given through urea is adequate. The basal dose of N can also be applied through urea by incorporating it into the soil at least 48 hours before planting during the field preparation. It comes over the constraints in using costly nitrogenous fertilizers of ammonium sulphate (AS) and calcium ammonium nitrate (CAN).

Intercultural operations and weed control: The objectives of intercultural operations in potato are weed control, earthing up for firming up the ridges to prevent exposure of growing tubers and application of split dose of Nitrogen and Thimet insecticide. However, operations involving human, animal and implement movement in standing seed crop should be minimal to prevent transmission of plant viruses through physical contact. It would be better if these operations are completed by 20-25 days after planting when plants attain the height of about 10-15 cm and foliage cover is still small. The split dose of Nitrogen and Thimet should be applied at hoeing and earthing up about 5cm away from the plants. The hoeing must not be delayed beyond 30 days in plains and 45 days in the hills after planting to avoid damage to the plant roots, foliage and stolons, which may adversely affect the number of tubers resulting in reduction in yield. Pre-emergence weedicides like Metribuzin @ 0.75 kg/ha, Oxyfluorfen @ 0.15 kg/ha, Linuron @ 0.5 kg/ha, Alachlor @ 1.5kg/ha and Isoproturon @ 0.75 kg/ha applied 2-3 days after planting are effective. Pre-emergence herbicides are most effective when applied in moist soil. Therefore, if soil is dry apply herbicides after first irrigation as soon as it is possible to enter the field. In case pre-emergence herbicides are not used, spray paraquat @ 0.5 kg/ha at about 5-10% plant emergence of potato provided sufficient weeds have appeared, as it kills only emerged weeds. Chemical weed control eliminates manual hoeing. Thus, full earthing up at planting combined with chemical weed control effectively minimizes undesirable physical intervention in standing seed crop.

Water management: Pre-sowing irrigation/ rains before land preparation is beneficial for early and uniform emergence. If pre-sowing irrigation is omitted at the time of field preparation, irrigate the crop immediately after planting. First irrigation following planting should be light to minimize damage to the newly formed ridges. Heavy irrigation before emergence leads to anaerobic conditions resulting in rottage of seed tubers, gappy emergence and reduced tuber yield. Second irrigation is given a week after first irrigation. Subsequently, irrigate the crop at 7-10 days interval depending upon the requirement. Avoid flooding over the ridges while irrigating and irrigate as far as possible in morning and evening hours. In a normal seed crop, 6-8 irrigations are required. Light and frequent irrigations are much better than heavy irrigations given less frequently. Excess moisture makes lenticels prominent due to rupturing and seed tuber quality is impaired. It also promotes certain diseases. Stop irrigation at about 10 days before dehaulming in light soil and 15 days in heavy soils. Moisture stress restricts re-growths after dehaulming and hastens curing of peel of seed tubers.

Plant protection: Additional plant protection measures against aphid and other vectors transmitting viral diseases are required in the seed crop. Application of granular systemic insecticide, Thimet 10G @ 10kg/ha at the time of earthing up takes care of jassids, leafhoppers and white flies at early stages of growth up to 30-35 days. After appearance of aphids, two sprays of imidacloprid 17.8% S.L. @ 0.004% may be repeated at an interval of 12-15 days depending on duration of the crop and level of infestation. Drenching of the ridges with chlorpyriphos 20EC @ 2.5liters/ha effectively controls cutworms attack during the early stages of the crop. In white grub prone areas, Chlorpyriphos 20EC @ 2.5 liters/ha should be applied either after mixing with sand or can be sprayed on the ridges before the final earthing up.

For control of early and late blight, one prophylactic spray of Mancozeb @ 0.25% is given. It may be repeated at an interval of 7-14 days depending upon the weather condition. It will also take care of other foliar diseases like phoma blight etc. In case of persistent and severe attack of late blight, spray of systemic fungicides like curzate M-8 @ 0.3% or Ridomil @ 0.25% may be given and repeat the spray after 7-10 days if required.

Inspection and roguing: Inspection of the seed crop thrice at 45, 60 & 75 days (plains) and 50, 75 and 90 days (hills) during growing season to remove or rogue out the off type and diseased plants showing mosaic, mottling, veinal necrosis, crinkling and rolling of leaves, marginal flavescence and pruple top roll symptoms is essential. At each roguing, make it sure to remove the tuber and tuberlets of rogued plants.

Dehaulming: Removal of haulms of the seed crop is essential by 5-15 January in the plains before aphids (*M. persicae* and others) population reaches the critical level of 20 aphids/100 compound leaves. Cut the haulms by 15th August in the hills. Dehaulming is done by manually cutting with the sickle close to the ground or by spraying non-selective herbicide Paraquat @ 0.5kg/ha. In the plains, if haulms are removed manually, it is preferred to keep the vines/haulms on the ridges to protect exposed tubers from high temperature and direct sunlight. Re-growths of leaves if any are also cut after a week of dehaulming, because the tender and succulent leaves are more attractive to aphid vector.

Harvesting and curing: Start digging 10-15 days after dehaulming when peel is firm to withstand handling operations and the fields are in workable condition. In the Indo-Gangetic plains, potato digging beyond February promotes rottage due to soft rot and charcoal rot. Digging may be done either manually by spades or by mechanical potato digger. Exercise care to avoid bruising of tubers during harvesting, handling and transportation. After harvesting, keep potato tubers in heaps on raised beds for about 15 days for hardening of peel and shedding of adhered soil from tubers surface. Heaps of about 1.5m high and 3.5m broad at the base and variable length as needed are convenient, effective and economical. Cover the heaps with paddy straw or tarpaulins.

Grading and seed treatment: Proper size grading of tubers in the produce of seed crop is beneficial. It also helps in controlling the seed rate effectively by adjustment of spacing according to tuber size. Before grading, surface dry the produce and sort out all cut, cracked and rotten tubers. Seed tubers are usually graded into four grades, *viz.* small (<25g), medium (25-50g), large (50-100g) and extra large (>100g). Seed tubers should be dip-treated with boric acid (3%) solution against tuber borne diseases like common scab and black scurf for 25 minutes. The fresh boric acid solution can be used for 20 times for treatment, provided tubers were washed clean with water. Dip treatment with organo-mercurial compound, Emissan 6 @ 0.25% for 20 min is also effective, but is considered hazardous and may be avoided. The treated tubers should be thoroughly dried in shade before bagging and storage.

Packing and storage: Keep the seed tubers in 50 kg bags and store in cold store (4°C) in the plains latest by the end of February. The produce in the hills can be stored in country stores by the mid November. The treated seed bags should be properly sealed and labeled "Poisonous" to avoid human consumption mistakenly.

Suggested Readings

Garg ID, SP Singh, VS Kushwah, D Kumar and Ashwani Kumar. 2008. Seed Plot Technique, *In: Twenty Steps Towards Hidden Treasure*. (S. K. Pandey and S. K. Chakrabarti, *Eds.*). pp. 33-49, Malhotra Publishing House, New Delhi, India.

Kushwah VS and JS Grewal. 1992. Agro Techniques for Seed Potato Production. Technical Bulletin No. 37, Central Potato Research Institute, Shimla, India. 32p.

Kushwah VS and PM Govindakrishnan. 2003. Cultural practices for seed and ware potato. *In: The Potato, Production and Utilization in Sub-tropics*. (S.M. Paul Khurana, J.S. Minhas and S. K. Pandey, *Eds.*), Pp. 104-10, Mehta Publishers, New Delhi, India.

Sharma AK, RS Chandel, V. Kumar and BP Singh. 2012. Potato Cultivation in North Western Himalaya. Technical Bulletin No. 95, Central Potato Research Institute, Shimla, India. 72p.

Singh S, VK Garg, S Kumar and GS Shekhawat. 2000. Seed Production Manual. Central Potato Research Institute, Shimla, India. 91p.

Venkatasalam, EP, KK Pandey, V Singh, and BP Singh. Seed Potato Production Technology. Technical Bulletin, Central Potato Research Institute, Shimla, India. 70p.

Wurr, DCE. 1978. 'Seed' tuber production and management. *In: The Potato Crop – The Scientific Basis for Improvement.* (P.M. Harris. Ed.). Pp. 327-354. Chapman and Hall Ltd. London.

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TRUE POTATO SEED TECHNOLOGY: PROSPECT AND PROBLEMS

Vinod Kumar, Vijay Bharadwaj and Rajendra Singh

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Introduction

Sexual or botanical seed of potato commonly called "True Potato Seed" (TPS) is a radical alternative to seed tubers for raising a commercial potato crop. Low multiplication rate, high storage and transportation costs, carry-over of pathogens, and physiological degeneration are some of the constraints associated with the use of seed tubers. Inevitably, performance declines as viruses accumulate due to which an elaborate and complex system of disease-free seed production is necessary. Costs of healthy seed tubers may account for 50 percent of the total production costs. Compared to seed tubers, TPS offers several advantages, such as low cost of planting material, reduced transmission of pathogens/pests, and convenience as well as inexpensiveness of storage and transport etc. With rare but important exceptions (e.g. potato spindle tuber viroid), TPS is indeed free of virtually all diseases including systemically transmitted viruses. By using TPS, a considerable amount of valuable potato stocks that is used as seed can be saved for consumption as food.

The possibility of raising commercial crop from TPS was first explored in India in late 1940s. The attempts, however, were not successful because efforts were mainly made to use self-seeds of cultivar Phulwa that flowers naturally under short days when potato crop is grown in plains. The produce of this population was highly heterogeneous for most of the economic characters and also had low yields due to inbreeding depression (Ramanujam,1954). Renewed interest and formal research efforts to exploit the TPS as low cost alternative for potato production in developing countries were initiated by International Potato Center (CIP) in 1977 (Mendoza, 1984). At present, there are few potato producing countries in the developing world where TPS has not been tried.

Production of hybrid TPS

The advantage of TPS technology has extended the use of botanical seed from mere breeding to raising of commercial crop. For this, production of TPS in large quantities becomes imperative. Generally, potato flowers under long photoperiod conditions. Such conditions are available in hills of our country where the crop is grown during summer. The TPS production in hills is however hampered owing to the regular occurrence of late blight and premature foliage killing of susceptible parents. Therefore, efforts were done to induce flowering under short day conditions. The main steps involved in hybrid TPS production:

i) **Planting of hybridization block:** Cut seed pieces (25-30g) or whole tubers of desirable parents are planted at 50 x 25 cm. Male and female lines should be planted in separate blocks under artificially extended photoperiod with the help of high density Sodium Vapour Lamps of 100/250 W per 100 sq.m. The extra light is given from germination till berry setting for 5 to 6 hours immediately after sunset. Male lines should be planted one week earlier and two to three batches to ensure continuous supply of pollen.

ii) **Hybridization:** Trim the female flower bunches to retain 6-8 large size buds per bunch. Collect right stage flowers from the male parents in the morning and remove anthers for storing overnight. Extract the pollen next morning by shaking anthers in a nylon tea sieve to separate the pollen and store in a refrigerator at 6-10°C if not required immediately. However, the use of fresh pollen every day is more effective. Pollinate each receptive stigma twice by dipping in pollen at 8 hourly intervals.

iii) **Harvesting of berries and seed extraction:** Harvest berries 6-7 weeks after pollination and allow them to ripen at room temperature till they become soft. Macerate the berries by hand or using reverse screw juice extractor into pulp. Treat the pulp with 10% HCl and stir for 20 minutes to separate the seeds from debris. Wash the seeds with water 3 to 4 times to remove the acid. Treat the seeds with 0.05% sodium hypo-chlorite for 10 minutes for surface disinfection. Dry the clean seeds in shade followed by sun drying to reduce moisture contents to 5-6%. Pack the seeds in double polythene bags and store over calcium chloride as desiccant under temperature below 20 °C in a refrigerator.

Use of TPS

TPS can be sown directly in the field or in nursery beds, and seedling grown from TPS can be left in place or transplanted. Seedling tubers (i.e. tubers harvested from TPS seedlings) can either be sold as ware potatoes or used as seed tubers. Since plants grown from TPS generally produce more and smaller tubers per stem than plants from seed tubers, seedling tuber production is especially suitable to form the basis of a seed tuber system.

***Direct seeding*:** Potato true seeds are small and seedlings rather delicate, and as such make severe demands on horticultural skills. Thus, raising the crop from direct seeding (Fig.1) prone to risks involving failure due to poor germination and mortality of seedlings. This method is thus rarely recommended for raising a commercial potato crop. However, under experimental conditions direct sowing of 200 g TPS per ha and an emergence of 75% in well-controlled field conditions was reported to produce a yield of 28-30 tons of seedling tubers with an average weight of 25-30 g (Renia, 1995).

***Seedling transplants*:** Raising seedlings in nursery beds and transplanting them to field is the possible alternative of TPS use for potato production (Fig.2). Nursery beds allow proper water and soil management, and ensure rapid germination and seedling growth. Sowing in nursery beds also permits off-season production as nursery beds can be protected against extreme temperatures and watered optimally. This shortens the growing

Fig 1. Direct seeding TPS crop

period of the crop in the field. Transplanting requires good field conditions, assured irrigation and carries considerable labor costs. Direct seeding or transplanting for ware tuber production seems to have potential only in areas where consumers accept small tubers.

Seedling tubers: Seedlings raised in the nursery beds can be allowed to grow to maturity in the nursery beds itself to produce seedling tubers (Fig.3). Seedling tuber production in nursery beds or otherwise well-controlled environments is the most feasible way of using TPS at present. Maximum yields of seedling tubers in nursery beds are obtained at plant densities of 80-100 seedlings per m^2 resulting in seedling tubers of 1 to over 40 g with an average size of 10-15 g. Only 750 kg of seed tubers of an average tuber size of 15 g suffice to plant one hectare of potatoes, compared with 2-3 tons for 40-60 g seed tubers (Wiorsema, 1985). This means that 6.0-7.5 g of TPS (0.60-0.75 mg per seed, 80% emergence) and 80 m^2 of nursery bed can produce seedling tubers for 1 ha potato crop.

The use of seedling tubers or later-generation tubers from TPS- varieties is culturally similar to the use of tubers from conventional cultivars (seed rate, initial crop development, number of tubers per stem etc.). Also the yield potential of seedling tubers and later generations of selected TPS

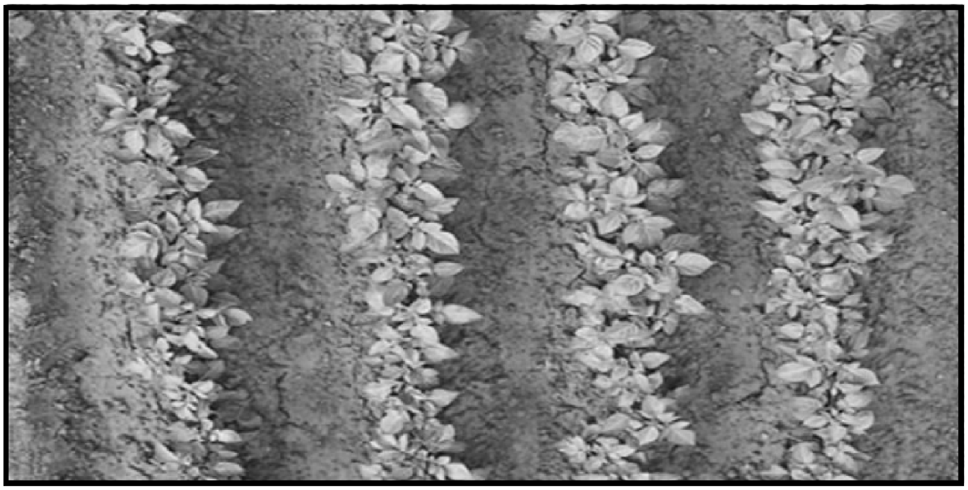

Fig 2. TPS seedlings transplant crop

varieties compares well with that of clonal cultivars. The variation in performance of the tubers derived from selected TPS varieties is not significantly larger than the tubers from a clonal cultivar.

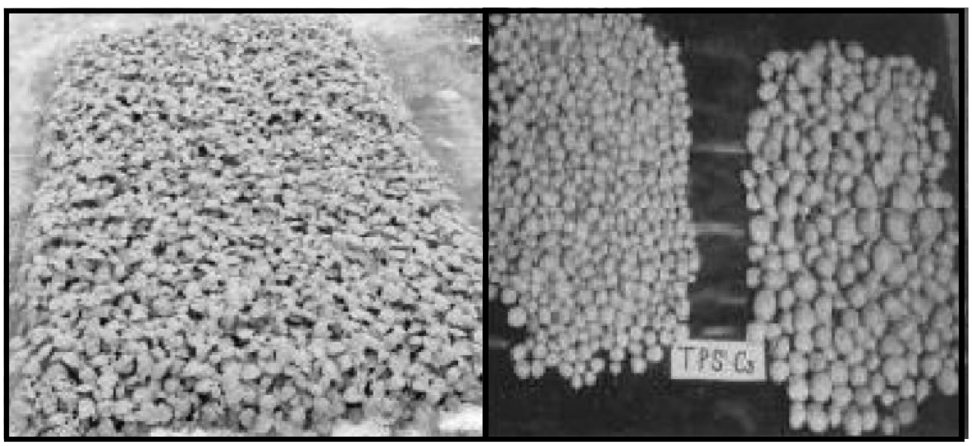

Fig 3. TPS seedlings in nursery bed and seedling tubers

TPS Quality

The quality of TPS is determined by genetic constitution of the parents, stage of seed development, nutritional status of mother plant and biochemical components of the seed. Seed vigour generally defined as the superior performance of a genotype after planting compared to the same genotype or other genotypes under defined experimental conditions is a good indicator of quality of seed. Upadhya *et al* (1981) described an additional quality component of TPS concerning the type of embryo shape of the seed. Seeds with a cercinnate and inverted "U" shaped embryos are heavier than seeds with other types of embryos (rod shaped, aborted etc.) and give a higher percentage of germination and more vigorous seedlings with higher yield. However, (Gopal, 2004) found that more than 90 percent seeds of both open and hybrid families have cercinnate and inverted "U" shaped embryos and these two classes of embryos were at par to each other for various seedling characters. By eliminating the poor vigour seedlings before transplanting the seeds with undesired embryos get eliminated and help in improving the productivity of the seedlings.

Breeding TPS Families

The most dominating difference between potato crops grown from TPS and from normal sized tubers is the slow initial development of plants grown from TPS. As a result, a TPS crop has a slow development of the ground cover. It also gives the crop a longer and more vulnerable establishment in the field. Although there is variation between progenies, typically, a stem grown from TPS produces a larger number of tubers with a lower average tuber weight than a stem from a normal sized tuber. This characteristic is further accentuated when a larger number of stems per unit area are used in a crop grown from TPS to compensate for the slower ground-cover. Identification of TPS progenies having quick seed germination and fast seedling growth speeds up the seedling establishment and development of ground-cover, thereby improving on the most important drawback in the use of TPS.

Genetics and Breeding of TPS: The cultivated potato is a complex tetraploid which exhibits tetrasomic inheritance. As a result the segregating population of potato is heterogeneous for various characters. So selection of TPS families with acceptable level of plant to plant variability particularly for tuber characters is the major objective in developing productive TPS families. While inbreeding can give the highest level of gametic uniformity and homogeneity, resulting in completely uniform progenies, it also causes significant yield reductions and poor performance stability. Deleterious effect of inbreeding is also due to the fact that most of characters including tuber yield in potato are determined by genes with non-additive effects (Gopal, 1998) and increase in homozygosity results in the loss of such interactions including epistasis.

Hybrid vs. Open-pollinated Families: In potato, hybrid families are more productive than the open-pollinated (OP) ones. For the production of hybrids, Tuberosum-Andigena crosses are particularly useful, as heterosis for yield is spectacular in such families (Gopal *et al*, 2000). However, OP families from some genotypes can be as productive as the best hybrid families because OP seed in potatoes is not exclusively the product of selfing, it also results from out crossing, thus offering us the possibility of using them in a TPS breeding program with expected favorable results.

Short Duration Families

As mentioned above, TPS crop needs longer duration and does not fit into the prevailing crop sequences particularly in tropical and sub-tropical countries where this technology is considered to have best potential Two alternatives i.e. early foliage maturity and early tuber bulking exist for developing short duration families. However, the choice would depend upon the comparative TPS production potential of the parent(s) so selected.

Gopal *et al*(2004) found that foliage maturity has positive association with duration of flowering as well as intensity of flowering indicating that late maturing genotypes flowered profusely and for longer duration. Very early clones generally did not flower at all. On the other hand, early bulking as judged from average tuber weight had no association with any of the flower production attributes. Thus unlike early maturing genotypes, early bulker may flower profusely, early as well as for longer duration. Hence out of foliage maturity and tuber bulking, later is a better criterion for selection of parental clones for developing short duration (early bulking) TPS families.

Hardy Families

Seedling mortality after transplanting is the major risk to which TPS transplant crop is exposed to after seed germination. Gopal (2004) found that transplant survival was highly correlated with seedling vigour. Hardy seedlings thus can be indirectly selected before transplanting based on their vigour. Other characters namely leaf area, root area, root length and seedling dry weight were also associated with transplant survival to varying extent but seedling vigor was a better indicator of seedling transplant survival than the root area or root length. Vigor as indicator of hardiness also has the advantage that it can be recorded visually and effectively, without any damage to the seedlings, whereas recording of leaf area, root area, root length and dry weight is cumbersome and time consuming besides being destructive.

Seedling vigor and other characters governing hardiness can be improved genetically, as enough variability was present for these in a population of wild and cultivated species (Gopal, 2004). Heritability and genetic advance values were also reasonably high. However, it was found that seedlings of wild species were less hardy than those of the cultivated ones. Wild species, in general, also had poorer performance for all characters associated with transplant survival i.e. seedling vigour, leaf area, root area, root length and dry weight. Majority (70%) of the tuber-bearing wild species are diploids These are self-incompatible and set seeds only when crossed with some other strain possessing compatible S gene combinations. Triploid and pentaploid species are mostly sterile. Self-fertile potato species too prefer to reproduce vegetatively as theoretically infinite number of exact replicas of the initially successful biotypes can be produced by this method (Hawkes, 1958). Predominance of vegetative reproduction thus might had led to poor seedling hardiness in tuber-bearing wild species. On the other hand, high vigour in cultivated potatoes might be because these had been subject to selection since domestication initially by farmers and later by potato breeders.

Advantages of TPS

i) TPS requirement for planting one hectare land cost 20 times less than the seed tubers (TPS costs approx. Rs. 3000-3500/ whereas, seed tubers costs RS. 60,000-65,000/ for one hectare land)

ii) Several viruses, bacteria, fungi and nematodes which contaminate seed tubers get filtered during the process of pollination and fertilization. TPS is thus disease free and saves investment on seed health testing

iii) TPS crop comprises of segregating population which gives multiline effect providing better safe guards against disease epidemics

iv) TPS can be stored at room temperature under dry conditions without the loss of viability for many years

v) Unlike seed tubers which are bulky, there is no transportation problem with TPS

vi) By using TPS a considerable amount of valuable potato stocks which are used as seed can be consumed as table potato. Currently the country is using 3.1 million tonnes seed tubers which by 2020 will be 6 million tonnes

vii) Tuber seed production for present area under potato requires 40,000 ha land whereas for the production of TPS for the same area only 2000 ha land is required

viii) Disease free potato tuber seed can be produced only in northern plains and north-western hills, whereas, TPS can be produced in most parts of the country

ix) In tuber seed propagation varieties are likely to undergo pathological and physiological degeneration but in hybrid TPS the hybrid vigour is ensured.

Constraints in adopting TPS technology

Raising of crop through TPS is labour intensive, needs constant attention and is more prone to damage by climatic vagaries like high temperature, heavy rains and drought etc. than the crop raised from seed tubers. TPS crop also takes about 20-25 days more for maturity than the conventional potato crop raised from seed tubers. Limited choice of hybrid TPS populations is also coming in the way of adoption of this technology. TPS being a segregating progeny, its produce is not so uniform as of the conventional potato crop and hence has lower market value.

Conclusion

If we summarise the experience gained with this technology, we can safely conclude that direct seeding (drilling) as method to raise a TPS crop has failed, transplants were better, but seedling tubers, still better. Technically, a crop raised from seedling tubers cannot be regarded as a TPS crop. In my opinion, the only practical way to raise a truly TPS crop is through seedling transplants. Further, for production of seedling tubers too, raising a successful seedling crop either in nursery beds or as transplants in field is mandatory. In its present state a successful crop of TPS seedlings can be raised at the most in restricted niches where small farmers grow potatoes with irrigation and intensive management in small plots. Those who have experience of raising vegetables' seedlings and enough family labor could better manage potato seedlings crop.

Breeding for hardiness and early bulking using conventional as well as non-conventional approaches is thus absolutely essential if this technology is to be popularized on a larger scale. On the other hand, a little variability within the produce of a TPS crop might not matter particularly for consumers in developing countries. Rather this might even be biologically advantageous for achieving good disease resistance. Identification of parents producing open-pollinated seeds under varying thermo-photoperiodic conditions and having reasonably uniform tuber progenies with high tuber yield is another aspect that needs to be further researched upon. This will help farmers to produce their own seed at a low cost and getting good returns for their efforts and time spent on production of seedling tubers and then raising normal potato crop from the seedling tubers. All this needs sustained efforts to overcome various intrinsic problems associated with TPS technology. The past long experience with this technology, however, makes one pessimistic about its future.

Suggested Readings

Gaur, PC and SK Pandey. 1993. True Potato Seed (TPS) Technology (ed. KL Chadha and JS Grewal). Advances in Horticulture, Vol. 7, 85-111. Malhotra Publishing House, New Delhi, India.

Gaur,PC, SG Ilangantileke and KC Thakur.1999. True Potato Seed: Asian scenario (ed. SM Paul Khurana, GS Shekhawat, BP Singh, SK Pandey).Potato, Global Research and Development. Vol.1, 656-667. Malhotra Publishing House, New Delhi, India.

Gopal, J. 1994. Flowering behaviour, male sterility and berry setting in tetraploid S*olanum tuberosum* germpalsm. *Euphytica*, 72:133-142

Gopal, J. 2004. True Potato Seed: Breeding for hardiness. *Journal of New Seeds*, 5(4):57-73

Gopal, J., Chahal, G.S. and Minocha, J.L. 2000. Progeny mean, heterosis and heterobeltiosis in *Solanum tuberosum* x *tuberosum* and *S. tuberosum* x *andigena* families under a short day sub-tropic environment. *Potato Research*, 43: 61-70

Gopal, J., Kumar, V. and Thakur, S.S. 2004. Hybrid and open-pollinated true potato seed production: Some considerations particularly for developing short duration families. *Journal Indian Potato Association*, 31:13-20

Hawkes, J.G. 1958. Significance of wild species and primitive forms for potato breeding. *Euphytica*, 7:257-270

Kadian, MS, PC Pande and MD Upadhaya. 1990. TPS as a propagating material for north-western indo-gangetic plains. In: Commercial Adoption of TPS Technology: Prospects and Problems. Report of Group Meeting, Delhi, India.pp.40-48.

Mendoza, H.A. 1984. Selection of uniform progenies to use in TPS commercial potato production, In: Innovative methods for propagating potatoes. Report of 28th Planning Conference, 10-14 December, 1984, Lima, Peru: International Potato Center, pp. 5-16

Ramanujam, S. 1954. The potato in Indian agriculture. *Journal of Soil and Water Conservation*, 3:4-14

Renia, H. 1995. True seed is a commercial reality in USA. *Potato Review*, 5:48-51

Upadhya, MD.1999. Present and future research for true potato seed technology (ed. SM Paul Khurana, GS Shekhawat, BP Singh, SK Pandey). Potato, Global Research and Development. Vol.1, 641-655. Malhotra Publishing House, New Delhi, India.

Ramanujam, S. 1954. The potato in Indian agriculture. *Journal of Soil and Water Conservation*, 3:4-14

Renia, H. 1995. True seed is a commercial reality in USA. *Potato Review*, 5:48-51

Wiorsema, S.G. 1995, The production and utilization of seed tubers derieved from True Potato See. Ph.D. Thesis, U.K; University of Reading.

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POTATO SEED CERTIFICATION

R. Muthuraj and Ashwani K. Sharma

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Introduction

The purpose of seed certification is to maintain and make available to the public, high quality seeds and propagating materials of notified kind and varieties so grown and distributed as to ensure genetic identity and genetic purity. Seed certification is also designed to achieve prescribed standards. Certification shall be conducted by the certification agency notified under section 8 of the seed Acts, 1966. Seed of only those varieties which are notified under section 5 of the seed act,1966 shall be eligible for certification.In the national policy of seed multiplication, the multiplication phases of seed have been grouped into three categories i.e. i) breeder or basic seed; ii) foundation I and II and iii) certified seed.

Breeder seed: breeder seed is seed or vegetatively propagating material directly controlled by the originating or sponsoring plant breeder of the breeding progamme or institute and/ or seed whose production is personally supervised by a qualified plant breeder and which provides the source for the initial and recurring increase of foundation seed.

Breeder seed shall be genetically so pure as to guarantee that in the subsequent generation i.e certified land foundation seed class shall conform to the prescribed standards of genetic purity. The other quality factors of breeder seed such as physical purity,inert matter, germination etc. shall be indicated on the label on actual basis. Breeder seeds are considered to be pure, disease free and no tolerance limit is fixed while for foundation (FS I and FS II) and certified seed the tolerance limits for viruses, off-type, tuber-borne diseases and grades have been fixed by Government of India.

Foundation Seed: Foundation seed shall be the progeny of breeder seed, or be produced from foundation seed which can be clearly traced to breeder seed. Foundation seed produced directly from breeder seed shall be designated as foundation seed stage –I. thus foundation seed produced from foundation seed stage-I shall be designated as foundation seed stage –II.

Certified Seed: Certified seed shall be the progeny of foundation seed and its production shall be so handled as to maintain specific genetic identity and purity.

Breeder seed is only being monitored by the certification agency but it is not certified by them. In India, there are nineteen state seed certification agencies in different states certifying the seed of different crops. The states in which potato seed certification is in operation are H.P, J&K, Punjab, Haryana, U.P, Bihar, W.B, Assam, M.P, Gujarat, Odisha, Karnataka and Tamil Nadu.

Certification standards of potato: : *(Solanum tuberosum L.)*

Application and Amplification of General Seed Certification Standards

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of seed potato.

B. Classification of seed potato on the basis of area of production: There shall be two types of seed potatoes, namely the Hills and plains-grown and shall be designated as Hill seed (HS) and plains seed (PS) respectively. Hill Seed (HS) shall be grown in the high hills generally 2500 meters above the mean sea level or in situations declared technically suitable for seed production. Plains seed (PS) shall be grown in such areas where aphid infestation is low during the crop growing season and which are technically suitable for seed production.

Land Requirements:

A crop of seed potato shall not be eligible for certification if grown on land infested with: wart (*Synchytrium endobioticum* (Schilb.) Perc. and or cyst forming nematodes; (*Globodera sp.*) -brown rot (*Pseudomonas solanacearum)* (E.f. Sm.) E.F. Sm. or non-cyst forming nematodes within the previous three years; common scab (*Streptomyces scabies* (Thaxt.) Waks. & Henrici).

Field Inspection:

A minimum of four inspections shall be made as follows:

1. The first inspection shall be made about 45 days after planting in the hills and about 35 days after planting in the plains to verify isolation, off-types and the extent of disease infection with specific reference to mild and severe mosaics, leaf roll, yellows, brown rot and other relevant factors.
2. The second inspection shall be made about 60-65 days after planting for early varieties and about 70-75 days after planting for late varieties or at appropriate growth stage depending on the crop duration of the variety concerned to check isolation, off-types and extent of disease infection with specific reference to mild and severe mosaics, leaf roll, yellows, brown rot and other relevant factors.
3. The third inspection shall be made immediately after haulms cutting/ destruction in order to verify that haulms have been cut/destroyed by the prescribed date and in proper manner;
4. The fourth inspection shall be made about 10 days after haulms cutting/ destruction and before harvesting in order to verify that no re-growth of haulms has taken place.

Field Standards:

A. General Requirements

1. Isolation

The fields of seed potato shall be isolated from the contaminants shown in the column 1 of the Table below by the distances specified in columns 2,3 and 4 of the said Table

Contaminants	Minimum distance (meters)		
	Foundation seed		Certified seed
	Stage-I	Stage-II	
1	2	3	4
Fields of other varieties	5	5	5
Fields of the same variety not conforming to varietal purity requirements for certification	5	5	5

B. Specific requirements

Factor	Maximum permissible limits			
		Foundation seed		Certified
		Stage-I	Stage-II	
1	2	3	4	5
Off-types	I & II Inspection	0.05%	0.05%	0.10%
Plants showing symptoms of mild mosaic	I & II Inspection	1.0%	2.0%	3.0%
Severe mosaic, leaf roll and yellows	I & II Inspection	0.50%	0.75%	1.0%
*Total virus	-	1.0%	2.0 %	3.0%
**Plants infected by brown rot (syn. Bacterial wilt) (*Pseudomonas* (E.F. Sm.) *solanacearum* E.F. Sm.)	I & II Inspection	None	None	3 plants per hectare
***Re-growth of plants after destruction of haulms	IV Inspection	0.50%	0.50%	0.50%

*Of the two inspections, the higher virus percentage will be considered for the purpose of the specified limits of tolerance.

**The presence of brown rot infected plants within the specified limits of tolerance shall be permitted in the areas known to be infected with this disease. In case of plants suspected to be infected with brown rot, the neighbouring plants, one on either side should also be rogued along with tubers.

***Standards for re-growth after destruction of haulms shall be met at fourth inspection to be conducted about 10 days after haulms cutting.

Note: 1. All off-types and diseased plants should be rogued out along with the tubers and destroyed. 2. Gaps in the seed plot should not be more than 10.0% 3. Haulms must be destroyed as close to the ground as possible before the date specified by the certification agency. Failure to destroy haulms in time shall render the crop liable for rejection.

Seed Standards

A. Specification in respect of size and weight of seed material for foundation stage-I, foundation stage-II and certified class shall be as under

Size	Mean length and two widths at the middle of tuber	Corresponding weight
(a) Hill seed (HS)		
Seed size	30 mm-60 mm	25-150 gm
Large size	above 60 mm	above 150 gm
(b) Plains seed (PS)		
Seed size	30 mm- 55 mm	25-125 gm
Large size	above 55 mm	above 125 gm

Note: 1.The size of tuber will be decided either on the basis of mean of two widths of a tuber at the middle and that of length or on the basis of corresponding weight of tuber. 2. In a seed lot, tubers not conforming to specific size of seed shall not exceed more than 5.0% (by number) 3. (a) The seed material shall be reasonably clean, healthy, firm and shall conform to the characteristics of the variety. The tubers not conforming to the varietal characteristics shall not exceed 0.050% and 0.10% (by number) for foundation and certified seed classes respectively. (b) Cut, bruised, unshapy, cracked tubers or those damaged by insects, slugs or worms shall not exceed more than 1.0% (by weight.) (c) Greenish pigmentation on tubers will not be a disqualification for certification.

B. Maximum tolerance limit of tubers showing visible symptoms caused by the diseases mentioned below will be as follows:

Diseases (Contaminants)	Maximum permissible limits		
	Foundation seed		Certified
	Stage-I	Stage-II	
1	2	3	4
Late blight (*Phytophthora infestans* (Mont.) de Bary), dry rot (*Fusarium caeruleum* (Lib) Sacc.) or Charcoal rot (*Macrophomina phaseoli* (Tassi) G. Goidanich)	1.0% (by number)	1.0% (by number)	1.0% (by number)
Wet rot (*Sclerotium rolfsii*) Sacc.)	None	None	None
*Common scab (*Streptomyces scabies*(Thaxt)Waks. & Henrici)	3.0% (by number)	3.0% (by number)	5.0% (by number)
**Black scurf (*Rhizoctonia solani* Kuchn.)	5.0% (by number)	5.0% (by number)	5.0% (by number)
***Total diseases	5.0% (by number)	5.0% (by number)	5.0% (by number)

*Even if a single tuber infected with common scab is detected in a seed lot, the entire seed lot shall be treated with approved fungicide before it is declared fit for certification. Seed lots having infected tubers more than the prescribed limits will not be certified even after treatment.

**(a) A tuber carrying 10.0% or above scurfed surface will be considered as one infected unit. (b) Seed lots having black scurf infection more than the prescribed limits could be certified after treatment with approved chemical/ fungicide.

***For all diseases, the higher disease percentage will be considered for the purpose of the specified limits of tolerance.

Tagging : There are three types of tags with two specifications for different classes of seed.

S.No.	Seed class	Tag colour	Size (cm)
1.	Breeder seed	Golden	12 X 6
2.	Foundation seed	White	15 X 7.5
3.	Certified seed	Blue	15 X 7.5

Quality control: Quality control test is being done to determine the genetic purity of a given seed lot of released cultivars and the extent to which the given sample confirm to the prescribed standards.

Sampling: The samples for grow out test is to be drawn simultaneously by the seed supplier and the seed recipient by following the standard procedure. In a lot of 100 quintal, 250 seed potato tubers are drawn by each party along with tag having details of source of seed, variety and lot number.

Procedure of grow out test: Grow out test is performed by growing the sample seed tubers in the next crop season as per standard package of practices. During this test, observation on germination, morphological characters and incidence of viruses are recorded to ascertain their genetic purity.

CERTIFICATION STANDARDS FOR POTATO TISSUE CULTURE RAISED MINITUBERS (PTCMT)

Application and Amplification of General Seed Certification Standards.

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of PTCMT. As the name implies, these standards are applicable to tissue culture raised mini tubers multiplied under laboratory and greenhouse conditions as laid here.

B. The General Standards are amplified as follows to apply specifically to the PTCMT:

Eligibility requirements for certification

The PTCMT to be eligible for certification shall be from a source meeting the following standards for laboratory and greenhouse facilities.

i. Laboratory and greenhouse facilities used for production of plantlets/ microtubers or minitubers shall be maintained free of potato insects or vectors of potato pathogens. Failure to keep such insects under control may cause rejection of all lots maintained in the facility. All potting or growth media shall be sterile. Clean water shall be used in a laboratory or greenhouse operation.

ii. Hygienic conditions should be maintained strictly during micro-propagation, potting, planting, irrigating, movement and use of equipment and other laboratory and greenhouse practices to guard against the spread of diseases or insects in the facilities used for seed multiplication.

iii. All micro-propagation and greenhouse facilities must be approved as per the standard/guidelines.

iv. The greenhouse (protected environment) must be insect proof and be equipped with a double-door entrance, provision for footwear disinfection prior to entering the protected environment and insect proof ventilation screening on intakes and exhaust openings. The persons entering the protected environment should use Wellington boots (Plastic boots)and change lab-coat in the changing area to reduce the chances of inadvertent introduction of vector or insects clinging to clothes.

v. The material being initiated for producing PTCMT must be of notified variety[1]and confirmed identity. It must be duly documented with respect to origin.

vi. The plants of potato varieties being initiated for tissue culture should be tested in an accredited laboratory for freedom from the following viruses viz. PVA, PVS, PVM, PVY, PYX, PLRV, PALCV, PSTVd and endophytic or epiphytic bacteria and fungi. Tests must be carried on a minimum of ten plantlets of each variety. For virus testing ELISA or an equivalent method should be used, for viroid RT-PCR should be used, and for fungi and bacteria light microscopy and culturing on media should be used.

Classes and Sources of seed

i. The facility should use recognized aseptic initiation and propagation procedures (i.e. follow procedures and use equipment, which will maintain sterile conditions as per standard tissue culture norms).

ii. The initiating facility must maintain following information on each variety for review and audit by the Competent Authority once in a year: variety identification, date of initiation, origin and testing results from accredited laboratory.

iii. Tests must be carried out on a minimum of ten plantlets selected at random, for each variety by an accredited laboratory. No plant should contain PVA, PVS, PVM, PVY, PYX, PLRV, P ALCV, PSTVd and other endophytic or epiphytic bacteria and fungi.

iv. Valid pathogen testing results are required prior to the initiation of micro-tuber production cycle or planting of test tube plantlets in the greenhouse.

v. PTCMT shall be produced and multiplied from certified *in-vitro* plants or microtubers, as per the requirements.

vi. PTCMT shall conform to the same Minimum Seed Standards as specified for breeder's seed.

vii. If required PTCMT may be used for producing Foundation stage-I and II, which can be certified using existing potato seed certification procedure.

Controlled Environment Requirements

i. All micropropagation and greenhouse facilities must meet the standards given above under eligibility requirements.

ii. The soil used for PTCMT production should not be infested with pathogen and pests of potato, particularly the following:

• wart *(Synchytrium endobioticum* (Schilb.) Perc.) or cyst forming nematodes; brown rot *(Pseudomonas solanacearum* (E.F. Sm.) E.F. Sm.) (non-cyst forming nematodes within the previous three years and common scab *(Streptomyces scabies* (Thaxt.) Waks. & Henrici).

Inspection of Controlled Environment Facility Used For PTCMT

a. The grower must notify the Competent Authority of his production plans well in advance of the planting.

b. The crop must be grown from certified basic *in-vitro* plants or micro-tubers, which were produced in an aseptic environment.

c. A minimum of three inspections shall be made as follows:

i. The first inspection shall be made 35 days and 45 days after planting for plains and hills respectively to verify growing conditions, extent of disease infection and off-types and also to confirm isolation requirement;

ii. The second inspection shall be made at 60-65 days after planting to verify off-types, disease infection if any and pathogen testing on a representative sample, comprising of 1% of the plants with a minimum of 5 and a maximum of 25 plants sampled for each variety;

iii. The third inspection shall be made immediately after haulm cutting/ destruction in order to verify that haulms have been cut/destroyed by the prescribed date and proper manner.

iv. Effective sanitation practices including insect and disease monitoring and prevention must be adhered to.

v. Basic Stock can be planted in commercially available medium, which has not been recycled. If nursery beds are used, the substrate should be properly sterilized before planting.

vi. The greenhouse must be free from all potato and other solanaceous plant debris before planting.

vii. No field-produced seed potatoes (including pathogen tested clonal selections), non-seed potatoes, nor any other solanaceous species of plants can be grown in the protected environment while used to produce Basic Stock.

viii. Varieties must be separated by appropriate partitioning of greenhouse to prevent varietal mixture.

ix. If testing performed by an accredited laboratory reveals the presence of banned virus (es), fungus or bacteria all the crops in the protected environment will be non-eligible for certification and the entire material will be destroyed.

x. In the eventuality of detection of insect (particularly aphids, thrips and white flies) vectors for which yellow sticky traps should be (put at least at three places in a greenhouse) by Competent Authority, the grower must provide post harvest test results to this authority. A representative sample, representing each variety grown in the protected environment must be post harvest tested and if the results are negative for PVA, PVS, PVM, PVY, PYX, PLRV and PALCV and PSTVd, the crop will be assigned Basic Stock status or otherwise rejected.

Field Standards:

Field Standards for direct use of PTCMT as seed

A. General requirements

1. Isolation: Not applicable as plants are grown in greenhouse.
2. All micropropagation and greenhouse facilities must be notified by Department of Agriculture and Cooperation, as per the standards given under eligibility requirements.

B. Specific requirements

Maximum permissible limits Factor	Maximum permitted (%)*
*Off -types	0.05
** Plants showing symptoms of:	
- Mild mosaic (Maximum)	0.05
- Severe mosaic, leaf roll, yellows and apical leaf curl (Maximum)	0.05
*** Brown rot (Bacterial wilt) (Ralstonia solanacearum)	0.00

*Maximum permitted before dehaulming **Maximum permitted at final inspection, though the diseases mentioned above are not expected to be present in tissue culture raised plants but it is essential to maintain a good crop hygiene.

***Plants infected by brown rot (syn. Bacterial wilt) *(Ralstonia solanacearum)*

C. Seed Standards for PTCMT

Factor	Permissible limit for certified class
Weight of mini tuber (Minimum)	1.0 gm
Physical purity(Minimum)	98.0 %
Germination/Sprouting(Minimum)	90 %
Varietal Purity (Minimum)	99 %
Seed-borne virus (Maximum)	0.01 %

Suggested Reading

Tanwar, N.S and S.V. Singh 1988.Indian minimum seed certification standards. The Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi 388 pp.

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POTATO MICROPROPAGATION THROUGH TISSUE CULTURE

R. Muthuraj, Tanuja Buckseth and KK Pandey

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Introduction

Micropropagation is a tissue culture (*in vitro*) method used for rapid and true to type multiplication of plants on artificial nutrient media under controlled environment. The controlled and aseptic environment of the tissue culture laboratory provides optimum conditions for multiplication of plant cultures. Further, the culture medium, the light and the temperature can be adjusted to meet specific requirements for growth and development of specific plants and plant parts. Micropropagation is the most commercially exploited area of plant tissue culture, having been widely used for production of quality planting material in vegetatively propagated species. The most significant advantages offered by micropropagation are: (i) large numbers of disease-free propagules can be obtained from a single plant in a short period, (ii) propagation can be carried out throughout the year, and (iii) the propagating material can be accommodated in a small space. Micropropagation has been successfully used in almost all potato seed producing countries to speed up initial stages of seed production. The process typically consists of: (i) production of virus-free potato plants using meristem culture, (ii) micropropagation of virus-free plants, (iii) production of micro-and/or mini-tubers from micropropagated plants, and (iv) growing healthy seed crop using minitubers as a planting material.

Micropropagation allows large-scale asexual multiplication of pathogen tested potato cultivars. At an interval of every 21 days of sub-culturing, minimum 3 nodal cuttings are obtained from a single microplants. Various techniques have been developed for producing large number of microplants on nutrient medium under aseptic conditions. Nodal segment culture in which axillary and terminal buds grow in to new plants is predominantly used for initial shoot multiplication. The method involves culturing of nodal explants of disease-free microplants on semisolid (agarified) or liquid culture medium. Considerable research has been done on the nutritional, hormonal and physical aspects of the culture media and their effects on explant growth. Murashige and Skoog's medium is most widely used for potato micropropagation. semisolid medium is used for initial nodal segment propagation.

In vitro microtuber production

Microtuber Production in Potato: Microtuber production technology involves i) initial multiplication of virus free plantlets on semi-solid medium, ii) mass multiplication of *in vitro* plantlets in liquid medium, iii) production of microtubers, iv) harvesting and storage and v) field planting.

Initial multiplication of plantlets in semi solid medium

Maintain and Multiply disease-free stock plants (obtained from meristem culture) through shoot cuttings (single nodal cuttings) on semi-solid MS medium in culture tubes (25x150 mm). The culture tubes should be closed with cotton plugs to allow maximum culture aeration and to faster optimum microplant growth. Incubate the cultures under a 16-h photoperiod from cool white fluorescent light (approx. 50-60 mmol $m^{-2} s^{-1}$ light intensity) at 24°C in non-hermetic culture rooms.

Mass micropropagation of plantlets in liquid medium

When large number of plants is produced in initial multiplication, liquid cultures are initiated for mass micropropagation. Initial liquid propagation cultures in 250ml Erlenmeyer flasks or magenta boxes. In each flask or magenta box, pour 20ml liquid propagation medium (composition same as in semi-solid medium except agar) and autoclave it. Inoculate 10-12 stem segments (each having 3-4 node segments) obtained from 6 to 21days old plantlets in each flask/box. Incubate the liquid culture under the same culture conditions as in semisolid propagation. In about 3 weeks, all the axillary buds will grow into full plants and fill the container.

Production of Microtubers

After 21 days of incubation, pour out (decant) the liquid propagation medium from the Erlenmeyer flasks or magenta box under aseptic conditions inside laminar flow work station, and pour in freshly prepared 40ml of microtuber induction medium. The microtuber induction medium is based on MS Basal nutrients supplemented with 10mg/l N^6-benzyladenine (BA) and 80g/1 sucrose (commercial sugar). Incubate these induction cultures under complete darkness at 15-20°C. Microtubers start developing epigeally at the terminal or axillary ends of the shoots within 9-10 days and they are ready for harvesting after 60-90 days depending upon genotype. In general, 15-20 microtubers with an average weight of 50-300mg are produced in each flask or magenta box.

Harvesting and storage

Before harvesting, green the microtubers *in vitro* by incubating the induction cultures under 16-h photoperiod (approx. 20-40 mmol $m^{-2} s^{-1}$ light intensity) from cool white fluorescent lights at 24ÚC for 10-15 days. Hand-harvest the green microtubers in plastic trays. Avoid damaging the microtubers, especially the thin periderm, during harvesting.

Post harvest storage of microtubers

Wash harvested microtubers under running water to remove adhering constituents of the medium. Treat harvested microtubers with 0.2% Bavistin for 10 minutes and allow them to dry in the dark 20ÚC for 2 days. Pack the dried microtubers in the perforated polyethylene bags and store at 5ÚC in a refrigerator for 4-5 months under dark for breaking the dormancy and till planting season. After 3-4 months of storage, the sprouted microtubers are ready for field planting

Field planting of microtubers

Plant the sprouted microtubers (1 microtuber/plastic bag) in perforated plastic bags (8x4cm) filled with 1:1:1 mixture of farm yard manure, sand and soil, and grow for 3 weeks in the greenhouse. Transplant the established plantlets into the removing the plastic bags without disturbing the root-soil mass. Apply fertilizer at the rate of 60kg N,100kg P2O5 and 100 kg K2O per hectare at planting time,and 60 kg N per hectare at first earthing up. Irrigate the plots by furrow irrigation throughout the growing period according to evapotranspiration requirements to avoid drought stress during crop growth and grow the crop following recommended package of practices. At maturity harvest normal sized tubes. Alternatively, the microtubers can also be planted on nursery beds at a distance of 20 x 10 cm under aphid proof net house.In this case, with progressive growth of microtuber plants soil- FYM mixture is added on the nursery bed to bury maximum number of nodes under the soil. Irrigation is done with watering can or sprinkler. The crop is allowed to mature on nursery bed and at maturity large number of minitubers (8-10 minitubers/ plant with an average weight of 10g) are harvested. The harvested minitubers are cold stored and used as seed for next crop.

Establishment of *in vitro* cultures

- **From seed tubers:** Treat the freshly harvested tubers with 0.2% mancozeb suspension for 15 min and allow them to air dry. If not for immediate use, the tubers can be stored at 4°C for about 1 year. For immediate use, allow the tubers to sprout under low light intensity (i. e. 500 lux fluorescent lamps) at 24°C. Since most cultivars are dormant after harvest, sprouting will initiate at least after 2 months. Harvest sprouts measuring about 2-5 cm long.

- **From node segments:** When starting with plants, excise node segments from the third and fourth nodes from the stem apex with a scalpel. The node segments should be 1-2 cm long, and the leaves should be detached. The stem cuttings should be processed so that to produce single node cuttings (SNCs) of uniform sizes without any leaf.

- In the laminar flow clean air work station, surface sterilize the sprout/ node segments for 10-15 min in 0.5% sodium hypochlorite solution, rinse in sterile distilled water for three times, and trim the both ends of the explants by a scalpel. Place the sprouts or nodal segments into individual culture tubes (25 x 150 mm) each containing 13 ml of semisolid nutrient (culture) medium.

- The culture medium is based on MS (Murashige and Skoog, 1962) basal nutrients supplemented with 30 gl^{-l} sucrose. The medium was solidified with 7.0-8.0 gl^{-l} agar.
- Incubate the cultures under a 16 h photoperiod from cool white fluorescent lights (approx. 50-60 µmol m^{-2} S^{-l} light intensity) at 24 °C.
- Allow the explants to grow up to 6-8 nodes/stem stage and then subculture through SNCs on fresh medium under the same cultural conditions.
- Shoot cultures can be maintained and multiplied *in vitro* by sub culturing (3 SNCs/culture tube) on fresh medium every 3 weeks.

Virus Elimination through Meristem culture

Viruses are systemic pathogens, and therefore, perpetuate through seed tubers. Thus, the losses caused by viral diseases are not only confined to the year when infection occurs, but continue as long as the diseased tubers are used as seed. While plants infected with bacteria and fungi respond to treatments with bactericidal and fungicidal compounds, there is no commercially available treatment to protect virus-infected plants. Being dependent on host for DNA replication and protein synthesis, selective interference of viral multiplication by chemical means without adversely affecting the plant nucleic acid and protein synthesis is almost impossible.

Meristem Culture for virus elimination

The term 'meristem culture' denotes *in vitro* culture of meristematic dome of actively dividing cells located at the extreme growing tip of the shoot is called as "apical meristem" and if it is located at axillary bud means it is called as "axillary meristem", along with a portion of the subjacent tissue containing one or two leaf primordia. This piece of tissue is called apical shoot tip about 0.1-0.3 mm in size. The production of pathogen-free mother plants is achieved by tissue culture. Elimination of viruses by meristem excision and culture is a rather old practice; it is based on the fact that not all cells from an infected plant carry the virus and in rapidly growing meristematic tips viruses are either absent or their concentration is very low. Meristematic tissue from roots and sprouts may be virus-free. Despite the phenomenal success of meristem culture in elimination of plant viruses, it remains still unclear as to why the apical/axillary meristems contain a little or no virus? There are several hypotheses. Some of these are given below:

- **Lack of true vascular tissue in this part of the plant:** Most viruses translocate efficiently inside a plant through the phloem or by passage from cell to cell through plasmodesmata. Since cell-to-cell movement is slow, the concentration front of a virus is slowed in rapidly dividing tissue.
- **High metabolic activity in the meristematic tissue:** Because viruses replicate using the metabolic process of the host, they find it difficult to compete with this high metabolic activity.
- Chromosome replication during mitosis and high auxin content in the meristem may inhibit virus multiplication through interference with viral nucleic acid metabolism.
- Existence of virus-inactivating systems with greater activity in the apical region than elsewhere.

Meristem excision and culture

Excise the meristems (terminal as well as axillary) from *in vitro* derived node segments under a stereoscopic zoom microscope (inside laminar flow) using scalpel and needle to peel away protective leaves on buds. Use a drop of sterile distilled H_2O to avoid meristem desiccation during excision.

- Trim the meristematic dome plus one set of leaf primordia with a scalpel to 0.1- 0.2 mm.
- Place the excised meristem on meristem medium in a culture tube (1 meristem/culture tube), and incubate the cultures under a 16 h photoperiod (approx. 50-60 µmol $m^{-2} s^{-1}$ light intensity) at 24°C.
- The meristem medium is based on MS basal nutrients supplemented with D-calcium pantothenate (2 mg/ l), gibberellic acid (0.1 mg/l), naphthaleneacetic acid (0.01 mg/l) and 30 g/l sucrose. The medium is solidify with 7.0 g/l agar.
- Test meristem derived plantlets for viruses by ELISA and/or ISEM.
- Multiply and maintain virus-negative meristem-derived clones by shoot cultures *in vitro.*

Thermotherapy

Multiplication of plants for a period at high temperatures (35-40°C) has shown to eliminate viruses from several vegetatively propagated plant species. Thermotherapy or heat treatment is usually effective only against isometric and thread-like viruses and not against rod-shaped viruses. This procedure has been used in potato via a simple technology reported to eliminate most viruses that affect the crop. Thermotherapy, however, is more efficient when used in combination with tissue culture. Apparently, the reduction of virus concentration in plants subject to heat treatment is due to the negative effect of high temperature on the multiplication and distribution of viruses in the plant. For this reason, agents such as PSTVd that require high temperature for replication and accumulation in plant tissues cannot be eliminated by this treatment, rather, their concentration is increased. On the contrary, elimination of PSTVd by treatment with low temperature (between 5 and 10°C) followed by the excision and culture of meristems has been reported. Growing host plants at higher temperatures significantly reduces replication of many plant viruses by disrupting viral ssRNA and dsRNA synthesis. Higher temperatures (35-37°C) cause disruption in the production and/or activity of virus- encoded movement proteins (MPs) and coat proteins (CPs). MPs are involved in cell- to-cell movement of viruses through plamodesmata and plant vascular system, while CPs plays role in the reconstitution of virus particles from replicated viral nucleic acids. Therefore, thermotherapy of infected plants followed by meristem culture improves virus freedom even from relatively large-size meristems. Reduction in virus titer is higher, if the infected plants are exposed to elevated temperature for longer periods. Current virus elimination programmes involve either growing of whole plants or *in vitro* cultures at temperatures close to the threshold of normal plant growth. The exact temperature and length of treatment vary with the virus and the heat tolerance of the host plant. Meristem culture combined with thermotherapy is widely used for virus elimination in potato. The source plants infected with viruses are incubated in a growth chamber under light intensity of 30-50 µmol $m^{-2}s^{-1}$ at 35-37°C for 2-6 weeks. After respective periods of thermotherapy, the meristems are excised and cultured on nutrient medium for regeneration. Cold therapy followed by apical meristem culture has also been shown to successfully eliminate several viruses from infected plants. Viroids, some of which are quite resistant to elevated temperatures, have been effectively eliminated by cold therapy. Low temperature therapy (4- 7°C) followed by meristem excision and regeneration has been used to eliminate potato spindle tuber viroid (PSTVd) from infected potato plants.

Pre-treatment of source microplants

- Amongst different therapeutic treatments, thermotherapy has been proved to the best option for successful pre-treatment of source explants prior to meristem isolation and culture.
- Establish single node cuttings (3 SNCs/culture tube) of *in vitro* cultures in culture tubes following the method described above.
- Place 7-day-old cultures in a BOD incubator at 35°C under a continuous photoperiod (approx. 20 µmol m^{-2} s^{-1} light intensity) and incubate for 3 weeks.
- After thermotherapy, test the plantlets for viruses immediately upon removal from BOD incubator.
- Plantlets tested virus-negative should be multiplied for making desired stock and virus-positive are used for meristem excision.

Chemotherapy

Chemotherapy involves the use of chemicals like antibiotics, plant growth regulators, amino acids, purine and pyrimidine analogues to inactivate viruses or inhibit replication/movement of viruses in tissues. These chemicals can either be sprayed on growing plants prior to excision of meristems or incorporated into tissue culture media. As early as in 1954, eradication of PYX from potato tissue cultures by malachite green and thiouracil treatments was reported. PVS was eliminated from certain cultivars only when the mother plant had been treated with 2-thiouracil, prior to meristem-tip excision. Inclusion of virazole (= ribavirin) into the culture media resulted in a higher percentage of virus-free progeny plants from virus-infected explants than were produced in comparable cultures without virazole. Of all the chemicals tested for plant virus elimination, synthetic nucleotide analogues like ribavirin @ 20 mg/lt (Virazole: I-D-ribofuranosyl- 1,2,4- triazole-3-3carboxamide) and DHT (5-dihydroazauracil) have been particularly effective in inhibiting different plant viruses. *In vitro* chemotherapy of meristematic explants with antiviral chemical ribavirin has been found to be most promising for elimination of major potato viruses. Though the exact mode of action of ribavirin on plant viruses is not understood, following three possibilities have been suggested:

- Ribavirin triphosphate, a major derivative of ribavirin, inhibits viral RNA polymerase synthesis.

- Ribavirin-5-phosphate, a derivative of ribavirin, inhibits IMP-dehydrogenase, and thereby decreases the GTP pool and nucleic acid synthesis.
- Ribavirin interferes with capping at the 5' end of viral mRNA leading to inefficient translation.

The concentrations of many antiviral chemicals required during chemotherapy to inhibit virus multiplication are very close to the toxic concentration for the host plant. In addition, there is always a possibility of mutations when the plants are exposed to antiviral chemicals (synthetic nucleotide analogues). Therefore, in vitro ribavirin therapy at low concentrations combined with thermotherapy has been used to eradicate viruses from infected potato cultivars.

Suggested Reading

Donnelly, D. J., Coleman, W. K. and Coleman, S. E. 2003. Potato microtuber production: A review. American J. Potato Research. 80:103-115.

Khurana, S. M. Paul, Chandra, R. and Upadhya, M. D.1998. Comprehensive potato Biotechnology. Malhotra publishing house, New Delhi. 352 + xviii.

Naik, P.S. (Ed.) 2000. Potato Biotechnology. Technical Bulletin No. 53. Central Potato Research Institute, Shimla 135pp.

Naik, P.S., Sarkar, D. and Gaur, P.C. 2001. Potato in : Biotechnology in Horticultural Crops, Parthasarathy, V. A., Bose, T. K. and Deka, P.C. (Ed.), pp.1-49 .Nayaprakash, Kolkata.

Naik, P.S. and Karihaloo, J.L. 2007. Micropropagation for Production of Quality Potato Seed in Asia-Pacific. Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi, India. p. 47+viii.

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ECONOMICS OF SEED POTATO PRODUCTION IN INDIA

NK Pandey and Dhiraj K. Singh

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Introduction

The potato is one of the most widely cultivated horticultural crops in India. It is the number one vegetable crop in the country. During 2012-2013, it accounted for about 25.5 percent of the total 163 million tonnes of vegetable production in the country. Potato is mostly grown as cash crop and provide good returns to farmers when grown scientifically. When grown with oter cereals as intercrop, it provides additional benefits. The contribution of potato to the national agricultural economy is manifold. For a developing country like India, where labour is surplus andlimited capital, high yielding and labour intensive crops like potato, have added advantage in increasing food production and employment generation. Being a short duration crop, it fits well in relay cropping systems. Returns from investment on research and development are an important yardstick to judge the importance of a particular crop in the national economy. Agriculture including allied activities contributed 14% of the GDP at constant price in 2011-12(Economic survey,2013). Current share of potato to agricultural GDP is 2.86% out of 1.32% cultivable area.

Potato being a labour intensive crop requires about 145 mandays for cultivation of one ha. of land. There nearly 270 million mandays of employment have been generated only for potato cultivation during 2011.Potato is the third most important food crop in the world after Rice and wheat. India is second largest potato producer after China leaving the Russian federation far behind(41.56,87.26 and 29.53 million ton during 2014.

The choice of a commercial crop enterprise like potato mainly depends on its profitability relative to other potential crop enterprises. This holds good strongly when the farm holdings are dwindling fast and if we take into account the fact that potato is cultivated by farmers belonging to all size-class of holdings. The farmer is motivated by various factors such as risk and uncertainty, his family needs and other socio-economic considerations in the formulation of his farm plans. But, in the ultimate analysis, the net returns per rupee of investment are the key factor for allocation of the farm resources. In this perspective, an understanding of the methodology to investigate costs and returns of crop enterprises and the economics of potato production assumes added importance for the farmers, researchers, policy makers etc. It helps particularly the growers in taking decisions on alternate efficient use of production inputs, allocating resources to different enterprises/crops for maximizing production, selecting crop combinations and deciding the levels of input use so as to economize expenditure and maximize returns.

Concepts, methods and estimation of costs

The economics of potato production is determined by input prices, resource use efficiency, technology, management, fixed costs, productivity, price policy, product prices and external market conditions. The items of cost of cultivation cover the variable costs and the fixed costs, which are paid by the farmer only once for a period of time.

The variable costs incurred to produce a crop consist of those costs which can be directly allocated to the crop and fixed costs are those costs which would not be allocated to a particular farm enterprise and have to be incurred whether the crop is grown or not. This classification of costs into two categories is essential because a farmer like another entrepreneur will continue to grow the crop if he covers the variable costs in the short run and both the costs (total cost) plus a sufficient margin in the long run. The items covered under these costs are as follows.

Paid-out costs

(i) Hired labour (human, animal and machinery (ii) Maintenance expenses on owned animals and machinery (iii) Expenses on material inputs such as seed (home-grown and purchased), fertilizer and manure (own and purchased), pesticides and irrigation.(iv) Depreciation on implements and farm buildings (such as cattle sheds, machine sheds, storage sheds (v) Land revenue and (vi) Rent paid for leased-in land

Imputed costs: Assessed value of family labour, rent of owned land, and interest on owned fixed capital, for which the farmer does not incur any cash expenses.

Cost concepts

The comprehensive scheme for studying the cost of cultivation of principal crops was initiated in 1970-71 in the country. The cost concepts such as cost A_1, cost A_2, cost B and cost C and procedure for evaluation and allocation of joint costs were laid down (Kapre, 1974). These have been further improved and redefined (Govt. of India, 1990). Different cost concepts have their own implications in policy formulation. Accordingly, the items of costs and these concepts of costs are as follows:

Cost A_1 **(i)** Value of hired human labour, **(ii)** Value of hired bullock labour, **(iii)** Value of owned bullock labour, **(iv)** Value of owned machinery labour, **(v)**Hired machinery charges, **(vi)** Value of seed (farm produced or purchased), **(vii)** Value of insecticides and pesticides, **(viii)** Value of manure (owned & purchased), **(ix)** Value of fertilizers **(x)** Depreciation on implements and farm buildings, **(xi)** Irrigation charges, **(xii)** Land revenue, cesses and other taxes, **(xiii)** Interest on working capital, and **(xiv)** Miscellaneous expenses.

Cost A_2 = Cost A_1 + rent paid for leased-in land.

Cost B = Cost A_2 + imputed value of own land + imputed interest on fixed capital

Cost C = Cost B + imputed value of family labour.

Cost of cultivation and cost of production

These two concepts are, more often than not, misunderstood and need clarification. Cost of cultivation refers to the economic valuation of variable inputs and fixed inputs per unit area say per hectare, while the cost of production for the crop is computed in terms of output per unit of weight say per quintal as follows:

$$\text{Cost of production (Rs/q)} = \frac{\text{Cost C (Rs/ha)} - \text{value of by-product, if any, (Rs/ha)}}{\text{Yield per hectare (in quintals)}}$$

Precautions in costing of input

The following main considerations should be taken into account while costing the inputs:

i) If an input has been purchased, its value should be taken as such.

ii) The home-produced inputs like seed, manure etc are evaluated at the rates prevalent in the village/cluster of villages at the time of planting of the crop

iii) Transportation charges incurred for the inputs have to be included under the appropriate cost component as miscellaneous costs.

iv) Owned tractor labour cost includes (a) cost of fuel (b) depreciation of tractor and sheds (c) cost on repairs and (d) wages of driver.

v) Family labour cost is imputed at the wage rates paid to the attached farm servant, subject to minimum wages fixed by state government for farm labour.

vi) Interest on working capital is calculated on the value of the purchased items of inputs for half the crop period at the bank rate of interest for crop loans.

vii) Interest on owned fixed capital is charged for the crop period.

viii) Rent on owned land. It is taken as per the prevailing rate in the village, subject to ceiling for fair rent fixed in land legislation of the concerned state.

ix) Main product and by-product are evaluated at the post-harvest rates prevalent in the village concerned.

x) Joint costs are to be allocated according to area under each crop.

Methods for Costing

Cost of cultivation can be calculated by following the survey method or cost accounting method. Normally, the cost of cultivation is estimated by using the survey method in the country. The cost accounting is used when the researcher wants to generate data for a number of years. This method is also useful while assessing the income from agricultural products and in determining the fixation of prices of the agricultural products. Cost accounting involves detailed enquiry entailing stay of the investigator in the village/cluster for longer time and frequent visits to the sampled farmers.

Economics of ware potato production

a) Costs and Returns from potato in the hills: The economics of potato in Shimla hills of Himachal Pradesh is was estimated. The total cost of cultivation (cost C) was Rs. 18,475 per hectare in 1989-90 in Himachal Pradesh, while the net returns were Rs 2998 and output-input ratio equal to 1.16. Category-wise analysis of economics of potato indicates that the large farmers earned the highest net returns of Rs 6903/ha, while the medium farmers earned the lowest i.e. Rs 1932/ha. The better returns accrued to the large and marginal farmers mainly due to higher productivity per unit area. Component-wise analysis of cost of cultivation shows that the seed input accounted for the highest average cost of 28.6%, followed by human labour 25.8%, rental value of land 23.2%, bullock labour 8.6%, fertilizers and manure 7.7%. The other cost factors such as plant protection, interest on working capital, interest on fixed capital and depreciation together contributed 6.1% towards the cost of cultivation of Rs. 18,475/ha. On the basis of the survey conducted on farmers fields in Shimla district during 1997-98, the cost of potato cultivation was estimated Rs. 36,950/ha, with net returns of Rs. 5990 /ha.

b) Costs and Returns from potato in plains: The plains, particularly in the Gangetic region are the potato bowl of India. It accounts for about 80% of potato production. Uttar Pradesh is the leading potato growing state of the country contributing about 33 % area and 40 % production during 2000-2001 to 2004-05. A CPRI study in 2009-10 in different potato growing states of the country showed that the total cost of cultivation was Rs.67395, 51229, 41524, 42274, 41530 and 42207 for Gujarat, West Bengal, Bihar, Punjab, MP and UP (Table 2). Component-wise cost of cultivation revealed that seed, human labour, fertilizer and manure cost were the major items of cost.

West Bengal is the second largest potato growing state in the country accounting for 25 and 32 percent of potato area and production during 2000-2001 to 2004-05.

Component-wise cost analysis in West Bengal showed that seed, human labour, manures and fertilizers and bullock, machineries were the major items of the total cost of cultivation (cost C) of potato.

Economics of Seed Potato Production

It is recognized that the informal seed potato production system meets the major requirement of seed potatoes in India. The input-output relationship, profitability and resource use efficiency in seed potato production was examined in Jalandhar district during 2003-04. The overall cost of seed potato production was estimated at Rs. 250/q. Expenditure towards seed was highest (32.84%) followed by manures and fertilizers (13.73%), farm machineries (11.29%), hired human labour (9.01%). Net income was worked out to be Rs. 11405/ha. Further, cost of production decreases with the increase in technology adoption due to increase in yield. Moreover it was found that seed potato production in Punjab was under decreasing return to scale.

Conclusion

Although potato production is a very remunerative crop enterprise yet its profitability is dented by the periodical gluts and price crashes. Being a vegetatively propagated crop, seed quality and adoption of the Seed Plot Technique (SPT) are critical for improvement of potato productivity and profitability. To sustain crop production at desired levels the government should develop a horticultural price policy. Since production and marketing are inter-related, the multifarious marketing problems need to be resolved with the help of a package of measures ensuring better returns to the growers especially small and marginal farmers. This can be achieved through promoting higher potato consumption for augmenting internal disposal and also boosting adoption of value addition techniques and strategies for encouraging the exports.

Suggested Readings

Dahiya, P. S. 1993. Economics of potato cultivation. In, (K. L. Chadha and S. S. Grewal Eds.) Advances in Horticulture Vol. 7 – Potato. Malhotra Publishing House, New Delhi. Pp 755-776.

Dahiya, P. S. 1995. *Economics and marketing of potato in India*. Tech. Bull No. 44, CPRI, Shimla. pp 49.

Govt. of India. 1990. Report of the Expert Committee for Review of Methodology of cost of production of crops, Ministry of Agriculture. 31 pp.

Gupta, S.S., S.K. Raheja, A.K. Srivastava, P.S. Dahiya and V.P. Malhotra. 1989. Sample survey for cost of cultivation, agronomic practices, area and yield rates of potato in Farrukhabad (UP), IASRI. New Delhi and CPRI, Shimla 119 pp.

Johl, S.S. 1986. Potato market – some peculiarities, problems and policies. *Agric. Situ. inIndia*. 41(5): 349-352.

Kapre, B.N. 1974. Comprehensive Scheme for studying the cost of cultivation of Principal crops. Directorate of Economics and statistics, Ministry of Agriculture and Irrigation. 8 pp.

Shekhawat, G.S. and P.S. Naik. 1999. *Potato in India*. Tech. Bull. No. 1. CPRI, Shimla 99 pp.

Table 1: Component wise breakup of cost of production in leading potato growing States (Rs./ha) for the Year 2009-10

Component	Punjab	Haryana	Uttar Pradesh	Bihar	West Bengal
Seed	22309.5	22345.5	29274	25570.5	13863
Farm Machinery	4144.5	2728.5	5611.5	5626.5	4722
Hired human labour	7785	8529	10642.5	13698	13536
Irrigation charges	432	861	976.5	847.5	4065
Plant protection	1189.5	1363.5	1185	1134	2116.5
Manure and Fertilizer	9868.5	9184.5	10977	867	13093.5
Miscellaneous expenses	18630	15549	8667	4077	17985
Total working capital	64359	60561	67333.5	59620.5	69381
Interest on working capital	3217.5	3028.5	2892	2980.5	2082
Value of family labour	282	1191	859.5	1905	1458
Total variable cost	67858.5	64780.5	71085	64506	72921
Yield (q/ha)	246.7	211.3	205	202.2	235
Variable cost of production (Rs/kg)	2.75	3.07	3.47	3.19	3.10
Transportation cost (field to cold store + Handling charges) (Rs/kg)	0.6	0.5	0.4	0.3	0.4
Cost of Gunny bag (Rs/kg)	0.5	0.4	0.3	0.4	0.4
Storage cost (Rs./kg) Total cost of production (Rs./kg)	1.5 5.35	1.4 5.37	1.2 5.37	1.5 5.39	1.3 5.20

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MARKETING AND EXPORT OF POTATO IN INDIA

Rajesh K. Rana and Dhiraj K. Singh

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Introduction

Fruits and vegetables are more difficult to market than to produce. Perishable and bulky nature of the produce makes marketing process more difficult and vulnerable to uncertainties to a higher extent. India has experienced silent potato revolution during last 66 years. In 1949 (when CPRI was established), India produced 1.54 million tonnes of potato out of 0.234 million ha with an average yield of 6.58 t/ha. However, the country produced 41.56 million tonnes of potatoes from 1.97 million ha area with an average yield of 21.1 t/ha showing an increase of 8.4, 27 and 3.2 times in area, production and yield , respectively. At present, India is facing a problem of plenty as far as potato is concerned. However, CPRI believes to take this production to 125 million tonnes by the year 2050 (Singh *et al.*, 2014).

Potato production is not a problem in India and planners need to think from marketing end for further improvement. The reported post harvest losses for potato are 16% of the annual production (FAOSTAT). The export performance of Indian potato is quite dismal as we have rarely been able to export more than 0.5% of our domestic production (Kumar, 2005). Potato processing in India is growing fast, yet the proportion of processed potato is still low i.e. nearly 7.5% of the production against up to 60% in developed countries (Rana, 2011 and Singh *et al.*, 2014). Other marketing functions such as grading, packing, storage and transportation etc. also need transformations and special attentions as for as potato is concerned (Pandit *et al.*, 2003).

Potato Marketing System

Conventional (APMC act)

Conventionally potatoes are taken to wholesale markets through different marketing channels and then go to consuming markets or consuming centres from these markets. A chain of market intermediaries such as field procurement/ assembling agents, forwarding agents, commission agents, wholesalers, and retailers are operating to complete the marketing process. However, some of these commission agents and wholesalers may act at more than one point. Due to lesser quantity of produce flowing through a particular marketing chain, the marketing efficiency of the process is generally low. For example, most of the small retailers have a target of earning Rs 400 to 800 a day and they accordingly adjust their marketing margins which may be up to 100%, or even more, of their purchase price.

Model Act

With the promulgation of Model Act in 2003 a new era of agricultural marketing was promised. The provision of creating private markets in various parts of the country resulted in varied performances in different states. Some of the states were quick in creating state of the art private markets having all modern amenities while the others showed lack-lustre interest. With the results big corporate houses to came and joined the business of procurement and retailing in agriculture. Since marketing margins under conventional marketing system were huge the new business model was assessed to be profitable for big companies.

Retail Chains

At present a large number of big and reputed corporate houses have shown interest in this sector. Very high level of apprehensions was built among the conventional retailers regarding the dangers to their existence. However, Dr P Chengappa, present Vice Chancellor at the University of Agricultural Sciences, Bangalore opined very early that fresh fruits and vegetables are a small part of this retail juggernaut and even if retail chains do very well, they will capture only 10 per cent of the market in another 10 years. Actually the retail chains have failed to corner a significant share of sales of fruits and vegetables in India. It is in spite of strong theoretical explanation that the new marketing system will eliminates market intermediaries by directly purchasing from the farmers and selling to the retailers, providing cheaper and better quality produce. Now the estimated 1.2 crore street vendors and small retailers in our country, out of which nearly 30 lac retailers and vendors sell fruit and vegetables, are much assured about their livelihood sustenance even in every part of every urban area in India.

Future trading

Futures trading is an agreement between a buyer and a seller obligating the seller to deliver a specified asset of specified quality and quantity to the buyer on a specified date at a specified place and the buyer, in turn, is obligated to pay to the seller a pre-negotiated price in exchange of the delivery. However, for speculators futures trading is a process under which sellers make promises to deliver something they don't have; and buyers promise to accept delivery of something they don't want- and both legally break their promises. Here profit maximization is the prime objective of the speculator while loss minimization is hedger's aim. Both speculators and hedgers seldom allow future contracts to mature, by nullifying the contract with reverse sale or purchase of contracts. In India MCX, NCDEX and NMCE are the three major commodity future exchanges while the first two trade in potato. Major part of potato future trades take place in MCX and some details of the potato contacts are given in table 1. Price discovery, hedging and speculation are the main functions of future markets. For further details on the subject the readers may refer to Rana *et al.* (2008).

Table 1: Contract details (MCX Potato)

Lot size	30 MT
Margin	6% of value
Leverage	16.67 times (Pay for 1.8 MT to buy a contract of 30 MT)

Contract farming

Contract farming is a written or verbal contract between buyer and seller of purchase/ sale of an agricultural commodity at pre defined terms and conditions. These terms and conditions are generally related to price, quantity and quality of the produce. Contract farming has been an important tool to cut risk in the procurement process of processing quality potatoes, seed potatoes and specialty potatoes. There are many contract farming models prevalent in various Indian states and some of them are exploitative too. The concept is still maturing in India and its popularization is required because from farmers' point of view contract farming can reduce price risk associated with excessive price volatility of farm produce.

Potato is a preferred crop for the industrial contractors due to the importance of potatoes as suitable raw material in the processing industry. It is worth mentioning here that industry needs potato tubers having high dry matter and low reducing sugars contents. Seed supply chain of specialized processing varieties is another important issue in this business. Hence, the processing industry opts contract farming in order to exercise better control over quality and quantity of the required raw material. For further details on the subject the readers may refer to Singh *et al.* (2011).

Important Potato Marketing Functions

Grading

Grading is very important function and offers a convenience of choosing a product according to customers' taste and preference(s). In Indian potato markets grades differ from market to market. Since very high proportion of grading is done by human beings hence size under the same grade may differ from person to person. CPRI has developed mechanical graders, which are used by large farmers only. Much needs to be done on popularizing grading practices adopted in international potato markets. Due to non-adoption of such grading practices our potato exporters are facing a lot of problems. Now Indian markets have started rewarding well graded and sorted produce with the higher prices.

Transportation

The transportation cost in India is very high due to very slow effective

speed of goods movement. Rail transport is quite cheap but railway's very low priority for potato transport creates problems for our domestic as well as export marketing. Frequent thefts in rail transport add to the problems. Bad condition of existing roads, absence of roads in rural areas and scarcity of express highways make our cargo movement very slow while frequent interruptions of cargo on inter state borders and traffic corruption aggravate the situation. Potatoes transported both using rail and road are liable to large scale spoilage due to hot weather and prolonged exposure to the sun. It creates wide price gap between potato producing and consuming area.

Cold Storage

Shortage of cold storage space in many states of India, erratic electricity supply, lack of cold stores on and near ports, inadequate cold chain and expensive cold storage or cold chain facilities create problems for potato marketing in India. We know that about 90% of potato in India is produced in Rabi season hence storage plays an important role in distributing supply over the remaining months of the year. Cold store operators also indulge in different malpractices such as changing/ stealing stored material. Farmers do not get any compensation even if the produce is spoiled due to the negligence of cold store operators. Except for few states where electricity supply is too much interrupted of obstructed, the cold storage facilities have been adequate. However, India needs to do a lot on the front of modernization of existing cold storage facilities. In order to cater to the needs of processing industry and consumers who dislike sweetness of conventionally cold stored (2-4 ^{0}C) potatoes, the popularization of potato storage at elevated temperature (10 to 12 ^{0}C) after CIPC treatment has proved to be a boon.

Processing

Food processing is the sunrise sector of India. The importance of this industry is not limited only to the contribution to the GDP, but it also provides many other desirable socio-economic benefits such as increased employment opportunities; improvement in income and lifestyle of the rural people leading to reduction of migration of rural masses to cities; and mitigation of huge post harvest and storage losses, specially, in fruits and vegetables. Tremendous potential of Indian potato processing industry and its rapid growth during recent past has been widely discussed (Chengappa, 2004;

Rana *et al.*, 2004; Pandey *et al.*, 2006; Rana and Pandey, 2007; Singh, 2010; Rana, 2011; Singh and Rana, 2012). India possesses wide agro-climatic conditions and areas suitable for adequate and round the year supply of processing quality potatoes. In addition, now we have potato varieties that are bred according to the requirements of the processing industry. The increasing proportion of potato processing in India shall not only avoid glut like situations but also carry forward the potato revolution in India. However, estimation of the requirement of raw material (processing quality potatoes) for potato processing industry is of utmost importance.

McCain Foods is popularizing French-fries in India in anticipation of a strong demand for convenience and variety in food products. Changing eating habits, growing number of working women and acceptance of western life style, specially in large cities has encouraged setting up of a large number of fast food restaurants in India that serve French-fries too. However, McCain Foods experienced constraints in the availability of raw material for French-fries in addition to infrastructural bottlenecks in the country. The company set up 30000 tonnes French fries plant in Gujarat during 2006 which has now been upgraded to more than double its original capacity. French fries is the fastest growing potato product in our country. With the results other French fries unit have started processing in Gujarat during the recent years. Potato chips, potato sticks, and potato 'bhujia' are one of the most common other processed products available in markets. Besides our traditional potato products like dehydrated chips, papads, waries and Laccha etc. are also finding increasing popularity not only in India but among NRIs abroad also. Potato powder/ flakes is another rapidly growing segment of potato processing industry in India. New players are establishing facilities and the existing ones are expanding aggressively. The raw material requirement of potato processing industry and the corresponding demand for processed potato products can be viewed from table 2 and 3, respectively.

Table 2: Raw material demand of potato processing industry (million t)

Product(s)	2010	ACGRs	2050
Potato chips	2.45	4.5	14.22
Potato flakes/ powder	0.29	7.6	5.44
Frozen potato products	0.06	11.6	5.40
Total	2.80	5.61	25.06

Source: Singh *et al.* (2014)

Table 3: Demand of potato products (thousand t)

Product(s)	2010		2050	
	Thousand t	Per capita g	Thousand t	Per capita g
Potato chips	612	506	3555	2194
Potato flakes/ powder	52	43	979	604
Frozen potato products	34	28	2808	1733
Total	698	577	7342	4532

Source: Singh *et al.* (2014)

Exports

Although, Indian potato is free from major prohibitive diseases like wart, ring rot, black leg, and nematodes etc., yet due to the want of appropriate certification our seed is badly affected under sanitary and phyto-sanitary sanctions. Opinion on genetically modified potatoes and anti-dumping duties are potential trade barriers of the future for Indian potato exports. Very high levels of farm subsidies by developed countries distort international potato trade too. Unfair means adopted by Dutch seed-potato multinationals who have been reported giving expensive gifts and bribes to control their business in Bangladesh and Sri Lanka. Lack of long term and consistent potato exports policy is one of lacking initiatives at our part. Absence of required market intelligence i.e. information on international prices and preference and non-seriousness on quality assurance are costing us a lot. Time of product arrival in the international market plays a crucial role in earning profits.

Variety is a most important consideration in the mind of farmers going for buying seed-potato. A number of Indian potato varieties and hybrids developed by the CPRI are already grown in different countries including Afghanistan, Nepal, Bhutan, Bangladesh, Sri Lanka, Philippines, Madagascar, Bolivia and Vietnam either under Indian names or modified local names e.g. Kufri Chandramukhi (in Afghanistan), Kufri Jyoti (in Nepal & Bhutan) and Kufri Sindhuri (in Bangladesh & Nepal). Five Indian hybrids, I-654 (as CCM-69.1 in Mexico); I-822 (as cv. Krushi in Sri Lanka); I-1035 (as cvs. Montanosa in Philippines and Mailaka in Madagaskar); I-1039 (as cvs. India in Bolivia and Red Skin in Vietnam); and I-1085 (as cvs. Sita in Sri Lanka and BSUP-04 in

Philippines) are being officially grown. Many countries are growing Indian potato varieties/ hybrids unofficially too.

Since many countries out of these are our actual or potential seed-potato importers, we have an important opportunity of increasing our exports to them. In most of our neighbouring countries potato in grown under short day conditions like India and the varieties as well as physiological age of seed produced under long day (temperate) conditions of Europe and Canada etc. are not suitable here. India is the only country in South Asia that has its own potato seed production programme, which further increases our seed potato export potential to these countries. The annual seed potato market in SAARC countries alone is 616,000 tonnes. Our exporters are getting inquiries even from the countries like Egypt and Turkey.

Bulk of Indian potato is harvested during January to March when fresh potato is not available in most parts of the Northern Hemisphere. It creates an important export opportunity for Indian table potato to many EU and other countries. Sri Lanka, Bangladesh, UAE, Nepal, Mauritius, Pakistan, Maldives, Singapore, Japan, Malaysia and Saudi Arabia are our existing or potential table potato importers. Our table potato of Kufri Sindhuri and Kufri Jyoti varieties is in great demand in Nepal and Bangladesh while Kufri Chandarmukhi has high preference in Afghanistan (Singh and Rana, 2005). Iran, although an important exporter of table potato in one part of year, imports sizeable potato during the other part. India should target this potential market too.

India is gradually becoming an important supplier of French-Fries to countries like Mauritius, UAE, Sri Lanka, Malaysia, Bangladesh, Nepal and Singapore etc. MNCs are showing increasing interest to make India an outsourcing destination for their global French-Fries need. McCain Foods, a leading MNC in French-Fries has started large scale contractual potato growing for French fries with the Indian farmers specially in Deesa area of Gujarat. This year a lot of such potato has been exported by McDonald's, another MNC in instant potato processing, after buying from the McCain Foods. This is an example that needs to be emulated by other corporates in India. Besides this India has been exporting potato chips to Bangladesh, Oman, Sri Lanka, Maldives, Canada, Kuwait, UAE, UK and USA etc.

Dried potato products like potato flour, starch, dehydrated chips and flakes etc. are exported from India to Sri Lanka, UAE Maldives, South Africa and UK. This is an area where Indian exporters should also concentrate. There is an untapped potential of exporting canned or baby potatoes from India. Presently we are canning potatoes for the requirements of our military and para-military forces. Processing quality potato from India is getting demand from Middle East, especially Dubai. Countries like Japan, China, Korea, Malaysia and Singapore etc. have great demand for processing potato. We have three varieties suitable for processing namely Kufri Jyoti, Kufri Chandramukhi and Kufri Lavkar,; and four specially bred for processing, namely Kufri Chipsona -1, Kufri Chipsona-2 and Kufri Chipsona -3 for chipping purpose and Kufri Surya for making French fries. In India we have a lot of scope for growing potato suitable of processing under warmer conditions. This is a great opportunity we should exploit for the betterment of our national economy and potato farming.

Gluts

Glut is a market situation where supply of a commodity exceeds its demand and with the result prices of that commodity crash. This term is more commonly associated with the agricultural goods and perhaps the most with the potato. The years 1975, 1979, 1982, 1985, 1987, 1988, 1997, 2000 and 2003 were the glut years for Indian potato. Although now potato is not thrown on the roads yet farmers face low prices after every 3-4 years. Acreage adjustment to the last year's potato prices; seasonal and regional production of potatoes; release of many short duration and high yielding potato varieties; inelastic price and income elasticities of potato demand; inadequate cold storage capacity; under-developed potato processing industry; very low exports of potato as well as its products; seed being the most important cost factor of potato cultivation, farmers use last year's unsold (cold stored) potato as seed; market manipulations; transportation bottlenecks; farmers' financial commitments against the crop to be harvested; majority of small farmers going for early potato crop with the objective of taking three crops a year; unawareness of general masses on potato nutrition; and non-adoption of low-cost/ input technology are the main reasons for potato gluts in India.

Large scale technical expertise and huge investments in mechanisation restricts regular potato growers from switching over to other crops however, higher profits in some years tempt new farmers to jump into potato business increasing crop area significantly. There are some other biotic and abiotic factors that contribute their share to make it very difficult to avoid potato gluts. As a result of easy availability of loans in agriculture sector over the recent past, more and more farmers are falling under the burden of debts. Many potato farmers fear loss of their land and occurrence of suicide stories like cotton growers under the influence of more frequent and violent price fluctuations of the concerned produce. However, prudent behaviour at farmers' level with the adequate support at government and research level can go a long way in mitigating the impact of gluts on farmers and their families. Potato being capital intensive crop, gluts have far reaching socio-economic adverse impact on potato farming community and it is very important to identify control measures for such gluts as well as to take concerted steps towards their proper implementation. Fortunately, the current market conditions indicate lower or even no incidence of gluts in agricultural commodities in general and potato in particular.

Projected Scenario

Potato has been found assuming an important role of food security option in India (Singh and Rana, 2013). Rapid urbanization, rising number of working women, elevated tendency of eating outside and increasing number of fast food restaurants in India is increasing per capita demand of potato in India at an annual compound growth rate of 2.04%. The population of India is estimated to rise at an annual compound growth rate of 0.78%. The component wise analysis of this huge rise in estimated demand (including potato demand in processing and seed sectors in addition to the wastage on account of post harvest losses) has been given in table 4. The marketing of fresh, processing quality and seed potatoes will bring new challenges in the future.

Table 4: Component wise potato demand (million t)

Year	Demand$	Fresh	Processing	Seed	Waste
2010	35.10 (100.00)	23.94 (68.21)	2.67 (7.61)	2.96 (8.43)	5.53 (15.75)
2050	121.81 (100.00)	78.47 (64.42)	25.06 (20.57)	6.10 (5.01)	12.18 (10.00)

Note: Figures in parenthesis are percentages; $: net domestic demandSource: Singh et al. (2014)

Conclusion

India is the second largest producer of potatoes after China however, cultivation of majority of potatoes in India under sub-tropical conditions pose highly area specific problems for us. More than 90% of our potato production faces hot summer soon after its harvest creating very strong need for cold storage in the country. Similarly more than 85% potato production takes place in North India states which emphasise the need of efficient transportation. Majority of potato growers being small and marginal are subjected to exploitation in the markets. Due to smaller volumes flowing in many marketing channels the marketing efficiency in India is low. Smaller holdings and marketable surpluses create conditions adverse for proper marketing especially grading, sorting and selling in the markets at the right time. The huge estimated rise in potato production in the future will further make the marketing process complicated and challenging.

Suggested Readings

Chengappa PG (2004) Emerging trends in agro-processing in India. *Ind J Agri Econ* 59(1): 55-74

Kumar NR, Singh BP, Khurana SMP, Pandey NK and Rana Rajesh K (2004) Destination of Indian Potatoes. In, Processing & Export Potential of Indian Potatoes. Khurana SMP, Singh BP, Luthra SK, Kumar NR, Kumar D and Kumar D (Eds). IPA, Shimla: 38-43.

Pandey SK, Sarkar D and Singh SV (2006) Potato processing in India: today and tomorrow. *Potato J* 33(1-2): 11-19

Pandit A, Rana Rajesh K, Pandey NK and Kumar NR (2003) Potato marketing in India. *Indian Horticulture*. 48 (2) July-September, 2003: 35-39.

Rana Rajesh K (2011) The Indian Potato Processing Industry-Global comparison and business prospects. *Outlook on Agriculture* 40(3): 237-243

Rana Rajesh K, Minhas JS and Khurana SMP (2004) Marketable Processing Sector Set for Rapid Expansion. *European Potato Markets (Monthly)* 108 (July 2004): 41-42

Rana Rajesh K and Pandey SK (2007) Processing quality potatoes in India: an analysis of industry's demand. *Processed Food Industry* 10(8): 26-35

Rana Rajesh K, Pandit Arun and Pandey NK (2008) Commodity Future Trading in India: How Potato Farmers can Benefit?. *Indian Farming*. Vol. 58 (9): 51-53 (December, 2008).

Singh BP (2010) Potato processing industry in India growing rapidly. *Foodprocessing360* (online magazine), 22 December 2010

Singh BP and Rana Rajesh K (2005) Potato: tremendous export potential. In, The Hindu Survey of Indian Agriculture 2005. Kasturi and Sons Ltd. Chennai: 64-66.

Singh BP and Rana Rajesh K (2012) Indian potato processing sector: analysis and prospects. In, Agriculture Today-Year Book-2012: 58-61

Singh BP and Rana Rajesh K (2013) Potato for food and nutritional security in India. *Indian Farming* 63(7): 37-43.

Singh BP, Rana Rajesh K and Govindakrishnan PM (2014) Vision 2050. Central Potato Research Institute, Shimla 171 001 HP: x+26p

Singh BP, Rana Rajesh K and Kumar M (2011) Technology infusion through contact farming: success story of potato. *Indian Horticulture* 56(3): 49-52

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DIFFUSION AND ADOPTION OF POTATO TECHNOLOGIES IN INDIA

Dhiraj K. Singh and NK Pandey

Contents

Introduction

Diffusion of agricultural technologies to end user *i.e* farmers and other stakeholders, is of utmost importance for development of agriculture sector in the country. During the Green Revolution Period, Extension System focused on dissemination of technologies for major cereal crops like rice, wheat and maize only and extension activities were largely carried out by State Departments of Agriculture (DOA). Other line departments, like Animal Husbandry (DAH), Horticulture (DOH) and Fisheries (DOF), had very limited extension capacity and primarily focused on the provision of subsidized inputs and services to farmers. According to the 2003 survey (NSSO, 2005), the major information sources for farmers on modern agricultural technologies was other progressive farmers (16.7 percent), followed by input dealers (13.1 percent), radio (13 percent), TV (9.3 percent) and newspapers (7 percent). Public-sector extension was used for information by only 5.7

percent of survey respondents. Most of the farmers sought information on seed for cultivation, followed by veterinary care in animal husbandry, and then management and marketing in fisheries.

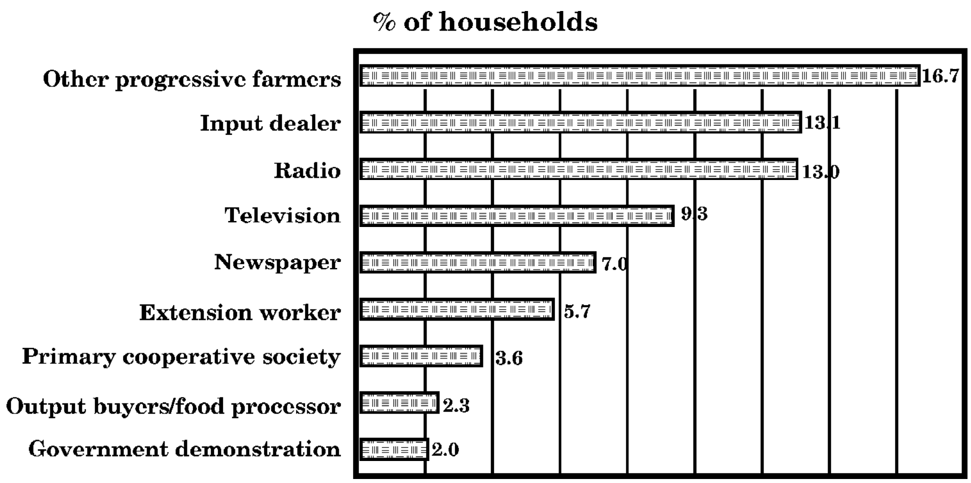

Fig. 1: Percentage of farmer households accessing information on modern agricultural technology through various sources
Source: Derived from data reported in NSSO (2005)

Agencies involved in diffusion of potato/other crops technologies in India

The last two decades witnessed declining support for public extension and emergence of a wide range of extension service providers in the private sector all over the world. The number and types of organizations providing extension services in India have also shown an increase. Potato is the third most important food crop of India after rice and wheat. Worldwide 365 million tones of potatoes were produced during 2012-13. India has now become the second largest producer of potato in world with a production of 45.34 million tonnes from an area of 1.99 million ha, thus contributing 12 per cent of total world production. The average productivity of potato in India is 22.7 tonnes/ ha which is a little higher than world average of 18 tons/ha (FAO website). However, it is much lower than many European and American countries such as Netherland (45.6 t/ha), United States of America (44.4 t/ha), France (43.6 t/ha) and Germany (43.8 t/ha). One of the important reason of low productivity is lack of knowledge about scientific methods of potato cultivation and its storage practices among farmers and low level of adoption of improved varieties and technologies. Therefore, to increase the productivity of potato, proper diffusion of potato technologies and its adoption among potato growers is necessary. Technology transfer in any crop including potato involves following agencies:

1. Public-Sector Extension Agencies

a. **State Departments of Agriculture:** Extension is implemented at the state level through the state Department of Agriculture (DoA). The extension staff of the DoA operate at the district and block levels, which are administrative subdivisions. The information is transmitted from the district and block extension staff to the village levels through contact farmers or para-extension workers.

b. **ICAR-Central Potato Research Institute (CPRI):** CPRI is a central institute of ICAR working on growth and development of potato sector in India. Its main aim is to develop new varieties and other technologies for improved potato cultivation and to increase its productivity. Social Sciences Division of the institute conducts various extension activities to transfer modern potato technologies to farmers as well as other stakeholders. The institute organizes various training programmes for extension functionaries of different states as well as progressive potato growers round the year. In addition to training, it organizes kisan melas, exhibitions, seminars and conferences to diffuse the latest knowledge and technologies to farmers and other stakeholders like privates processing companies, input dealers etc.

c. **Agricultural Technology Management Agency (ATMA):** This new institutional arrangement for agril. extension was designed to help farmers diversify into high-value crops and livestock enterprises as a means of increasing farm incomes and rural employment. The key elements of the ATMA model included organizing small-scale farmers, including women, into farmer interest groups (FIGs);linking these groups to markets; decentralizing extension decision-making down to the district and block levels and taking a more “farming systems” approach.

d. **State Agricultural Universities (SAUs):** Almost, each state has a state agricultural university (SAU), which provides extension and training activities through the Directorate of Extension. The other extension activities of ICAR are achieved through the 40 Agriculture

Technology Information Centres (ATICs) which works as single window delivery system for farmers and provide consultancy services and some inputs such as seeds and planting material and publications to farmers.

e. **Krishi Vigyan Kendras (KVKs):** KVKs or farm science center, is a multidisciplinary educational institution situated at the district level, with funding and technical supervision from ICAR. There are currently 642 KVKs, almost one for each district in India. Each center is under the administrative control of a state agricultural university, NGO, or central research institute.

2. Public-Private Partnership: Agriclinics and Agribusiness Centres (ACABC) Scheme: Agriclinics and agribusiness centers (ACABC) provide agricultural advisory services to farmers through technically trained agricultural graduates at the village level, known as "agripreneurs." The objectives of the program are to supplement the public extension system, increase the availability of inputs and services for farmers, and provide employment to agriculture graduates. The role of an agriclinic is to provide expert services and advice to farmers, while agribusiness centers provide inputs and farm equipment hire.

3. Private-sector Extension: A large number of private agencies provide advisory and other support service to farmers engaged in agriculture and allied sectors. These include input agencies, farmer organizations, producer cooperatives, agro-processing companies, agri-marketing firms, NGOs, agri-business companies, individual consultants, consultancy firms, financial institutions, media and internet services. However, the presence of these private extension providers is generally skewed towards well-endowed regions and high value crops. They are mostly profit oriented and therefore, rarely meets the need of poor farmers.

4. Civil Society Organizations: Due to the number of smallholder farmers, farmer-based organizations (FBOs) and self-help groups (SHGs) are key organizations to make extension demand-driven. This approach reduces many generic problems of public-sector extension, namely accountability to farmers and incentives for extension staff. Advantages of FBOs include the possibility of farmers achieving economies of scale and the shortening of the supply chain. Additionally, because the main source of information for farmers is other progressive farmers, belonging to an FBO or SHG may be an effective way of sharing information.

5. Mass Media and Information and Communication Technology(ICT) Approaches: To improve the quality and accelerate the transfer and exchange of information to farmers, ICT need to be given a high priority, particularly as a tool for improving the marketing aspects of farm enterprises. ICT has the ability to reach farmers directly, can enable two-way information sharing processes, has greater storage capacity, is faster, and can increase market efficiency by addressing information gaps and blockages. The mass media support scheme launched a Kisan Channel on Doordarshan, which telecasts agriculture-related programs. Kisan Call Centres is another central government scheme introduced to provide information to farmers on demand. Mobile phone based extension services are also found to be effective at some places and need to be promoted by govt.

Thus, it can be seen that India has a pluralistic extension system and many organizations are involved in transfer of technology activities.

Adoption of Agricultural technologies

The learning which is expected to result from the communication activities called extension is, in turn, expected to lead to desirable voluntary change in behaviour. When we look at extension as a function of Agriculture Knowledge and Information System (AKIS), its goal is to ensure adoption of agriculture innovations by the end users (farmers). This goal is achieved through transfer of agriculture information from the technology generating system to the technology utilizing system by using appropriate methods/media. The innovation-decision process is the process through which an individual (or other decision making unit pass from first knowledge of an innovation to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation of the new idea and to confirmation of this decision. Thus, the innovation –decision process consists of five main steps:

1. **Knowledge:** It occurs when an individual is exposed to the innovation's existence and gains some understanding how it functions.
2. **Persuasion:** It occurs when an individual forms a favourable or unfavourable attitude towards the innovation.
3. **Decision:** It is the process by which an individual engages in activities that lead to a choice to adopt or reject the innovation.
4. **Implementation:** It is the process by which an individual puts an innovation to use.

5. **Confirmation:** it is the process by which an individual seeks reinforcement of the decision already made.

Thus, at the knowledge stage an individual becomes aware of the innovation or technology through selective exposure. Mass media plays important role in creating awareness of the technology. At the persuasion stage, attitudinal change in the individual occurs through selective perception. The individual evaluates the attributes of the innovation or technology and decides to adopt or reject it. At this stage the role of extension agents is very critical. The extension agents may persuade the individual to adopt the technology by bringing about favourable attitudinal change.

Adoption is the process by which an individual make sure the use of an innovation to the best course of action available (Rogers, 1983). However, an individual may also decide to discontinue the adoption of a technology. Discontinuance occurs when the individual is not satisfied with the performance of the technology or when a superior technology replaces the existing one. Dissatisfaction ours when the individual lacks proper knowledge of using the technology or when the technology do no have perceived relative advantage. When discontinuance occurs due to dissatisfaction it, becomes impossible for the extension agent to persuade the individual to again adopt the technology.

Adopter categories

Based on relative earliness in adopting a technology, the ends users or farmers in a social system are classified in to different categories called adopter's categories. There are five major **adopter's categories** in any social system.

Innovators: They are the first to adopt a technology and do not require any persuasion from extension agents. These people are venturesome, cosmopolite and possess substantial financial resources to bear the risk associated with the adoption of a new technology. The constitute about 2.5 per cent of the total population.

Early Adopters: Principles they adopt the technology after the innovators have adopted it. They are localities opinion leaders and serve as role model for others in the society. They constitute about 13.5 per cent of the total population. The extension agent has focus on this category of people who may serve as local missionary for technology transfer.

Early Majority: They adopt the technology just before the average members of the social system. Their innovation-decision period is relatively longer than that of the innovators and early adopters. However, they serve as an important link in the technology transfer process between the very early and the relatively late to adopt the technology. The extension agent has to persuade these people through individual and group contact methods in order to make them to adopt the technology. Since, they provide interconnectedness in the systems network, they cannot be ignored at all. This category of people constitutes 34 per cent of the total population.

Late Majority: They adopt the technology just after the average member of the social system. They are generally skeptical about a new technology and do not adopt it until most others in their social system have done so. They can be persuaded by extension agents to adopt a new technology, but the pressure of peers is necessary to motivate them.

Since, they possess relatively scarce resources to bear the risk, they adopt a new technology only when all their doubts are removed and they feel safe. They can be persuaded to adopt a technology only though individual contact method. This category of people constitutes 34 per cent of total population.

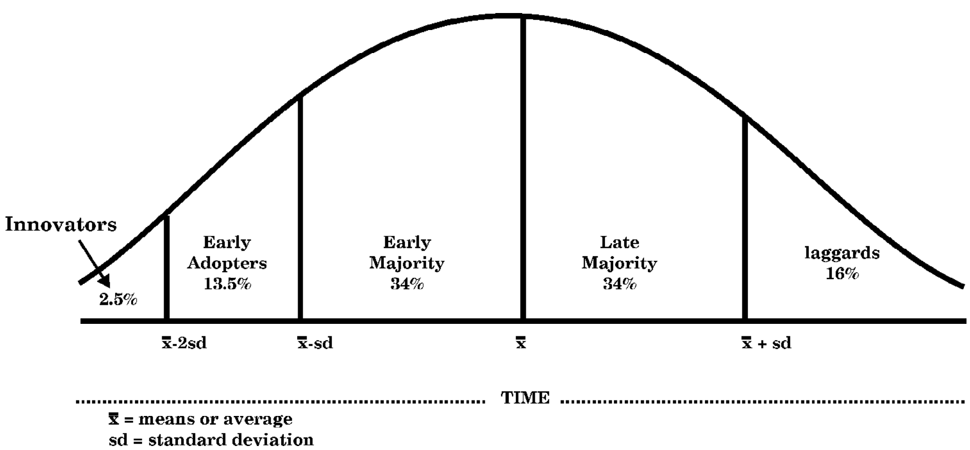

Fig. 2: Adopters category with respect to earliness or lateness in adoption of innovation

Laggards: They are the last in the social system to adopt a new technology. They possess limited resources and lake capacity to bear any risk. They are highly influenced by societal norms and traditions. They are also suspicious of innovations and change agents. They constitute about 16 per cent of the total population. When laggards finally adopt a technology, it may already have been superseded by another more recent technology. The laggards' precarious economic situation forces them to be extremely cautious in adopting a new technology.

Thus, in any social system 100 per adoption of technology cannot be achieved at time. Specific strategy has to be followed for each category of adopters in order to ensure grater adoption of the technology. The adoption behaviour of farmers very much conforms to the normal curve-limited percentage of farmers. According to Rogers (1983), the adopter of a technology fall on a normal distribution curve in which the percentage of different adopters categories may vary in different social system depending on the education, social economic status and other factors of the members.

Suggested Readings

http://faostat.fao.org

National Sample Survey Organisation (2005). *Situation assessment survey of farmers: Access to modern technology for farming.* National sample survey, 59th round (January–December 2003). Report 499(59/33/2). New Delhi: Government of India, Ministry of Statistics and Programme Implementation.

Rogers, Everett M. (1983), Diffusion of innovations, 3rd ed. New York: The free press

Glendenning CJ, Suresh Babu and Kwadwo Asenso Okyere (2010) Review of Agricultural Extension in India, IFPRI discussion paper 01048, International Food Policy Research Institute, Eastern and Souther Africa Regional Office, Addis Ababa, Ethiopia.

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