ICAR Sponsored Winter School

on

Advancement in Potato Production Technology and its Future Prospects

(November 19 to December 09, 2019)

Organized by

ICAR-Central Potato Research Institute

Regional Station, Modipuram-250110, Meerut (UP)

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19th November to 09th December, 2019

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Foreword

Potato (*Solanum tuberosum*) is designated as "*Food for Future*" by FAO because of its high productivity and nutritive value. It has already emerged as the third most important food crop in the world after rice and wheat. India ranks second after China with a production and productivity of 51.31 million MT and 24.00 t/ha, respectively covering an area of 2.14 million ha. However, it is projected that India needs to produce 55.00 and 122 million MT of potatoes by 2025 and 2050, respectively to meet the demand of the growing population and economy. Potato produces comparatively higher economic yield per unit area and unit time and, therefore, has become more important where cultivable lands are scarce. That is why even the small and marginal farmers of the country have taken up potato cultivation. But, over and again the potential yield of potato is limited by various biotic and abiotic factors in hills, plains and plateau regions of our country. Among the various factors related to quality seed and ware potato production, farmers are often forced to face water scarcity, changes in rainfall patterns and its intensity, frost and fog, post harvest losses, pests and diseases, issues related to processing and entrepreneurship *etc.* The scientists at ICAR-Central Potato Research Institute and its Regional Station, Modipuram are addressing these issues and working on future technologies like genome sequencing of pests and diseases, development of trait specific new potato varieties, organic potato production, plant nutrition, water management, forecasting models, soil health and high-tech seed production through aeroponics and tissue culture. The need of the hour is to sensitize and educate various stakeholders such as Scientists/ Assistant Professors of various research organizations and universities to disseminate latest technologies to the farmers. Therefore, this winter school entitled **"Advancements in potato production technology and its future prospects"** is being organized to provide latest information related to scientific and technological advancements in potato production technology which can help in doubling the farmer's income by 2022. I am sure this training manual will be of great value to the fellow participants and I congratulate the contributors and editors of this manual for their efforts in compiling the information with latest updates on advancements in potato production technology, for the benefit of the potato fraternity.

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CONTENTS

Chapter - 01

POTATO RESEARCH IN INDIA: ACHIEVEMENTS AND THRUST AREA

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Introduction

Invention of settled agriculture about 10,000 years ago and its all-pervading popularity in subsequent centuries seriously restricted our food preference to a handful of cereals belonging to the grass family. This exceptionally narrow food choice is now considered as a threat to the food and nutritional security of mankind. Immediate diversification of food and agriculture is imminent for ensuring food and nutritional security. Global food demand is forecasted to at least double by the year 2050 when the world population is expected to reach from the current 6.3 to 9.3 billion of which about 90% will reside in Asia, Africa and Latin America. In India, the population has already exceeded 1.0 billion and our country is projected to be the most populous in the world with 1.5 billion by 2050. The arable land is diminishing every year as it is diverted for industrial, residential, recreational and other human needs. Other resources like water, fertilizers and labor are also becoming scarce and costly. About 1.2 billion people in the world are afflicted by severe poverty of which 852 million in the developing countries suffer from malnutrition. 1.4 billion women (22% of world population of which 55% in the developing countries) suffer from iron deficiency anemia, which impairs immunity and causes mental as well as physical weakness. About 140 million children suffer from vitamin A deficiency. An estimated 250,000 to 500,000 vitamin A deficient children become blind every year, half of them dying within 12 months of losing their sight. Such unfortunate children in India alone are about 50,000. Such unfortunate scenario prevails in spite of record food grain production and indicates a necessity for food diversification.

Horticulture can be a step towards food diversification. It infuses the elements of sustainability through crop diversification; profitability through high-valued produce; nutrition security through high quality produce; job security through labour intensive nature; women empowerment through gender preference; food safety through organic farming and preservation of biodiversity. Production of horticultural crops is especially attractive for small-scale farmers since these crops usually have much lower scale of economies compared to cereal crops and livestock production. Horticultural crops have a comparative advantage over cereal crops in countries like India where land is scarce and labor is abundant. Horticulture will play a key role in poverty alleviation and comprehensive rural development in India. The potential of horticulture was realized early in post-independent India. Systematic research on fruits, vegetables and ornamental crops were initiated in 1954 and pursued with full tenacity. As a consequence, India has made a fairly good progress on the Horticulture Map of the world with a total annual production touchng over 149 million tonnes. India has been bestowed with wide range of climate and physio-geographical conditions and as such is most suitable for growing various kinds of horticultural crops such as fruits, vegetables, flowers, nuts, spices and plantation crops (coconut, cashewnut and cocoa). With the focused attention given to horticulture, there has been spectacular change in terms of adoption of new technologies, production and availability of horticulture product. At present India is the second largest producer of the Fruits (45.5 million tonnes) and vegetables (90.8 million tonnes) in the world, contributing 10.23% and 14.45% of the total world production of fruits and vegetables respectively. The availability of flowers has increased significantly in all major cities in the country. India has a good opportunity of growing of medicinal and aromatic plants. It is the largest producer, consumer and exporter of spices. It ranks first in the total production of coconut and arecanut and is the largest producer, processor, consumer and exporter of cashew nut in the world. Horticultural crops cover about 25 per cent of total agricultural exports of the country. The corporate sector is also showing greater interest in horticulture. A major shift in consumption pattern of fresh and processed fruits and vegetables is expected in the coming century. There will be greater technology adoption both in traditional horticultural enterprise as well as in commercial horticulture sectors. Diversification and value addition will be the key words in the Indian horticulture in the 21st Century. Thus, India is at the brink of a Golden Revolution in horticulture.

Potato

Potato (*Solanum tuberosum* ssp. *tuberosum*) possesses all the virtues to be a potential food crop. It produces substantially more edible energy, protein and dry matter per unit area and time than many other crops. Potato tubers constitute a highly nutritious, wholesome food. It provides carbohydrates, proteins, minerals, vitamin C, a number of B group vitamins, and high quality dietary fiber. People of several European and Latin American countries consume potato as a staple food. On the contrary, it is still being used as a dietary supplement in our country. The per capita consumption of fresh potato in India is a paltry 15 Kg/year compared to 193 and 126 Kg/year in Denmark and The Netherlands respectively. Therefore, there is a wide scope to increase potato consumption and production in the country.

The potato was introduced to this ancient agrarian sub-continent only about 400 years ago by sea voyagers from Europe. This New World crop was originally domesticated about 8,000 years ago by communities of hunters and gatherers in the Andes mountain range of South America, on the border between Bolivia and Peru. It is most likely that the Portuguese traders first took potato to India during late 16th to early 17th century. The first written mention of potato in India occurs in Edward Terry's account of a lavish banquet hosted by Abdul Hassan Asaf Khan (elder brother of Nur Jahan and father of Mumtaz Mahal) who was the Governor of Punjab under the Mughal Emperor Jehangir, in honour of the British Ambassador Sir Thomas Roe in 1615 at Ajmer. Though potato was first introduced to the Southern coast of India, it was probably not cultivated by the farmers of the region, instead it established quickly in the gardens of Surat and Karnataka. In the subsequent two centuries and half, agri-horticultuarl societies and the botanical gardens took keen interest in promoting its cultivation throughout India. The Royal Agri-Horticultural Society founded by the great missionary scholar William Carrey in the year 1820 at Calcutta was one such society that popularized potato cultivation in eastern India. In 1832, Captain Trichmond grew potatoes from a variety imported from England and distributed by the Royal Agri-Horticultural Society. He observed that the England potatoes were much superior to that of local varieties in size and weight. This new English potato varieties were introduced to hill stations like Naini Tal and Shillong. In the mean time, other army officers took keen interest in extending and stabilizing potato cultivation in Indian hills. Its cultivation on the hills north of Dehra Dun was first started by Major Young and consolidated by Captain Townsend. Yet another enthusiastic military officer, Captain Mundi, took keen interest in extending potato into the Simla hills by 1828. Similarly, potato was introduced into the Nilgiri hills by Mr. Sullivan in the year 1830. Later on, the Government Botanic Garden established in the year 1848 at Ootacamund extended potato cultivation in the entire Nilgiri hills. In the hills, the imported European potato varieties found a hospitable, temperate climate. Thus potato cultivation became well established in both plains and hills of Indian subcontinent by the year 1840. In the beginning, when the potato was introduced, the orthodox Brahmins objected to its use because it is not mentioned in the Hindu Puranas as an article of food. The prejudice vanished gradually and potato was accepted as a primary vegetable supplement largely because of its mild flavour, which lends itself readily to combinations with other foods. In fact, on days of fasting, the Hindus in some parts of India now consume potato in large quantities as it is one of the root crops included in the list of articles which can be eaten during a fast.

Potato cultivation in the country during next 100 years remained, at the best restricted and the entire Indian subcontinent contributed less than 1% of world's potato area and production by 1941. This was primarily due to non-availability of locally adapted varieties and technologies for growing potato under sub-tropical climatic condition. To take care of those problems, an organized research programme on potato was initiated on 1st April, 1935 with the opening of three breeding and seed production stations at Simla, Kufri (both Simla hills) and Bhowali (Kumaon hills), under the Imperial Agricultural Research Institute, New Delhi. In 1945, a scheme for the establishment of Central Potato Research Institute was drawn up under the guidance of the then Agriculture Advisor to the Government of India, Sir Herbert Steward and Sir Pheroz M. Kharegat, Secretary, Ministry of Agriculture. Dr. B. P. Pal, Dr. S. Ramanujam, Dr. Pushkarnath, and Dr. R.S. Vasudeva participated in the formulation of the scheme and in establishment of the institute. Dr. S. Ramanujam, who was then working as Second Economic Botanist at IARI, was appointed as an Officer on Special Duty for implementing the scheme in 1946. The institute was established in August 1949 at Patna and started functioning from an old single-storey, barrack-type building provided by the Government of Bihar. Three small units under the IARI looking after potato, namely Potato Breeding Station at Shimla, Seed Certification Station at Kufri, and Potato Multiplication Station at Bhowali were merged with the newly created CPRI. The headquarter was shifted to Shimla, Himachal Pradesh in 1956 in order to facilitate hybridization work and better maintenance of seed health. A major boost in potato production came after the release of the unique late blight resistant variety Kufri Jyoti in the year 1968. This was the time when green revolution was initiated and Govt. was committed to extend irrigation facility to more and more lands. Supply of other basic inputs like fertilizers, pesticides, fungicides were also ensured, be it primarily for wheat and rice. The variety Kufri Jyoti was highly responsive to irrigation and fertilizer and as a result potato emerged as a principle component of the profitable maize-potato-wheat sequence in the vast North-western plains. Similarly, potato after paddy became a successful crop sequence in many areas of eastern Indo-Gangetic plains. Throughout the green revolution phase, potato remained a subsidiary crop to the major cereals but benefited immensely from the infrastructure facilities created for those crops. This was further augmented by innovations of appropriate technologies by CPRI. Availability of indigenous varieties, good quality seeds and right package of agronomic practices triggered a revolution in potato production causing very fast growth in area, production and productivity. Potato production jumped from 1.54 million metric ton (MT) in the year 1949-50 to 24.22 million MT during 1996-97, thus making India the third largest potato producer in the world after China and Russia.

Achievements

- Establishment of a germplasm collection consisting of more than 3,000 accessions. This collection is being maintained, evaluated and utilized for breeding potato varieties possessing tolerance to biotic/abiotic stresses and other desirable attributes such as high yield, adaptability, tuber characters, keeping quality and processing attributes.
- Developed 43 high-yielding varieties belonging to early (70-80 days), medium (90-100 days) and late (100-110 days) maturity groups. All the varieties developed for hills and newly released medium duration varieties for the plains possess resistance to late blight. Varieties with resistance/tolerance to cyst nematodes, wart, viruses, frost, water stress, and high thermo-periods have also been bred to address specific problems. Besides, 5 varieties are suitable for processing. These are Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Himsona, Kufri Lauvkar, and Kufri Surya.
- Development of "Seed Plot Technique" made it possible to carry out disease-free seed production in the plains under low aphid periods and establish a national disease-free seed production programme. This programme annually produces about 2600 t of breeder's seed, which is sufficient for the country's requirement if multiplied and utilized properly. The availability of disease free seed in adequate quantities is a major input for significant increase in potato production in the country. "Seed Plot Technique" was also instrumental in decentralization of potato breeding programme. This technique enabled seedling raising, evaluation, selection and multiplication of breeding material under disease free condition in the plains. This has greatly helped in development of zone-specific varieties and varietal diversification.
- Identification of suitable parental lines for production of high yielding botanical seed (TPS) and its use for raising commercial crop in potato seed deficient areas is another important contribution of potato research. Three TPS populations, viz. HPS I/13, TPS C-3 and 92-PT-27 have been identified for commercialization. However, of late it has been observed that the technology needs some more refinements for its successful adoption.

- Development of package of practices for different agro-climatic regions of the country. These packages comprise integrated potato production methods for maximizing yields without putting much pressure on scarce resources such as fertilizers and water.
- With a view to increasing potato production per unit area and efficient use of scarce resources, the institute has identified profitable potato-based cropping systems in different agro-climates including inter-cropping of potato with sugarcane and wheat. Optimal schedules for integrated management of fertilizers, water and weeds in these intensive cropping systems were also worked out.
- Use of GIS for spatial and temporal diversification of potato crop. Cursory look at the meteorological and soil data indicates that potato cultivation is possible in many additional locations other than Indo-Gangetic plains. Using GIS, these places have been identified for spatial diversification. Temporal diversification is possible through increase in the area and productivity of early and spring crops in the northern Indo-Gangetic plains. This is expected to spread the availability of fresh potato for a long period and reduce the gluts.
- Simulation modeling is another tool useful in working out tactical decisions. Potato model (INFOCROP-POTATO) have been developed to determine the best growing period, yield potential during the growing period, the optimum management practices to achieve the yield potential and also to develop new efficient cropping systems.
- There is much scope for use of remote sensing in potato development. The tool is being used for estimation of acreage and production prior to harvest so that proper planning can be made in advance for marketing, storage etc.
- An expert problem solving behaviour of computer aided Expert Systems can be advantageously utilized for economic planning and management of different crops. "Potato Expert System" for management of nutrients, insect pests and diseases has been developed at CPRI.
- In addition to late blight resistant cultivars, late blight forecasting systems were developed for the hills and plains to manage this dreaded disease. These have been instrumental in reducing the labour and cost on plant protection by avoiding unnecessary and untimely use of fungicides.
- In order to make potato cultivation eco-friendly, integrated packages of practices for management of late blight, bacterial wilt, viruses and soil & tuber-borne diseases, potato tuber moth (PTM) and cyst nematodes were developed. These packages included host resistance, sanitation, crop rotations, use of safer chemicals, predators, bio-control agents, botanicals and agronomic practices.
- Developed sensitive virus detection methods such as ELISA, ISEM and NASH. Such sensitive methods have been of great help in eliminating quarantine pathogens from the imported germplasm material having low concentration of viruses/viroids and also in testing of mericlones. Besides, deployment of these methods in seed production was responsible for practically zeroing the virus incidence in basic/nucleus seed.

- Standardized tissue culture techniques for micropropagation, *in vitro* conservation of genetic resources and genetic transformation. Meristem culture coupled with micropropagation has been successfully integrated with potato seed production programme. More than 1300 germplasm accessions have been conserved in *in vitro* form and we plan to conserve entire germplasm within next 15 years. An efficient method has also been developed for long term cryoconservation in potato.
- Potato transgenics have been developed for late blight durable resistance (RB-transgenics), reduction of cold-induced sweetening, superior nutritional quality (*AmA1* gene of *Amaranthus hypochondriacus*), insect resistance (*cry1Ab* gene), virus resistance. Field testing of RB transgenic potato showed very good level of late blight resistance. Field trial with *AmA1* transgenic potato showed no yield loss of the selected transgenic lines. DNA fingerprinting of released potato cultivars and advanced potato hybrids completed.
- Improvised low cost on-farm storage structures that can hold table/processing potatoes for 3-4 months in north Indian plains.
- Storage of table and processing potatoes at 3-4 ^{0}C in cold stores leads to accumulation of reducing sugars which makes tubers unfit for processing. Institute has standardized method of storing potatoes at elevated temperature (10-12 ^{0}C) by incorporating the component of CIPC spray to check sprout growth. This has revolutionized continuous availability of raw material for processing in the country.

Critical gaps

- ***Stagnation of cultivated area*****:** The area under potato crop has stagnated at 1.2 million ha since last 10 years. However, to achieve the projected production level, at least 1.7 million ha should be available for potato cultivation by the year 2020. Keeping in view the present trend in land use pattern, it will be impossible to bring new areas under potato thus creating a gap in cultivated area. Innovative strategies are required to bridge the gap.
- ***Non-availability of tailor-made varieties*****:** Development of high yielding varieties by CPRI contributed largely for fast growth of potato cultivation during second half of 20th century. However, the momentum of yield gain has slackened considerably during last 10 years. There is hardly any new variety with a quantum jump in yield potential. Besides, absence of varieties with specific desirable attributes like shorter crop duration, heat & drought tolerance, high input efficiency, cold-chipping, French fry preparation, and better nutritional quality is now posing a hurdle for extending potato in new areas. These issues need to be addressed on priority.
- ***Improper management of natural resources*****:** Natural resources like land, water, soil, forest, livestock, fish, biodiversity (plant, animal and microbial genetic resources), along with air and sunlight constitute the very foundation of human survival, progress and prosperity. Ruthless exploitation of natural resources during green revolution period resulted in declining agricultural productivity and profitability (15% drop during the past 10 years), decelerating Total Factor Productivity (TFP) growth rate and highly aggravated

cost-risk-output (income) imbalances. Though potato alone contributed little in this regard, appropriate technologies for all crops including potato are now necessary for remediation of natural resources.

- ***Resource based planning for different agro-ecological zones*****:** The technologies and package of practices generated by the institute so far are not based on location specific, need-based situation of different agro-ecological conditions. It resulted in widening gap between technology generation and adoption. In order to maximize the production from the available resources and prevailing climatic conditions, it is necessary to critically analyze agro-ecological conditions and cropping patterns of particular agro-ecological zones and come out with technologies based on natural resources, major crops, farming systems, production constraints and socio-economic conditions prevalent in that zone.
- ***Sub-optimal utilization of potato*****:** Though India is the third largest potato producer in the world, its per capita consumption is just 17.3 kg/year compared to 140 kg/year in Ukraine. Potato is a wholesome food and is the staple diet for many nations. However, in India huge piles of potato tubers are often left to rot primarily due to lack of its diversified utilization. To avoid glut and market fluctuation, it is necessary to ensure year-round utilization of both fresh and processed potatoes.
- ***Insufficient supply of quality planting materials*****:** Potato is propagated by seed tubers that constitute about 40% of total cost of cultivation. Seed is a bulky input and approximately 2 million metric ton potato out of 24 million metric ton total produce is used annually as seed. Ensuring proper seed health is crucial for a vegetatively propagated crop like potato. With the current infrastructure, only about 40% potato area can be cultivated with quality seed leaving behind a huge gap of 60%. Appropriate policy decisions and planning are necessary to bridge that gap.

Thrust areas

- Cent per cent breeders' seed production through Tissue Culture Nucleus stock.
- Extension of potato cultivation to newly created irrigated areas, as *kharif* crop in plateau region, as component of inter-cropping, relay-cropping and multiple cropping systems.
- Development of early and medium maturing potato varieties; varieties suitable for French fry, flakes and flour production; varieties with durable resistance to multiple disease; heat, drought and salt tolerant varieties; and varieties with efficient nutrient and water use efficiency.
- Potato genome sequencing and functional genomics for tuberization and late blight resistance"
- Development transgenic potato resistant to late blight, bacterial wilt and reduced cold-induced sweetening; potato genome sequencing and functional genomics for realizing yield potential, marker assisted selection, diagnostics, conservation of genetic resources and micropropagation. Biosafety and food safety of transgenic crop are to be determined prior to their release.

- Soil health improvement to overcome the widespread macro- and micro-nutrient deficiencies – the "hidden hunger". Balanced and efficient fertilizer use has to be supplemented with increasing soil organic matter content by incorporating crop residues, green manuring, application of FYM, compost, vermi-compost, biofertilizers and other bio-digested products. Biosafety and biosecurity aspects of introduced bioagent or living modified organism (LMO) are to be studied critically.
- Eco-region specific technology generation based on maximum productivity of available natural resources like climatic condition, soil fertility and water. Information technology (IT) tools like geographic information system (GIS), crop modeling, precision farming are to be used for sustainable utilization of natural resources of the specific agro-ecological zones. The technology packages to be developed for potato would be an integral component of multi-functional agriculture of the specific zone. IT-based decision support systems would be used for technology transfer.
- Integrated management of emerging diseases and pests. Emphasis would be on identification of new and effective bio-molecules for management of biotic stresses and deployment of resistances sources. Gene pyramiding and multiple disease resistance would be encouraged for eco-friendly and sustainable management of diseases and pests.
- Diversification of potato utilization, renewed emphasis on storage and post harvest processing, encouraging export.
- Strengthening quality seed production in seed deficit potato growing regions. Tissue culture techniques would be effectively integrated for disease-free seed production.
- IT based enabling mechanism for technology transfer and socio-economic impact analysis of technologies developed by the institute.

Chapter - 02

DISEASE FORECASTING FOR EARLY AND LATE BLIGHT OF POTATO

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Potato, like any other crop, is also attacked by large number of pests and diseases leading to crop losses up to 25%. These losses can be contained by adopting three prolonged strategies i.e. by employing chemicals (including disease forecasting), cultural practices, and host resistance in an integrated manner. Cultural practices mainly aim at reducing the initial inoculum load and arresting the disease spread. Practices used for achieving these objectives are use of disease free planting material, burying/burning the infected plant parts, removal of volunteer, collateral/alternate host plants etc. It is possible to manage the disease by applying chemical sprays but the number of sprays required on a susceptible variety would be more than double the sprays required on a resistant variety, which is rather uneconomical for most of the farmers. Even if they are able to apply the required number of sprays, it would result in environmental pollution and also the development of fungicide-resistant strains of the pathogen. Similarly, resistant varieties may be used for managing the diseases but there is a risk of breakdown of resistance if the resistance is governed by major genes. However, if the resistance is broad based, it would still require support of prophylactic chemical sprays. In this context usage of chemicals become inevitable. To reduce the cost of management and pesticide residues, their need based application is the need of the day. In this direction disease forecasting can play an important role. Disease forecasting is a management system used to predict the occurrence or changes in severity of plant disease population. Historically disease forecasting has been attempted in late blight of potato. However, there is dire need to develop forewarning systems for other important diseases as well.

Principle and concept of disease forecasting

Forecasting systems are based on assumptions about the pathogen's interactions with the host and the environment. Forecasting systems can only be designed if there is an understanding on the actual disease triangle parameters. The principles of disease forecasting are based on relationship between the weather parameters and the disease epidemiology. Van Everdingen (1926) for the first time utilized weather parameters (temperature, RH, rainfall, dew) to develop a late blight prediction system, commonly known as 'Dutch rules'. Since then large number of forecasting models based on minimum temperature and RH, moving days concept, severity values, risk values etc. have been developed worldwide but most of them are region specific. Van Everdingen (1926) used dew periods, night temperature, cloudiness and rainfall, known as the "***Dutch rules***", to predict initial appearance of late blight in Holland. Dutch rules were found usually satisfactory but sometimes the blight appeared even when the Dutch rules were not completely fulfilled. Subsequently, these rules were modified for England and reduced to two conditions which were known as '***Beaumont rules***' (Beaumont, 1947). These rules were based on specific temperature and RH periods for two consecutive days. They successfully forecast late blight under UK conditions. Hyre (1954) proposed a concept popularly known as '***Moving days concept***' which uses average temperature for the last 5 days and total rainfall for the last 10 days for determining the initial occurrence of the disease. The initial appearance of late blight is forecast 7-14 days after the first occurrence of ten consecutive blight-favorable days. A day is considered to be blight-favorable when the 5-day average temperature is below 25.5° C and the total rainfall for the last 10-day period is > 3.0 cm. Days on which the minimum temperature falls below 7.2°C are considered unfavorable for blight development.Wallin (1962) developed a forecasting model for predicting the initial occurrence and subsequent spread of late blight based on relative humidity (RH) and temperature. This system is based on the seasonal accumulation of '***Severity values***'. Severity values are numbers arbitrarily assigned to specific relationships between duration of RH periods > 90% and the average temperature during those periods. The first occurrence of late blight is predicted 7-14 days after 18-20 severity values have been accumulated from the time of plant emergence. Ullrich and Schrodter (1966) developed '***Negative prognosis***' concept, which uses measurements of temperature, relative humidity, and rainfall to predict when late blightepidemics are not likely to occur. It has been used in Germany and has been implemented in Europe to predict the timing of the first prophylactic treatment.

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.

Forecasting for 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. Taking weather parameters in account, Bhattacharyya *et al*. (1982) developed forecasting models for Shimla (North western hills), Shillong (North eastern hills) and Ootacamund (Southern hills) 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^{o}C or less continues for 7 consecutive days, late blight would appear within 3 weeks. Once these conditions are met, then more accurate prediction based on RH and temperature was developed. It states that if hourly temperature remains in between 10-20^{0}C associated with the RH ≥80% for continuous 18 hr for at least 2 consecutive days, late blight would appear within a week. This model has been put to successful use for predicting late blight in Shimla hills since 1983 and it is still working very well.

Forecasting for sub-tropical plains

Late blight forecasting in the sub-tropical plains is different to that of temperate highlands as 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. A computerized forecasting model '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. For rainy years, if 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^oC) for 105 hrs or more, blight would appear within 10 days time. For non-rainy years, if 7-day moving >85% RH period 60 hrs or more and 7-day moving congenial temperature (7.2-26.6^oC) for 120 hrs, blight would appear within 10 days time. Besides, decision rules for predicting first appearance of late blight in Punjab under non-rainy conditions have also been developed using JHULSACAST model as template. The model specifies that 7-day moving sum of RH ≥ 85% for at least 90 hr coupled with a 7-day moving sum of temperature between 7.2-26.6^oC for at least 115 hr would predict appearance of late blight within 10 days of satisfying the conditions. JHULSACAST has also been calibrated for Tarai Region of Uttarakhand. The model specifies that if 7 day moving relative humidity (≥85%) period ≥ 85 hours and 7 day moving congenial temperature (7.2 to 26.6^oC) ≥135 hrs conditions prevail for 7-consecutive days, blight would appear within 14 days. Similarly, JHULSACAST has also been calibrated for plains of West Bengal. The modified JHULSACAST model could predict late blight within 14 days with accuracy of 100% if 7-day moving relative humidity (≥90%) period ≥105 hrs coupled with 7-day moving congenial temperature (7.2 to 26.6^oC) ≥150 hrs prevail for 7-consecutive days **OR** if 5-day moving relative humidity (≥90%) period ≥65 hrs, 5-day moving congenial temperature (7.2 to 26.6^oC) ≥105 hrs for 5 consecutive days and sum of two consecutive days rainfall (≥2.5 mm) prevail.

Recently, a wireless sensor network was used for validation of 'JHULSACAST' with other late blight forecasting models in western Uttar Pradesh using human participatory sensing approach and results revealed that'JHULSACAST' is more accurate than the other tested models (Jagayasi*et al*., 2015). Based on JHULSACAST, Decision Support System (DSS) has also been developed which has three components i.e.(i) prediction of first appearance of disease, (ii) decision rules for need based fungicide application, and (iii) yield loss assessment model.

INDO-BLIGHTCAST: Pan India Model for Prediction of Late Blight

Recently, INDO-BLIGHTCAST, a web based model has been developed to predict first appearance of late blight using daily weather data of meteorological stations. This is an improvement over JHULSACAST model as it is applicable pan India and requires only daily weather data and does not need local calibration for different regions.Hence, it is more robust and its predictions are more broad based. The model involves computation of physiological days (P-days) and mean relative humidity of the night accrued over seven consecutive days.

The model has two modules one for data entry and the other for the users to see the status of late blight forecast. The data entry module is operated by authorised persons for inputting daily temperature and RH data. The user module can be accessed by any stakeholder, including growers, to know about the blight situation in their region through this model. The late blight status is displayed through colour. Green colour indicates that late blight is not likely to appear soon; yellow colour indicates that late blight would appear very soon; and red colour indicates that the weather conditions have become congenial for late blight and it can appear any time within fifteen days. Thus, depending upon the time required for taking control measures, the user may start preventive measures at yellow or red colour indication. The model has been developed and tested using the data on late blight appearance collected at CPRI regional stations and AICRP centres over the past several years. The model was tested at different locations in the plains, tarai region and the hills and the results showed that it predicted late blight appearance at all the locations within the stipulated period of 15 days.

Early Blight Forecasting

Early blight is a serious disease of potato which occurs in relatively warm and humid regions. Among the fungal diseases of potato, it is next only to late blight worldwide as far as economic importance is concerned. Therefore, forecasting of early blight under Indian situations is essential. Recently, a model based on P-days has been developed to predict appearance of early blight. The model specifies that early blight would appear at accumulated P-days of 300 when P- days are calculated with the lower, optimum and maximum cardinal temperatures of 7.2, 25 and 35^{o}C, respectively. The user has to input the daily weather data and start date as well as date of forecast. The software would compute the P-days accrued from date of planting (start date) till the date of forecast according to the cardinal temperatures. As soon as P-days reaches to 300, software would issue an advisory "*watch out for early blight symptoms and spray the crop if it has appeared*". The software advises adoption of control measures only if symptoms are observed because early blight does not spread as fast as late blight.

Suggested References

Arora RK, Sharma Sanjeev and Singh BP. 2014. Late blight disease of potato and its management. *Potato J*. 41(1): 16-40.

Singh BP and Sharma Sanjeev. 2013. Forecasting of potato late blight. *Intern. J. Innov. Hort*. 2(2): 1-11.

Singh BP, Govindakrishnan PM, Ahmad Islam, Rawat Shashi, Sharma Sanjeev and Sreekumar J. 2016. INDO-BLIGHTCAST-A model for forecasting late blight across agroecologies. *Intern J Pest Managem*DOI.org/10.1080/09670874.2016.1210839

Chapter - 03

ADOPTION AND IMPACT OF IMPROVED POTATO VARIETIES IN INDIA

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India is predominantly an agriculture based country in which agriculture and allied activities contributes about 17 percent to the country's Gross Value Added and provides employment to about 54.6 percent of the population. Potato plays a very important role in Indian agriculture as potato alone contributes about 21 percent of the total vegetable area and 26 percent of total vegetable production of India. Potato is a nutrient-rich crop which provides more calories, vitamins and nutrients per unit area than any other staple crops. FAO declared potato as the crop to address future global food security and poverty alleviation during 2008. As per FAOSTAT data for the year 2017, India with 48.6 million t is ranked second in potato production in the world, only behind China with 99.2 million t. The productivity in India is higher than in China and Russia, the third largest potato producer. However, the productivity is lower than most of the developed European countries. One of the major reasons is that, in Europe, 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.

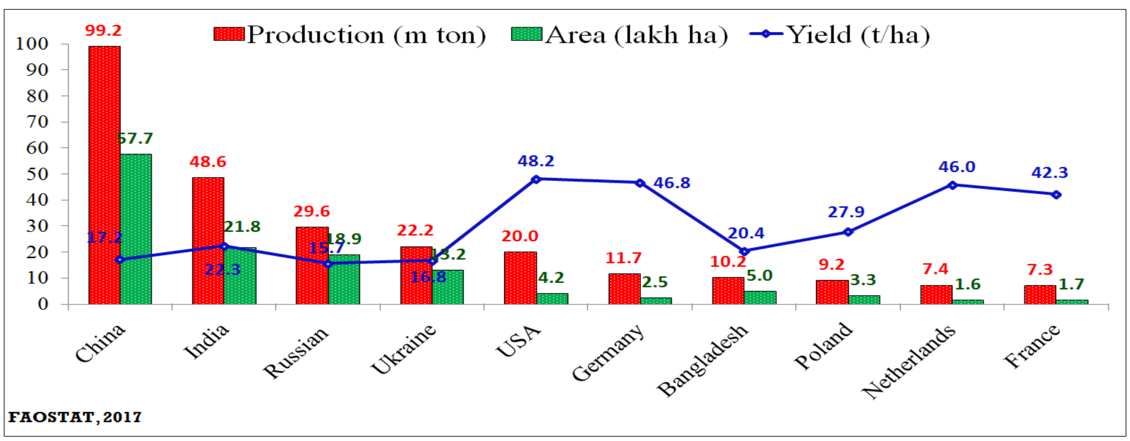
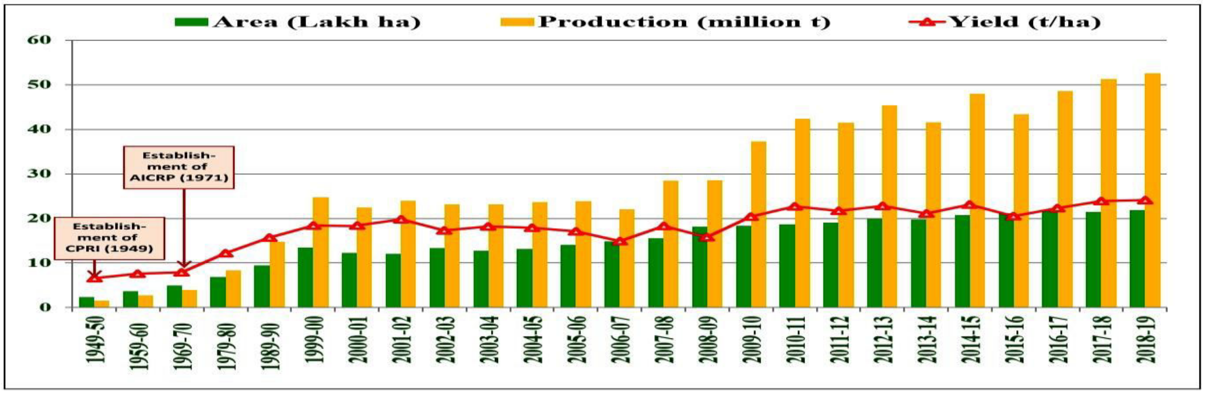


Fig.1: Top 10 potato producers in the world

Trends in area, production and productivity of potato in India

At the time of inception of CPRI, in the year 1949, India produced only 1.54 million t potatoes from 0.234 million ha area at an average productivity level of 6.58 t/ha. As per the 1st advance estimates by National Horticulture Board, the potato production in India during 2018-19 was 52.6 million t from 2.18 million ha area with a productivity of 24.13 t/ha. Over the period of 1949-50 to 2018-19, the compound annual growth rate (CAGR) in potato area, production and yield were 3.3 per cent, 5.4 percent and 2.0 per cent per annum, respectively. It is the hard work of potato farmers, scientists and policy makers that potato area, production and productivity increased over 7 decades by 8.5, 34.06 and 3.65 times, respectively. Contribution of CPRI and AICRP on Potato has been adequately recognised by the nation on several occasions.



Compound Annual Growth Rate (%) of area, production and yield of potato in India

Year	Area	Production	Yield
2009-10 to 2018-19	2.1	3.2	1.1
1949-50 to 2018-19	3.3	5.4	2.0

Fig. 2: Trends in area, production and yield of potato in India

Adoption of improved potato varieties in India

The adoption of improved potato varieties is critical for achieving sustainable and higher productivity and production. So far, Central Potato Research Institute, Shimla has developed 58 potato varieties for different agro-climatic regions of the country and majority of them are for north Indian plains. Potato varieties developed by CPRI are very popular among farmers and cover nearly 95% of total area under potato. Four varieties, *viz.* Kufri Jyoti, Kufri Bahar, Kufri Pukhraj, and Kufri Chipsona1 together contributed around 75% of total area under potato. The varietal adoption patterns of potato varieties in major producing states are as follows:

Uttar Pradesh: The study conducted during 2016-17 crop season showed that overall, varieties like Kufri Bahar (38 % of potato area), Kufri Pukhraj (21 %), Kufri Khyati (12 %) and Kufri Chipsona-1 (9 %) were the leading potato varieties in Bulanshahr and Meerut district of Uttar Pradesh.

West Bengal: The survey conducted in Bardhaman and Hooghly districts of West Bengal for 2017-18 crop season revealed that overall, Kufri Jyoti (52 % area) was the most popular variety, which was followed by Kufri Chandramukhi (18 %) and Kufri Pukhraj (16.2 %).

Bihar: A survey for assessing varietal adoption patterns in two major potato growing districts, *viz.,* Nalanda and Patna of Bihar during 2016-17 crop season revealed that Kufri Pukhraj (69.53 % potato area) was the most popular variety, followed by Kufri Sindhuri (6.8 %) and Kufri Khyati (5 %).

Madhya Pradesh: In Madhya Pradesh, Kufri Chipsona-3 (26.5 % area) and Kufri Chipsona-I (22.3 % area) were the leading potato variety closely followed by Kufri Jyoti (22.07% area) during 2014-15 crop season.

Gujarat: Thesurvey conducted in Banaskantha and Aravalli district of Gujaratduring 2017-18 crop season revealed that the most popular varieties were Lady Rosetta (40.5 %) and Kufri Pukhraj (33.3 %). Other important varieties were Kufri Lauvkar (12.6) and Kufri Badshah (6.3 %).

Punjab: Study in Jalandhar, Ludhiana and Hoshiarpur districts of Punjab revealed that during 2016-17, Kufri Pukhraj was the most popular variety in both Jalandhar (50%) and Hoshiarpur (76%). Other popular varieties of Jalandhar were Kufri Jyoti, Lady Rosetta and Badshah. But, in case of Ludhiana processing varieties from private companies,like Lady Rosetta (28%), FC-3 (25%) and FC-5 (15%) were popular among farmers. CPRI varieties like Kufri Chipsona-1 (16%) and Kufri Chipsona-3 (13%) were also having significant area under potato.

Assam: In Assam, Kufri Jyoti (50 % potato area) and KufriPukhraj (33% area)were the most popular varietiesduring 2015-16 crop season.

Meghalaya: In Meghalaya, Kufri Jyoti (34% area) and Kufri Megha (14% area) were the leading potato varieties followed by Kufri Giriraj 10% area) during 2015-16.

Impact of major CPRI varieties in India

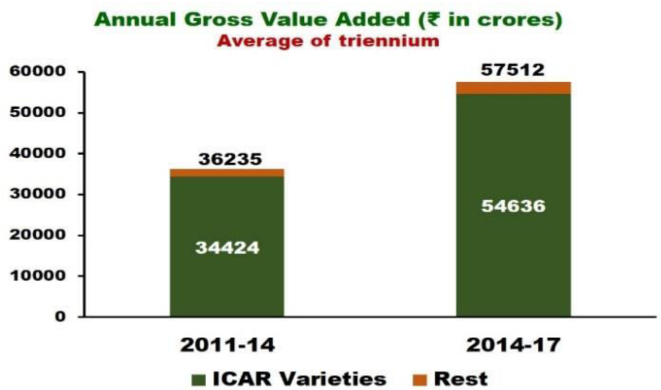
Potato varieties developed by ICAR-Central Potato Research Institute cover nearly 95% of total area under potato. India produced about 45.87 million tonnes of potato annually during the triennium 2014-17 and contributed Rs. 57,512 crore annually to the Gross Value Added (GVA) at current price. The varieties developed by ICAR-CPRI contributed Rs. 54,636 crore annually during this period.

Kufri Jyoti, a day-neutral variety released in the year 1968 played a lead role in popularizing potato throughout the country. Because of wide adaptability of this variety, potato emerged as a principle component of the profitable maize-potato-wheat sequence in the vast North-western plains. Presently it occupies about 21% area in the country and thereby contributing about Rs. 11,800/- crore to the agricultural economy.

Kufri Bahar released in 1980 became the principal potato variety of Uttar Pradesh, the highest potato producing state of the country. It occupies about 17% area in the country and contributes about Rs. 9,551/- crore to the agricultural economy.

An early bulking variety (60 days), **Kufri Pukhraj** released in 1998 is the leading variety today in India occupying >33% area. It contributes about Rs. 18,541 crore in the agricultural economy of the country. It is most suitable for rice-wheat based sequence in the northern plains.

Kufri Chipsona 1released in 1998 is 4th leading variety of the country today occupying about 4% area under potato and contributing about Rs. 2,247/- crore to the agricultural economy. Besides, five more processing varieties have been released by the Institute catering to almost 35% of raw material for the processing industries. Potato processing companies like M/S Frito Lay India (Pepsico), ITC Ltd., Merino Industries, Mc Cains India, PRAN Food Ltd., Haldiram, Pailan Food Ltd., Balaji Wafers, Golden Fries, Bikaji Foods International Ltd. etc. use Indian processing varieties and sell their products as >100 brand names. This has resulted in tremendous growth of processing sector from mere <1% during 1990s to > 8% now.



Impact Assessment of potato varieties using Economic Surplus Model

Kufri Pukhraj: The Economic Surplus Method with closed economy was used to measure the benefits of and returns to research and development (R&D) of an early bulker and drought-tolerant potato cv. Kufri Pukhraj in India. A period of 40 years from 1978 (the year in which breeding of Kufri Pukhraj started) to 2018 was considered for developing the cost–benefit stream. All these estimates of costs and benefits were expressed in real terms by adjusting to Wholesale Price Index with 2018 as the base year. The results of the model revealed that the total cost of R&D of Kufri Pukhraj was Rs. 12.1 crore. The Net Present Value (NPV) of the benefits of Kufri Pukhraj R&D was Rs. 9012crore and 3328 crore at 5 and 8 per cent discount rate respectively and the internal rate of return (IRR) of the net benefit was 41 %.

Kufri Chipsona-3: Economic Surplus Model was used for assessing the impact of returns to research investment for developing processing potato cv., Kufri Chipsona-3. Research cost computed for the period 1990-91 to 2006-07 while the adoption cost was estimated during 2007-08 and 2012-13. All estimated expenses were adjusted to consumer price index of industrial workers with the 2012-13 as base year. Returns to investment for developing Kufri Chipsona-3 were evaluated during different scenario in order to articulate different funds availability situations. It was found that the IRR was 58.90 %. The net present worth was found to be Rs. 5871 million and 2726 million at 5 % and 10 % interest rate.

Chapter - 04

IMPACT OF CLIMATE CHANGE ON POTATO PRODUCTION: PRESENT SCENARIO AND ADAPTATION STRATEGIES

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Climate change is posing serious threat to human survival on the earth in one or the other way. The disturbances in earth's climate have been greatly accelerated during the past century. It's a well-established fact that greenhouse gas (GHG) emission is responsible for climate change and is increasing rapidly at an alarming rate.

Potato is the third major food commodity of India after rice and wheat in terms of production. India has made tremendous progress in potato production and the per capita availability of potato has increased from 4.37 kg in 1950 to 21.52 kg in 2012. However, the climate change is likely to have a negative effect on potato growth in India, including productivity, production and profitability. The increase in CO_2 is expected to bring on increase in productivity of potato as reported by many workers. However, increase in temperature and atmospheric CO_2, both are interlinked and occur simultaneously and the CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on tuber yield. Worldwide potato crop losses due to late blight have been estimated at €12 billion (Haverkort *et al.,* 2009). In India, severity of late blight varies from region to region, being more severe in temperate highlands than in the sub-tropical plains with an average of 15% crop losses annually (Collins, 2000). In case of late blight, the effect of climate change on the most dreaded disease of potato in India also, could be mixed. Late blight caused by *Phytophthora infestans* is often regarded as the most important disease of potato globally. In potato cultivation, potato seed is most expensive input accounting for 40 to 50% of the production cost. Since the eastern, northeastern, Deccan and south western parts of the country are not suitable for quality seed production barring few locations, the farmers of these areas have no option but to buy the seed potato from northern India. The high hills of Himachal Pradesh, Indo-Gangetic plains of Punjab, Haryana, north-western part of Uttar Pradesh, and Bihar are suitable for nucleus and breeder seed production. However, Punjab and western Uttar Pradesh are two major states which supply quality potato seed to rest of the country. In case of climate change scenario, the temperature change is likely to affect the late blight outbreak in Punjab and western Uttar Pradesh, thus affecting the potato seed production.

Bacterial wilt is causing huge losses in warmer area of Madhya Pradesh and plateau region. Presently, in North Western Indo-gangetic region, the disease severity is very less but due to warming, the disease may enter the new areas where it is not present. The present studies were conducted to assess the yield losses due to climate change, to develop suitable adaptation strategies and to assess effect of climate change on late blight and bacterial wilt prevalence. In this paper, I'm presenting the findings of studies carried out at ICAR-CPRI, Shimla on climate change impact on potato production.

Impact on potato productivity

For impact on potato productivity, we used WOFOST (**Wo**rld **Fo**od **ST**udies) crop growth simulation. WOFOST, a mechanistic model which simulates the growth of a crop based upon eco-physiological processes is widely used to assess the effect of climate change on the growth and yield of many crops which includes wheat, rice, maize potato, barley, soybean, sugar beet throughout the world (Boogard *et al*., 1998, Wolf *et al*., 2010) and is one of three most widely used crop growth model for climate change studies (Diepen*et al*., 1987). WOFOST has been calibrated for Indian potato cultivars using the time course data on potato growth and development (Dua*et al*., 2014). Hence, WOFOST model was used for impact assessment of climate change on potato productivity and scheduling planting date and selection of suitable cultivar to minimize climate impact in Uttar Pradesh, Punjab, Madhya Pradesh, Gujarat, Bihar and West Bengal. The simulation studies were carried out for four potato cultivars, Kufri Badshah, Kufri Bahar, Kufri Pukhraj and Kufri Jyoti. The model was run for different planting dates depending upon the locations and the cultivar selected. The simulation study was carried out for potential yields of potato cultivars for all the scenarios. IMD district normals of 1971-2000 of 61,13, 29, 13, 20 and 38 districts of Uttar Pradesh, West Bengal, Bihar, Gujarat and Madhya Pradesh respectively were used for baseline scenario (year 2000). The simulation studies were carried out for A1FI high emission scenario. For generation of scenario for 2020 and 2055, projected changes in surface air temperature for sub-regions of the Asia under SRES A1FI pathway, based on the Fourth Assessment Report (AR4) Atmosphere-Ocean General Circulation Models (AOGCMs) were added on the baseline data. Projected atmospheric CO_2 concentration based on the Bern-CC model for A1FI scenario was used for incorporating the effect of change in CO_2 concentration in WOFOST model. The figures used in this study for atmospheric CO_2 concentration were 367 ppm (for baseline), 415 ppm (for 2020) and 590 ppm (for 2055).

Punjab: The potential productivity of Kufri Badshah, Kufri Pukhraj and Kufri Jyoti was 52.6, 51.2 and 49.0 t/ha under baseline scenario. Under future climate scenario, when the effect of temperature and CO_2 fertilization was considered together, productivity of Kufri Badshah is projected to remain unchanged in 2020 (-0.08%) and will reduced by 2.62% in 2055. However, in case of Kufri Jyoti an insignificant 0.4% increase is expected in 2020 (from 48.9 to 49.0 t/ha), which will decline by 4.59% to 46.6 t/ha) in 2055 as compared to baseline yield. The maximum increase is likely in productivity of Kufri Pukhraj from 50.8 to 51.2 t/ha (0.69%) in 2020 and maximum decline (to 48.1 t/ha; 5.33%) in 2055.

Uttar Pradesh: The productivity of Kufri Badshah Kufri Bahar and Kufri Pukhraj was 46.0, 46.8 and 45.3 t/ha respectively under baseline scenario. The productivity under climate change scenario is expected to decrease by 5.5, 6.1 and 7.0 per cent respectively for Kufri Badshah, Kufri Bahar and Kufri Pukhraj during 2020 and by 9.4, 10.9, 13.4 percent respectively in 2055 as compared to the baseline scenario (Table 1).

Bihar: In the baseline scenario, the potential productivity of potato in Bihar was 40.7, 38.7 and 40.8 t/ha for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj respectively. A decrease of 5.1, 6.2 and 6.9 percent in productivity was recorded during 2020 while productivity is likely to decrease by 8.7, 10.8 and 12.7% during 2055 for the three cultivars, respectively.

West Bengal: In West Bengal under the baseline scenario, the potato productivity was 38.9, 37.2 and 39.2 t/ha for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj respectively. A decrease of 5.1, 5.9 and 6.1 percent in productivity was recorded during 2020 while productivity decreased by 8.8, 10.5 and 12.0 percent during 2055 for the three cultivars respectively.

Gujarat: The potential productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj was 40.3, 36.1 and 37.5 t/ha respectively under baseline scenario 2000.The productivity under climate change scenario was found to decrease by 7.6, 9.7 and 10.9 per cent respectively for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj during 2020 (Table 1). The productivity was found to increase by 19.5 per cent for Kufri Badshah while it decreased by 22.1 and 25.5 respectively for Kufri Jyoti and Kufri Pukhraj during 2055 as compared to baseline scenario.

Madhya Pradesh: Under baseline scenario of 2000, the potential productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj was 43.6, 40.0 and 42.2 t/ha respectively. The productivity under climate change scenario was found to decrease by 6.4, 7.3, 7.6 per cent respectively for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj during 2020 and it decreased by 10.9, 12.8 and 14.3 respectively for the three cultivars during 2055 as compared to baseline scenario.

Overall, the impact analysis using WOFOST crop growth model has shown that under A1FI scenario of climate change although there will be no change in potato productivity in Punjab in 2020, in other states the productivity is likely to decline in 2020 (Uttar Pradesh - 5.5 to 7.1%, Bihar - 5.1 to 6.9%, West Bengal - 5.1 to 6.1%, Madhya Pradesh - 6.4 to 7.6% and Gujarat - 7.6 to 10.9%) and 2055 (Uttar Pradesh - 9.4 to 13.4%, Bihar - 8.7 to 12.7%, West Bengal – 8.8 to 12.0%, Madhya Pradesh – 10.9 to 14.3% and Gujarat – 19.5 to 25.2%) (Table 1). With the simple and practical adaptation measures like change in date of planting and selection of suitable variety, the decline in productivity can be brought down to 5.2, 1.9, 4.1, +1.7 and 0.8% in 2020 and 9.2, 6.6, 8.1, 3.6 and 10.4% in 2055 in Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh and Gujarat, respectively.

Table 1: Change in potato yield over baseline scenario.

State	Cultivar	Baseline yield (t/ha)	Change in yield in 2020		Change in yield in 2055	
			Without adaptation (t/ha)	With adaptation (t/ha)	Without adaptation (t/ha)	With adaptation (t/ha)
Bihar	*Kufri Badshah*	40.7	-5.1	-1.91	-8.7	-6.6
	Kufri Jyoti	38.7	-6.2		-10.8	
	Kufri Pukhraj	40.8	-6.9		-12.7	
West Bengal	*Kufri Badshah*	38.9	-5.1	-4.1	-8.8	-8.1
	Kufri Jyoti	37.2	-5.9		-10.5	
	Kufri Pukhraj	39.2	-6.1		-12.0	
UP	*Kufri Badshah*	46.0	-5.5	-5.2	-9.4	-9.2
	Kufri Jyoti	46.8	-6.1		-10.9	
	Kufri Pukhraj	45.3	-7.0		-13.4	
MP	*Kufri Badshah*	43.6	-6.4	1.7	-10.9	-3.6
	Kufri Jyoti	40	-7.3		-12.8	
	Kufri Pukhraj	42.2	-7.6		-14.3	
Gujrat	*Kufri Badshah*	40.3	-7.6	-0.8	-19.5	-10.4
	Kufri Jyoti	36.1	-9.7		-22.1	
	Kufri Pukhraj	37.5	-10.9		-25.2	
Punjab	*Kufri Badshah*	52.6				
	Kufri Jyoti	49.0				
	Kufri Pukhraj	51.2				

Impact on Late Blight

JHULSACAST model was used to work out the effect of climate change on potato late blight outbreak, duration of favourable period and disease severity in Uttar Pradesh, Punjab and West Bengal. The model requires hourly temperature data (°C), relative humidity (RH %) and daily rain (mm) data as input. The model was run for baseline scenario (year 2000) and future climate scenarios (years 2020 and 2055). IMD district normal of 1971-2000 were used for baseline scenario (year 2000) and for future climate scenarios of the years 2020 and 2055 A1FI scenario of temperature (SRES A1FI pathway) was used. It is not possible to predict the daily humidity in years 2020 and 2055 during cropping period, therefore, we assumed that favourable RH would start from a week of emergence of the crop in western Uttar Pradesh and Punjab respectively and proceed with 10 days intervals after the setting of required RH. Thus, the model results are the outcome of the effect of temperature input. To estimate the number of sprays required in seed crop, the daily severity values were calculated on the basis of decision support system developed for western Uttar Pradesh and Punjab (http://cpri.ernet.in). The number of sprays needed in seed crop was calculated by dividing total accumulated severity by 180 for contact fungicides. The value of divisor 180 was derived empirically. The study was done for entire Punjab state, 23 contiguous districts of western Uttar Pradesh and 11 districts of West Bengal. The JHULSACAST model was run on available weather data for 13 districts of Punjab, 21 districts of western Uttar Pradesh and 11 districts of West Bengal. Appearance of late blight is expected to be delayed in both 2020 and 2055 climatic scenarios in all the three states based on Jhulsacast Model. The number of days favorable for the disease will increase in Punjab. The earliest Late Blight appearance, which is 13-15 October, in 2000, may be delayed by 0-6 days in 2020 and 12-14 days in 2055. However, due to rise in temperature in future scenario, there will not be mid-season breaks in late blight favourable days. The late blight favorable days during 2000 were 105 and these increased by 30 and 35 days by 2020 and 2055, respectively. Hence more number of fungicide sprays will be required for the control of this disease. However, in the remaining two states the number of favorable days for late blight may decrease and hence less number of fungicides sprays will be required.

In western Uttar Pradesh, earliest late blight appearance during the potato crop season is predicted during 13th October to 1st November in baseline year 2000 and is expected to be delayed by 0 to 8 days in 2020 and 10-21 days in 2055. The delay in late blight appearance in 2020 and 2055 is due to expected increase in temperature by 1.08 and 2.98 ºC respectively over the baseline year 2000. In western Uttar Pradesh, potato growing season would be warmer which would decrease late blight favorable days by 7 and 27 in 2020 and 2055, respectively. The maximum number of sprays required to control late blight in potato seed crop thus would be 7.3 and 8 in future scenario (2020 and 2055) in comparison to 6.5 in baseline (2000) in Punjab. In contrast, there would be no change in number of sprays in year 2020 (over baseline year 2000) in western Uttar Pradesh, however, due to further increase in temperature in year 2055, it could be reduced by 2.

In West Bengal, earliest late blight appearance during the potato crop season was predicted during 4th to 11th October in baseline year 2000 and is expected to be delayed by 7.6 days in 2020. The delay in late blight appearance in 2020 is expected due to increase in temperature by 1.08 over the baseline scenario. However, due to delay in appearance of late blight in the season, the total late blight favorable period is likely to be reduced by 17.7 days in 2020, respectively. The number of sprays required to control late blight in potato seed crop would be 4.2 in future scenario of 2020 in comparison to 5.5.5 in baseline (2000) in West Bengal. Hence, less number of fungicides sprays will be required.

Impact on survival of *R. solanacearum* in potato growing districts of plateau region

For studying the survival of *Ralstoniasolanacearum* in soils of plateau region of India, results of the experiment conducted under controlled condition of various temperatures on the survival of *R. solanacearum* in soil were used to develop. A logical mathematical model which give the time (in days) in which the bacterium will not survive in the soil. The model gives the results on the basis of daily mean soil temperature. For baseline survival, IMD normal were used and for future climate, temperature rises for A1F1 scenario of the climate change for 2020 and 2055 were added on the baseline temperature. The presence of *R. solani* in the soil was presumed on 1st of January and the days it will survive in the soil of 60 potato growing districts of eight states in plateau region of India were worked out, based upon soil temperature.

Tamil Nadu and Kerala: Under the baseline climate scenario (2000), the bacterium would survive till 18th March in soils of Idukki, Kannur, Malappuram, Pathanammitha, Wayanad districts of Kerala and Dharamapuri, and Virudinagar districts of Tamil Nadu and no changes are expected in 2020. However, in 2055, the bacterium is likely to survive in soil of these districts till 03 March only. The bacterium is likely to disappear 0-05 days earlier in 2020 and 05 to 15 days in 2055.

Karnataka: The bacterium could survive in soil till 18 March in Gadag, 7 April in Dharwad, Bidar, Chitradurga, Karwar, Udupi, and 27 April in Rural and Urban Bangalore districts of Karnataka in baseline scenario. In 2020, the bacterium is likely to survival in soil till 18th march in some areas of Dharwad and Chitradurg while in rest of districts, no change is expected. The bacterium is likely to disappear 0-08 day earlier in 2020 and 11-15 days in 2055.

Andhra Pradesh, Maharashtra, Odisha and Chhatisgarh: The bacterium may survive in soil from 7 to 27 April in different districts and is likely to disappear 3-8 and 11-25 days earlier in Andhra Pradesh and Maharashtra, 3-8 and 11-20 days in Odisha and 3-5 and 11-15 days in Jharkhand in 2020 and 2055, respectively.

Jharkhand: Under the baseline (2000), the bacterium could survive in soil maximum till 27 April in Gumla and 17 May in Ranchi and Singhbhum. No change is expected in Gumla in 2020, however, in Ranchi and Singhbhum, the survival is likely to be up to 6th May only.

Madhya Pradesh and Gujarat: The bacterium may survive in soil from 27 April to 17 May in different plateau districts of Madhya Pradesh and Gujarat in 2000. The bacterium is likely to disappear 3-8 days earlier in 2020 and 5-15 days in 2055 in Madhya Pradesh and 3-5 days earlier in 2020 and 11-26 days in 2055 in Gujarat.

Rajasthan: Under the baseline climate scenario (2000), the bacterium survived in soil till 17 May. The period is likely to reduce by 0-5 days in 2020 and 5-15 days in 2055.

Adaptation and Input Strategies

The various adaptation strategies to combat the impact of climate change on potato productivity may include breeding short duration and heat tolerant cultivars, developing potato cultivars that tuberises at higher night temperatures. Mining for biodiversity to heat tolerance should be given priority. Breeding drought and salinity tolerant cultivars would be effective to face the future challenges of climate change. Use of wind breaks around fields and crop residue mulches for some period after planting, using drip and sprinkler irrigation in place of furrow and basin methods and altering cultural management in potato based cropping systems are few examples of agronomic management practices to reduce the impact of climate change. Besides, conservation tillage and on farm crop residue management are required to increase input use efficiency. Advance planning for possible relocation and identifying new areas for potato cultivation is needed. Improvement and augmentation of cold storage facilities and air conditioned transportation from producing to consumption centers will be required for storage and transportation of this semi-perishable commodity. Strengthening education, research and development in warm climate production technology for ware and seed potato crop is also required to meet the production targets in future climates.

Suggested References

Boogaard, H. L., Van Diepen, C. A., Rötter, R. P., Cabrera, J. M. C. A. and Van Laar, H, H.1991.WOFOST 7.1; User's guide for the WOFOST 7.1 crop growth simulation model and WOFOST Control Center 1.5. Wageningen (Netherlands), DLO Win and Staring Centre. Technical Document.

Collins, W.W. 2000. The global initiative on late blightalliance for the future. In, Potato, Global Research and Development Vol. I (Eds S. M. P. Khuranaetal.), Indian Potato Association, CPRI, Shimla, India.

Chapter -05

BREEDING POTATO VARIETIES FOR DIFFERENT PARTS OF INDIA

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The potato (*Solanum tuberosum* L.) is believed to have originated near Lake Titicaca basin in Peru-Bolvian region, where the largest genetic diversity of potato exists. Potato belongs to the family *Solanaceae* and the large genus *Solanum*, which contains about 2000 species, out of which nearly 235 are tuber bearing (Hawkes, 1990).

These are confined mainly to the Andean region of South America. The basic chromosome number in potato is $\underline{x} = 12$ (Howard, 1970). The ploidy level of potato species varies from $2\underline{x}$ to $6\underline{x}$ (Hawkes, 1994). The commonly cultivated potato is an autotetraploid (Swaminathan and Howard, 1953) and belongs to the species *Solanum tuberosum* L ($2\underline{n} = 4\underline{x} = 48$), which includes two subspecies viz. ssp. *tuberosum* adapted to long days and ssp. *andigena* adapted to short days. Besides these, seven primitive species viz., *Solanum ajanhuiri*, *Solanum goniocalyx*, *Solanum phureja* and *Solanum stenototum* (all diploids); *Solanum chaucha* and *Solanum juzepczukii* (triploid); and *Solanum curtilobum* (pentaploid) are also under cultivation, but are restricted to the high Andes from Central Peru to Central Bolivia. While ssp. *andigena* is confined to Andes of Venezuela, Colombia, Equador, Peru, Bolivia and North-West Argentina; the ssp. *tuberosum* has become most widespread and cultivated in Europe, Asia and elsewhere.

Cultivated potato is tetraploid and highly heterozygous. Heterosis is observed on crossing diverse parents. More than 50 traits should be combined in a modern potato variety (Ross, 1986) and this complicates the choice of parents for production of such a progeny. Hence, breeding of potato involves hybridization between identified parents and selection of superior clones from the progeny. The genetic constitution of the genotype obtained following hybridization is fixed in seedling stage, and due to vegetative propagation the genetic constitution of potato genotype with all its intra- and inter-locus interactions responsible for its phenotypic expression are maintained in the clonal generations. Hence, a clone if perceived desirable can be multiplied for commercial cultivation even though initially it may be present as a single plant.

In India, potato breeding programme was initiated in 1935 at the Potato Breeding Station, Shimla. However, a regular breeding programme was started in 1949 with the establishment of the Central Potato Research Institute (CPRI) at Patna, Bihar. Headquarter of the CPRI was later on shifted to Shimla in order to facilitate hybridization and maintenance of seed health. The major breakthrough in potato improvement programme came in 1963 with the development of "Seed Plot Technique", which made it possible to raise, evaluate, select and multiply breeding material under disease free conditions in plains. This led to the development of a system, wherein crossing was attempted in the hills and raising of seedling, evaluation and maintenance of segregating population was done in the plains. This approach yielded rich dividends both for potato improvement and potato seed production in the country. All varieties released by the CPRI carry the prefix 'KUFRI' as a memento to the place of hybridization.

India has diverse soil types and agro-climatic conditions. Successful potato cultivation requires maximum and minimum temperatures of 33°C and 15°C with sunny days and cool nights. Indian sub-tropical plains offers optimum conditions for potato cultivation, where 85-90 per cent of potatoes are grown during short winter days from October to Feb. 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. These zones (Table 1) lie in two major potato growing area i.e. north Indian hills and north Indian plains, while southern and north Bengal and Sikkim hills and plateaus are three special problem areas.

Development of potato varieties for different areas is being done under the programme "Breeding to evolve trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses", which address the requirement of potato varieties for table/processing purposes possessing various biotic and abiotic stresses. Parents for hybridization programme are selected based on the objectives of the programme. In general, phenotypic performance, genetic divergence, combining ability, heterosis and progeny tests are considered for selection of promising parents, to generate variability for making selection effective. In order to have a reasonable chance of identifying a 'winning' selection, it is proposed that an initial population of 50,000 seedlings of about 25 cross combinations may be raised. A minimum of 2,000 seedlings per cross are needed to have a reasonable chance of selecting a superior genotype from a cross. The clones from the seedling stage are evaluated in clonal generations. A few promising advance clones are finally included in multi-location testing trials across the country, before a clone is found worth release as a variety for general cultivation (Luthra 2006).

Table 1. Potato zones of India

Zone	Varietal requirements
North-western plains	Short day adaptation, early bulking, heat tolerance and late blight resistance. Tolerance to frost is an added advantage.
West-central plains	Short-day adapted, early bulking, moderate resistant to late blight and slow degeneration rate
North-eastern plains	Short day adapted, early bulking and late blight resistant. Red skin tubers are preferred in some areas.
Plateau region	Early bulking, able to tuberize under high temperatures and resistant to bacterial wilt, mites & potato tuber moth and slow rate of degeneration.
North-western and central hills	Long day adaptation (14 h days), highly resistant to late blight and bacterial wilt.
North-eastern hills	Long day adaptation (14 h days), highly resistant to late blight and bacterial wilt.
Southern hills	Long day adaptation, early bulking, late blight and cyst nematode resistance.
Sikkim and north Bengal hills	Resistance to late blight and immunity to wart. Red skin potatoes are also preferred.

Steps in the development of potato variety

1. ***Selection of parents:*** Selection of parents involves collection, field maintenance, evaluation for adaptability, yield potential, keeping quality/processing quality, biotic (late blight)/abiotic stresses (heat tolerance). The choice of parents is done carefully keeping in mind the objectives of the programme *eg.* for breeding varieties for west-central plains in addition to yield and medium maturity, keeping quality and late blight resistance are important characters to be incorporated.
2. ***Flowering in Potato:*** In potato varietal improvement programme, availability of ample flowers at proper time with functional male and female parts is an indispensable requirement for hybridization. Genotype, day-length and temperature are main factors, which determine the flowering and fruiting in potatoes. Though flower primordia of potato can arise in total darkness, a photoperiod of 14-18 hours and night temperature of 15 to 20°C favour flower production and berry setting (Almekinders, 1992). In tropics and sub-tropics, conditions conducive to flowering and fruiting are available only at high altitudes (>1500m above sea level) where crop is grown during summer season. Under short day conditions, flowering in potato is achieved through extended photoperiod (LD) of 6 hours by 250w high pressure sodium vapour lamps. Application of hormones (GA 50ppm+ IBA10 ppm+Kinetin 2ppm) under LD conditions (LD+H) further enhances the flowering intensity, flowering duration and advances the flowering as well (Luthra and Khan, 2000, Luthra 2005). However hormonal induced flowering (LD+H) reduces flower vigour and size (Khan e*t al*., 1994) and in some genotypes abnormal flowers are obtained leading to pollen sterility (Gopal and Rana, 1988, Luthra 2005).
3. ***Hybridization Technique:*** Emasculation is done in female parents by retaining about 4-5 flower buds/bunch. In the process of emasculation anthers, petals and half portion of sepals is removed. Pollen fertility of the male parents is tested by squashing anthers in 2% Aceotocarmine solution. Freshly opened flowers of male parents are collected and their stigma and petals are removed from the flowers. Anthers are separated in the morning and pollen is extracted shacking anthers in nylon tea sieve and is stored in a refrigerator at 6-8^{0}C if not required immediately. The use of fresh pollen is more effective for better results. Each receptive stigma is pollinated by dipping it in the pollen. Repeated pollination of receptive stigma twice or thrice at interval of 8 hours is known to produce higher percentage of berries per flower bunch and more seeds per berry (Thakur and Uphadhya, 1990). Berries formation can be seen just 4-6 days after pollination. Berries are harvested after 6-7 weeks after pollination and are allowed to ripen at room temperature till they become pale yellow in colour and soft. Berries are macerated by hand or using reverse screw juicer extractor into pulp. Pulp is treated with 10 % hydrochloric acid and stirred for 20 minutes to separate the seeds from debris. Washing of seeds is done by water 3 to 4 times to remove the acid. Clean seeds are dried in shade on a stretched muslin cloth for 72 hours followed by half an hour drying under sun to reduce moisture contents to 5-6 per cent. Seeds are packed in polythene bags and stored over calcium chloride desiccant at 6-10^{0}C in refrigerator.

4. ***Seedling stage:*** If fresh true seeds are used then it is better to treat them with 1500 ppm GA_3 for 24 hours to break the dormancy to achieve uniform germination. Seeds are sown in nursery beds in the last week of September or first week of October in lines marked at a distance of 10 cm apart. Seeds are covered with fine FYM and water is given through sprinkler or water can. The seedlings become ready for transplanting within 25-30 days. Transplanting of seedlings is done on the ridges at 60 x 25cm spacing. Seedlings are raised in plains in aphid free/low aphid period. Seedlings are harvested normally after 90 days of transplanting. Seedlings showing viral infection, long stolen, irregular tuber shape, deep eyes, russetting cracking and undesirable tuber colour are rejected. Yield is not considered at this stage for selection and five tubers each of the selected one are retained for subsequent evaluation.
5. ***F_1C_1 stage:*** Five tubers of each selected clones are planted in short observation rows with control varieties after every 30th row. At full growth, weaklings and diseased (Late blight/virus) clones are rejected. At harvest rejection is again done on the basis of undesirable tuber shape and colour. Harvesting is done at 60/75/90 days after planting as per objective of the programme. At harvest, 30 tubers of the selected clones are retained for further evolution.
6. ***F_1C_2 stage:*** The clones are evaluated in duplicate row trial (30 tuber trial) along with control varieties. On the basis of tubers shape, size and colour inferior clones are rejected. At harvest 120 tubers of promising clones are retained.
7. ***F_1C_3 stage:*** Selected clones from F_1C_2 stage are evaluated in multiple row trial (120 tubers, 8 rows, 15 tubers/row of 3 meter) along with control varieties. At this stage, yield is also taken into consideration in addition to tuber shape, size and color. Promising clones yielding 10 % higher than controls and clones with about 18% tuber dry matter are selected.
8. ***F_1C_4 stage (Preliminary Yield Trial-PYT):*** After cold storage selected clones from F_1C_3 stage are examined for rottage, shrinkage and sprouting. Promising advance hybrids are evaluated in randomized block design (180 tubers, 4 rows of 15 tubers, 3 rep. at each harvest date) along with control varieties. The trials are harvested as per mandate of programme and high yielding advance hybrids with late blight resistance are selected. Keeping quality of advance hybrids is studied at ambient room temperature.
9. ***F_1C_5 stage (Confirmatory Yield Trial-CYT):*** Selected hybrids from PYT are evaluated in randomized block design (180 tubers, 4 rows, 15 tubers/ row of 3 meter, 3 rep. at each harvest date) along with control varieties. The trials are harvested as per mandate of programme and high yielding advance hybrids with late blight resistance are selected. Keeping quality of advance hybrids is studied at ambient room temperature. Tuber material of selected hybrids is supplied for studying NPK requirement, storage behaviour, processing characters, resistance to late blight and other insect pests.
10. ***F_1C_6 stage (Final Yield Trial-FYT):*** Selected hybrids are evaluated as in CYT in randomized block design (180 tubers, 4 rows, 15 tubers/row of 3 meter, 3 rep. at each harvest date) along with control varieties. Based on three-year performance of one or two advance hybrids are introduced in AICRP for multi-location testing.

11. ***All India Co-ordinated Research Project-Potato (AICRP-Potato):*** The promising hybrids are multiplied in seed Preparatory Unit of AICRP at Modipuram following seed plot technique. Tubers of uniform size and same physiological ages are supplied to 18 AICRP centers for conducting genetical trials. In AICRP locations, the advanced stage hybrids are evaluated in IVT (Initial varietal trial), AVT 1(Advanced varietal trial) and AVT 2 and results of these trials (3 years) are discussed in workshop and only best one or two hybrids are recommended for release.
12. ***Release of variety:*** On the recommendation of AICRP-Potato, Central Variety Release Committee releases and notify the best hybrid as variety for general cultivation in the country. At the time of release at least 10 tons of seed should be available with the breeder.

Till date, CPRI has developed and released 65 improved varieties of potatoes and one TPS population (92-PT-27) for commercial cultivation. These varieties cater to the need of the farmers across the country; have superior agronomic attributes and resistance to different biotic and abiotic stresses. The parentage analysis of Indian varieties shows that two varieties namely Kufri Safed and Kufri Red are clonal selections from indigenous varieties Phulwa and Darjeeling Red Round, respectively. Among the varieties, 25 varieties, both the parents are of Indian origin, 27 varieties have one parent of Indian origin and one of exotic origin and remaining 12 varieties have both the parents of exotic origin. The exotic cultivars that have figured more frequently as parents of Indian varieties are Adina, Craigs Defiance, Ekishiraju, Katahdin, Up-to-Date and few parental lines obtained from late Dr. William Black of UK Potato varieties namely Kufri Safed and Kufri Red are clonal selections from indigenous varieties Phulwa and Darjeeling Red Round, respectively and remaining 64 varieties are hybrids. About 90% of potatoes are grown in north Indian plains and commensurate with this area, the largest number (45) of cultivars has been developed for this region. Cultivars have also been developed for north Indian hills and other special problem areas *viz.,* Sikkim and North Bengal Hills and South Indian Hills. The potato cultivars fall in 3 maturity groups *i.e.* 8 are early maturing (75-80 days), 44 are medium maturing (90-100 days) and 14 are late maturing (100-110 days). All the cultivars developed for the hills and newly released medium maturing cultivars for the plains possess resistance to late blight. Cultivars with resistance/tolerance to cyst nematodes (Kufri Swarna), wart (Kufri Kanchan), viruses (Kufri Lalima and Kufri Sindhuri), frost (Kufri Sheetman) and heat tolerance (Kufri Surya, Kufri Lima) have also been bred to address specific problems. Prominent potato varieties are Kufri Jyoti in the hills and state of West Bengal, Kufri Badshah in Gujarat and Kufri Bahar in Uttar Pradesh occupying 80-90% areas under potato in respective states. Rapid degeneration of seed stock is a serious problem in sub-tropical plains of India. The popular varieties Kufri Jyoti, Kufri Bahar and Kufri Sindhuri have a low rate of degeneration. Besides, six varieties *viz.,* Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Himsona and Kufri Frysona, Kufri Chipsona-4, Kufri FryoM, MP/6-39 have been developed for processing purposes. In addition to these, cultivars Kufri Jyoti, Kufri Chandramukhi, Kufri Lauvkar and Kufri Surya are also suitable for processing when grown in specific areas. Recently red skin new potato variety Kufri Lalit and Kufri Manik has been recommended for release for cultivation in eastern plains of India. Among, the new potato varieties Kufri Khyati, Kufri Garima, Kufri Mohan and Kufri Ganga are suitable for growing in North Indian Plains. The new potato variety Kufri Neelkanth produces attractive purple ovoid tubers and is suitable for growing in North Indian Plains. Recently three drought tolerant advanced stage hybrids namely WS/05-146, CP4175 and J/92-167 has been.

In addition to above cultivars, the State Agricultural Departments have also released some potato cultures. These are: ON-1645, PS-555, K-22, and G-4 in Uttar Pradesh; Co-Shimla in Tamil Nadu; and Gulmarg Special and Gulmarg Queen in Jammu & Kashmir. Some of these cultures *viz.*, ON-1645 and K-22 are still in cultivation in small pockets of Uttar Pradesh and Bihar. Many Indian varieties have found favour in foreign countries as well. Indian varieties are grown in Mexico (I-654 as CCM-69.1), Sri Lanka (I-822 as cv. Khrushi, I-1085 as cv. Sita), Philippines (I-1035 as cv. Montanosa, I-1085 as cv. BSUP-04), Madagascar (I-1035 as Mailaka), Bolivia (I-1039 as cv. India), Vietnam (I-1039 as cv. Red skin), Afghanistan (Kufri Chandramukhi), Nepal (Kufri Jyoti, Kufri Sundhuri), Bhutan (Kufri Jyoti) and Bangladesh (Kufri Sindhuri).

Availability of indigenous varieties, good quality seeds and right package of agronomic practices triggered a revolution in potato productivity causing very fast growth in area, production and productivity. The potato production in India during 2017-18 was 51.31 million t from 2.14 million ha area with a productivity of 23.97 t/ha as compared to 1949 when India used to produce 1.54 million t potatoes from 0.23 million ha area at an average productivity level of 6.6 t/ha. It is the hard work of potato farmers, scientists and policy makers that potato production, area and productivity increased over more than seven decades by 33.31, 9.30 and 3.63 times, respectively. India is the second largest annual producer of potato after China.

Suggested References

Almekinders, CJM. (1992). The effect of photoperiod on flowering and TPS production in the warm tropics. *Potato Res*. **35** : 433-442.

Gopal, J and MS Rana. (1988). Induction of flowering in potato in North-western plains of India. *J. Indian Potato Asoc.* 15:91-93.

Hawkes, J.G. (1990). The Potato, Evolution, Biodiversity and Genetic Resources. Belhaven Press, London, 259p.

Hawkes, J.G. (1994). Origin of cultivated potatoes and species relationships. In: Potato Genetics. (Eds : Bradshaw, J.E. and Mackay, G.R.). CAB International, U.K., pp.3-42.

Haynes, K.G. (2001). Variance components for yield and specific gravity in a diploid potato population after two cycles of recurrent selection. Amer. J. of Potato Res. 78: 69-75.

Howard, H.W. (1970). Genetics of Potato (*Solanum tuberosum* L.). Logos Press Ltd., London, pp.20-24.

Khan, I. A; S. K. Luthra and R. Ezekiel (1994). Flowering induction in potato by extended photoperiod and application of growth regulators. In proceedings of "Potato: Present and future". Ed. by G.S. Shekhawat. S.M. Paul Khurana S.K. Pandey & V.K.Chandla. Indian Potato Assoc., CPRI, Shimla. pp. 46-48.

Luthra, SK. 2005. Suitability of Induced Flowering in Potato under Short Day Conditions. Seed Research. 33(2):221-223.

Luthra, SK and IA Khan, 2000. Induction of flowering in potato under short day conditions. In Potato; Global Research and Development- Volume-I (Eds: SM Paul Khurana, GS Shekhawat, BP Singh and SK Pandey). Indian Potato Association, CPRI Shimla. pp.150-152.

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.

Ross, H. (1986). Potato Breeding-Problems and Perspectives. Paul Parey, Berlin, 132p.

Thakur, K.C. and Upadhya, M.D. (1990). True potato seed (TPS) production technology. In Commercial adoption of True Potato Seed Technology- Perspective and problems. (Ed. P.C. Gaur). CPRI, Shimla. pp19-28.

Swaminathan, M.S. and Howard, H.W. (1953). The cytology and genetics of potato (*Solanum tuberosum* L.) and related species. Bibilographia Genetica 16: 1-192.

Chapter -06

AGRONOMY OF POTATO SEED PRODUCTION

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Central Potato Research Institute is distinct from other ICAR institutes as it has functional seed production system, which generates huge revenue. Presently about 2650 tonnes of breeder seed is being produced by CPRI, Shimla and its seven regional stations spread across the country. As per the mandate, the breeder seed is supplied to different state governments as per their requirements, according to potato acreage and multiplication system and it is expected that these state governments will multiply the breeder seed potato in four stages (Foundation-I, Foundation-II, Certified-I and finally into Certified-II) before giving to farmers for commercial cultivation. It is believed that if this is followed in letter and spirit then the country is almost self sufficient as far as seed potato requirements is concerned. However, due to different constraints these state governments are not able to multiply as per the procedure, therefore, huge gap in demand and supply for quality seed potato still exists. This situation is forcing potato growers to use sub standard seed that ultimately reflect in poor yields and lower profits.

By keeping in view the above constraints, agronomic interventions are discussed in the ensuing text by which the quality of seed potato can be improved and ensured during multiplication of breeder seed into Foundation-I, Foundation- II, Certified-I and Certified-II.

Selection of field and crop rotation: The field being used for multiplication of seed potato should be free from soil borne diseases viz., common scab, black scruff, brown rot etc. and nematodes.

Among cultural methods, proper crop rotations should be followed and as per seed act requirements the 2-3 year crop rotation is desirable, means the seed potato crop should not be grown in the same field before two to three years. Besides this there are certain crops viz., tomato, brinjal, lady finger, sunflower etc. which has common insects pests like potato, such crops should never be included in the cropping sequence.

Hot weather cultivation and field preparation:

Hot weather cultivation during May/June is highly desirable. This reduces the infestation of weeds and incidence of soil borne pathogens and pests. Further, it is well documented that green manure crop like *dhaincha* reduces the incidence of soil borne diseases like black scruff and common scab. The green manure crop should be incorporated atleast one month before planting of seed potato crop to facilitate proper decomposition.

Before field preparation the pre planting irrigation is recommended to ensure uniform emergence. As the economical part of this crop exist in the soil hence proper field preparation is required as per soil texture.

Seed preparation and planting: Seed potato should be withdrawn from the cold store 10-15 days before planting. This seed should be spread in shade under diffused light and proper ventilated conditions. It has been reported that diffused light promotes the formation of ABA, which suppress apical dominance and encourages the multiple sprouting. Multiple sprouting in seed crop is desirable to realize higher tuber number per unit area. Moreover, pre sprouted tubers ensure early emergence, better stand, early tuberisation and maturity and higher total and seed sized tubers.

In seed plot technique the timely planting is very vital factor for getting quality and physiologically mature seed. The major reason that deteriorates the quality of seed potato is viruses, which spread though aphids. Through extensive surveys in our country the low aphid periods (<20 aphids/100 compound leaves) have been identified for all seed potato growing states. Accordingly taking the advantage of low aphid period the planting time has been recommended. For UP planting time varies from 2nd week of October to last week of October (west to east).

Crop geometry and Interculture: Seed potato should be planted at 60 -67.5 cm row spacing; however the plant to plant spacing may vary from 15 to 35 cm depending upon the size of the seed tuber. The seed tuber should be placed at 8-10 cm depth in moist zone for quick germination and to avoid greening of developing tubers because exposed tubers become green and chemical haulm killing may damage the tubers. One Interculture is recommended for seed potato crop to increase aeration and reducing the infestation of weeds. The Interculture operation should be done 20-25 days after planting when the plants are of 10-15 cm height. Due care should be taken during Interculture that machinery used or tractor does not touch the potato plants as that may lead to spread of diseases or contact viruses like PVX and PVS. After doing Interculture the earthing up should be completed on the same day after weeding and application of remaining N dose to have better tuber development.

Nutrient management: For seed potato crop the recommended NPK dose is 175 kg N, 80 kg P_2O_5 and 100 kg K_2O per hectare. Half N and full P and K should be applied as basal application, while rest half N should be applied at earthing up.

Water management: The importance of pre planting irrigation has already been highlighted. As potato is shallow rooted crop hence its requirements of irrigation water is quite high (400-600 mm). In sandy/sandy loam soils the light and frequent irrigation (8-10 days interval) is desired. The seed potato crop should not suffer due to water stress especially during critical stages of crop development like stolon initiation, tuberization etc. Presently modern methods of irrigation like sprinkler and drips are becoming popular as these saves about 30-50% irrigation water. It has been reported that in fertigation there is also appreciable saving of N (25%). Besides these, the yield benefits, reduced weed infestation and improved quality have also been documented by using drip and sprinkler in seed potato crop over furrow method.

Weed management: Weeds compete with crop for nutrients, water, sunlight and space. Due to this competition the reduction in potato yield has been reported from 10-80%. In seed potato crop the weed management becomes much more important because weeds serve as alternate host to potato diseases pathogens and pests. As earlier said the major factor that led to degeneration of seed potato is viruses which needs vector to spread them. In potato, aphids (*Myzus persicae* and *Aphis gossypii*) and white fly works as vectors to spread viral diseases. It is well evident that almost all weeds present in the potato field serves as alternate hosts for aphids. Similarly large numbers of potato weeds harbour the diseases pathogens and viruses. The critical period for weed control in plains is 20-40 DAP. In seed potato crop the cultural methods of weed control is not recommended in later phase as frequent entries by human beings or machinery in the field may spreads contact viruses. Hence the chemical weed control remains the only option. Though many herbicides have been recommended to control weeds in potato but the most effective and popular is use of metribuzin @ 500 g/ha as pre-emergence (3-7 DAP). Soil applied herbicides require proper soil moisture for high efficacy.

Roguing: Roguing is the inevitable component of quality seed potato production programme. Rogue out all diseased and off type plants along with the tubers observed during visual observations. Generally three roguings are recommended from 30 days crop stage following an interval of 15 days for successful raising of seed crop.

Plant protection: Potato crop is infested by large number of insects and diseases. Therefore the management of these pests is very crucial for taking disease free seed potato crop. Since last 10-15 years the infestation of apical leaf curl virus (ALCV) has increased to a alarming level. For ALCV white fly acts as a vector, population of this pest is reported to be very high during initial phase of potato crop (October-November). Therefore, for taking good seed potato crop foliar spray of imidacloprid (40 ml/100 liter water) is recommended at 85% emergence to control white fly and other sucking pests. After this, thimet 10 G @ 10 kg/ha should be used along with the urea at the time of earthing up to check the population of aphids, cut worms, white grubs etc under threshold level. After this in seed crop the prophylactic spray (for late blight) on rotation basis of mancozeb (0.2%) or propineb (0.2%) or chlorothalonil (0.2%) is recommended from mid November onwards or when canopy closes, at interval of 8-10 days. However, if the late blight has been appeared in seed crop or even in the vicinity then instead of mancozeb/propineb/chlorothalonil the combination of mancozeb and systemic fungicides like cymoxanil based (0.3%) at 8-10 days interval is recommended to keep the disease under check. The systemic insecticides like imidacloprid (30 ml/100 liter water) or thiomethoxam 25G (40-50 g /100 liter water) should also be spray to control the build up of aphids and minor pests. This spray on rotation basis should be repeated after 10 days. Both the insecticides can be clubbed with the fungicidal spray for late blight management.

Haulm killing: In seed crop the killing of haulm have been recommended before reaching the aphid population at critical level (20 aphids/ 100 compound leaves at unsprayed crop). The main purpose of haulm killing is to stop the spread of viruses due to aphids. Besides this, the haulm killing also check the tuber growth and ensure skin hardening. The use of non selective contact herbicide paraquat (gramaxone @ 3 litre/ha with 1000 litre water) has been recommended to kill both haulms and weeds. Exposed tubers should be covered with soil immediately after haulm killing. Further more, the regrowth of haulms should again be check to spread of viruses.

Harvesting: In seed potato crop the harvesting is recommended 15-20 days after haulm killing. This duration has been found optimum for skin curing to avoid skin bruising. At this stage cut/crack/bruised/damaged and diseased tubers should be removed to stop the spread of infection.

It has been found that 225-250 q/ha seed tuber yield can easily be harvested by adopting the above said agro techniques.

Curing: The basic purpose of curing is skin hardening and healing of wounds that may occur during harvesting. For curing, the healthy seed potatoes are heaped to a height of 1to 1.5 m with 4 to 5 width in shade and ventilated area for about 10-15 days depending upon the weather and cultivars skin thickness. The heaps should be covered with gunny bags/tirpal/patera mats etc. Heaps should not cover with polythene sheets.

Grading: It is required to ease in managing plant to plant spacing in subsequent crop and for better marketing. It can be done either by manual methods or by mechanical graders. According to seed act the tubers of 20 to 125 g are seed potatoes. Tubers of >125 g are oversize and <20 g are chats. Chats should not be used for seed as these are physiologically immature due to late setting and more prone to viral infections.

Seed treatment and storage: It is being done to check the soil borne diseases in subsequent crop. For this the seed potatoes are dipped in 3 % boric acid solution for 10-15 minutes and then dried in shade before packing. Once prepared the boric acid solution can be used for 15 to 20 times, if properly washed tubers are being dipped.

Since seed are required to be stored for long time (6 to 8 months) hence its proper storage is must. Seed potato must be stored in cold stores by maintaining 2-4^0C temperature.

Chapter -07

VALUE-ADDED PROCESSED FOOD PRODUCTS FROM POTATO

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Potato (*Solanum tuberosum L*) belongs to the family Solanaceae, occupies an important plant kingdom comprising a large and composition group of about 90 genera and 4000 species (Marwaha, 2007). Potato is a non-cereal crop grown in about 150 countries. Potato is a staple food crop in many countries of the world and emerging as a truly global food. The contribution of potato towards securing the food, nutrition and eradicating hunger can be compared with rice, wheat, and maize. This crop produces more food per unit time and area and has high nutritional value to sustain the increasing population. Per capita availability of potato has gone up to 24.4kilograms per year. Potato is a wholesome food containing carbohydrate (16 %), protein (2%), dietary fiber (0.8 %), and minerals (1%) such as potassium, calcium, iron, phosphorus, magnesium and vitamins. Potato is a good source of vitamin C. On dry weight basis, the protein content potato is similar to that of cereals (FAO, 2008). The combination of high potassium and relatively low sodium makes potato an ideal food for people suffering from hypertension (McGill *et al.,* 2013). Potato also contains an assortment of phytochemicals such as carotenoids and polyphenols, which act against colon cancer, improve glycose tolerance and insulin sensitivity, lower plasma cholesterol and triglyceride concentration increase satiety and possibly even reduce fat storage (Hylla *et al.,* 1998). It is a versatile food as it can be cooked in many ways can be processed into a number of products each having its characteristic taste and can fit into any meal. Boiled potato of an equal weight of boiled rice contains almost equal and superior protein than rice.

Necessity for Processing

At present in India, about 68% of potato is consumed as fresh while 8.5% is utilized as seed 7.5% for processing purposes and remaining about 16% goes as waste due to various reasons that include small size, rottage,and wastage during the entire potato supply chain (Vision 2050, CPRI). In India from April onwards, temperatures in the plains start shooting up and the produce has either to be consumed within a short period or is required to be shifted to the cold stores. Due to inadequate, expensive and unevenly distributed refrigerated storage facilities, there are frequent gluts in the market causing substantial economic loss to the farmers and wastage of potatoes. Such gluts have occurred every 2 to 3 years. Therefore, it is essential that potato consumption is increased to sustain this increase in production and to ensure remunerative prices to the farmers. Under the existing circumstances, diversion of potatoes into various processed potato products is a viable option which can help to extend the shelf-life, save the wastage of precious food during gluts, solve the problem of storage. This would benefit both growers and consumers, as it would help to extend the storage life and serve as a means of increasing the supply in off-seasons (Marwaha et al., 2010)

Current status of potato processing

In India, potato processing industry mainly comprises four segments: potato chips, frozen products, potato flakes/powder and other processed products such as dehydrated chips, *Aloo Bhujia, Samosa,* and *Tikkis*. However, potato chips and French fries still continue to be the most common and popular processed product. Now the production of potato flakes/powder is also witnessing an impressive growth. Even after this processing, the post-harvest losses are very high (about 16%). Hence, still, there is the possibility for growth in the processing sector by producing the novel value-added products from potato. ICAR-CPRI, Shimla is working on this aspect and has developed bakery and dehydrated products utilizing potato.

Potato is being processed into different products by the application of different processing techniques. Therefore, the requirements of the raw material vary for each product as the quality of the finished product is highly influenced by the quality of raw material used for their preparation. Moreover, variety of the potato used for processing also significantly affect the quality of the finished product. Some of the Indian processing varieties are given in table-1. From the processing perspective quality of the potato majorly depends upon the morphological characters as well as the biochemical composition (Table-2)

Table 1: Indian potato varieties for processing

Variety	Crop Duration (days)	Shape/Size	Dry matter (%)	Reducing sugars (mg/100g FW)	Acrylamide (µg/Kg FW)
Kufri Chipsona-1	100-110	Oval/Large	21-24	45-100	< 100
K. Chipsona-2	100-110	Round/Large	21-25	44-93	<100
K. Chipsona-3	90-110	Round-Oval/ Medium	22-24	30-50	< 100
K. Chipsona-4	90-110	Round	21-23	60-140	< 100
K. Frysona	90-110	Oblong/ Large	22-23	<100	< 100
K. Himsona	110-120	Oval/ Medium	20-25	<50	< 100
K. Jyoti	90-100	Oval/Large	18-21	106-275	< 800
K. Lauvkar	80-85	Round/Large	18-20	200-250	< 300
K. Chandramukhi	80-85	Oval/large	18-20	250-324	< 500

Table 2: Tuber quality requirement for some popular potato-based products

Product	Shape	Size (Diameter)	Dry matter (%)	Reducing sugars (mg/ 100g FW)
Chips	Round	45-80 mm	> 20	<150
French Fries	Oblong	>76 mm	> 20	<150
Potato flakes	Any shape	Not specific	> 20	<100
Canning	Any shape	20-40 mm	<18	Not specific
Starch	Any shape	Not specific	22-24	Not specific
Dehydrated products (Cubes, shreds, sticks)	Any shape	>30 mm	22-25	<150
Porridge and semolina	Any shape	Not specific	>20	Not specific
Flour and bakery products	Any shape	Not specific	>20	Not specific

Gluten-free food market and potato products

Food allergies and food intolerance are a growing public health concern causing a rapidly growing demand for gluten-free food. The target group for the gluten-free foods market includes people suffering from celiac disease or gluten sensitivity as well as people who are very health-conscious. Individuals who have celiac disease require a gluten-free diet throughout life. Ingestion of gluten in these individuals causes an adverse reaction which damages intestinal cells and can lead to serious health problems. People who experience an adverse reaction to gluten but who do not have celiac disease may have non-celiac gluten sensitivity (also called "gluten sensitivity"). In this condition, the problems caused by gluten are not thought to be as extensive as in celiac disease, but for both conditions, the treatment is a gluten-free diet. In the past few years, the considerable number of gluten-free food products are accessible in the food markets.

According to a report from the Institute of Agri-Business Management (IABM), governed by the Indian Council of Agricultural Research (ICAR), India has a potential of 2,347-kilotonnes of gluten-free products, against 7.55-kilotonnes produced in 2016. As per expert's reports, the estimated market share of gluten-free products in India is only 0.5-2% of global production. A recent study in International Journal of Current Microbiology and Applied Sciences by Big Data Practice and Innovation Lab and Culinary Arts and Food Science, Drexel University, major reasons for this disparity were lack of awareness, and poor rate of diagnosis, lack of purchasing power. But now this scenario is changing and people are demanding for gluten-free pizza, pasta, and noodles. Few exclusive gluten-free restaurants also opened in big cities of India. It is expected that the Indian market share would increase in coming years due to an increased rate of diagnosis of Celiac Disease and greater awareness about quality gluten-free foods and may reach up to 8.7% in the near future. Till now in India, mainly flour and multigrain mixes lead the market segment of gluten-free foods.

Under these situations, the advantage of Potatoes being free from gluten and fasting friendly can be taken. Moreover, potato processors are also constantly searching for new and innovative solutions to effectively use potatoes (Ruzaike et al., 2015). Recently CPRI has developed the technology forpotato cookies, halwa premix, porridge,and semolina.It has the advantage of both being gluten-free and fasting friendly.

Novel potato products developed by ICAR-CPRI

(a) Potato Cookies: Potatoes based cookies are completely free from wheat/gluten/maida and have novelty in their composition, which makes these cookies to stand alone among different cookies available in the market (Fig. 1). Moreover, potatoes of any shape, size, and variety, sugar content and, the period of storage can be utilized for production of cookies. Even these cookies can be prepared from partially damaged as well as both fresh and cold-stored potato tubers. These potato cookies are agood source of fiber due to the utilization of whole potatoes. The production process involves the use of potato flour as a major ingredient along with sugar, fat and leavening agents. Thereafter dough is shaped and baked for sufficient time. Potato cookies have the shelf life of 4 months if stored in a cool, dark and dry place. Potato flour can be easily procured from the market or prepared in a large amount during gluts at relatively low cost. This flour can be stored at ambient temperature throughout the year. The process can be easily adopted by industries involved in the production of baked foods. Since biscuits and cookies are consumed by the population of all age and income groups. Therefore, there will be huge business opportunities for potato cookies. In our knowledge at present, there is no such type of potato-based cookies available in the Indian market. Till date ICAR-CPRI has developed a total of 10 variants of gluten-free cookies and some variants are fasting friendly also.

(b) Low fat potato halwa premix: Traditionally potato halwa preparation involves a two-step process, first boiling fresh potatoes and then roasting boiled potatoes along with sugar in a good amount of fat. The whole process involves the continuous cooking of about 30-40 minutes. ICAR-CPRI has developed and standardized the process for ready-to-cook potato halwa premix. Halwa premix is gluten-free, fasting friendly, very low fat, low sodium, a fiber-rich product having a shelf life of 6 months at ambient storage conditions (Fig.2). This halwa premix requires less than10-minute cooking in boiling water or milk before consumption. Whole potatoes of any shape, size and variety can be used for halwa premix. Moreover, partially damaged or cold stored potatoes can also be utilized for premix. The simplicity of the process makes the technology adaptable at any levelof production with minimum investment. Potato halwa premix can also be consumed by patients suffering from celiac and cardiovascular diseases.

(c) Lactose-free potato burfi: In India, burfi is the most commonly consumed sweet in routine diet, during festive seasons and celebrations. Traditionally burfi is prepared from condensed milk, dry fruits, flavour, and sugar. All milk-based burfi contains lactose or milk sugar and are not suitable for Lactose intolerant (a condition in which a person can't tolerate milk and milk products) population. However, few vegetables such as carrot, bottle gourd, and ash gourd or fruits-based burfi are also available in the market which doesn't contain lactose. ICAR-CPRI has developed the process for the preparation of low-fat potato burfi using fresh potatoes (Fig. 3). The potato burfi can be prepared from the potato of any shape, size, colour, and duration of cold storage. The preparation process involves mashing of boiled potatoes and then cooking along with sugar, flavour and other additive till the desired consistency. Potato burfi is also suitable for lactose intolerant population. The shelf life of the burfi is 20 days.

(d) Potato porridge/*Daliya* and semolina: Porridge is used to make a nutritious dish at breakfast or whenever a light meal is required. It can be made sweet or salty according to taste. Potato porridge and semolina is made from 100% potatoes and can be cooked in milk or water(Fig.4& 5). It can be consumed as a breakfast with added fruits or vegetables by the population of all ages. Moreover, potato porridge is a gluten-free alternative of wheat porridge for a population suffering from celiac disease or wheat allergy. Likewise, potato semolina can be used to prepare halwa, upma, idli etc. The production process involves proper cleaning and pre-treatment of potato and further drying at a controlled temperature. The process involves the use of the whole potato of medium to high dry matter varieties. Potatoes of all size and shape can be used for making the porridge and semolina. Potato porridge and semolina has a shelf life of 9 months if stored in a cool, dark and dry place. Due fasting friendly properties the demand of these products will be higher during festive seasons/Navratri, and other occasions where cereals and millets cannot be consumed.

(e) Dehydrated cubes and shreds: Potato is a perishable commodity and in fresh form cannot be preserved for long time with low sugar level. Another problem associated with the potatoes is more storage space requirement and high transportation cost which are more important for hilly regions. To target the storage and transportation related problems ICAR-CPRI has developed the and improved process for dehydrated cubes and shredshaving better rehydration properties and minimal change in taste and texture (Fig. 6&7). After 3-4h rehydration, the dehydrated cubes can be used to prepare curried vegetables, pulao and dry vegetables. These cubes can also be used to prepare the flour. For the preparation of dehydrated cubes, washed and peeled potatoes are passed through a dicer with the die ranging from $5mm^3$ to $10mm^3$. After pre-treatment with additives, the cubes are drained and dried in either hot air oven or in sun. These cubes can be stored up to 8-9 months in a moisture proof packaging.

Similarly, for the preparation of dehydrated shreds, peeled potatoes are either passed through square die of 3 x 3 mm to form sticks of 5-6 cm in length or through shredders. These shreds are treated with additives, drained, molded in to a desired shape and dried in the sun. These dehydrated shreds can be used for the preparation of noodles as a gluten-free alternative of refined wheat flour-based noodles. These shreds can also be fried in oil for the preparation of snacks. The dried sticks/shreds can be stored for several months after proper packaging. Unlike, popular fried potato products such as chips French fries, lachha and sticks, dehydrated cubes and shreds are not affected by the reducing sugar content of the potatoes.

Suggested References

Hylla, S., A. G. Gostner, H. Dusel, H. P., Anger, S. U., Bartram, H., Christ and W. Kasper, S. (1998). Effect of resistant starch on the colon in healthy volunteers: Possible implications for cancer prevention. Am J. Clin.Nutr., 67: 136-142.

Marwaha, R. S., Pandey, S. K., Kumar, D., Singh, S. V., & Kumar, P. (2010). Potato processing scenario in India: industrial constraints, future projections, challenges ahead and remedies—a review. Journal of food science and technology, 47(2), 137-156.

McGill, C. R., Kurilich, A. C., & Davignon, J. (2013). The role of potatoes and potato components in cardiometabolic health: a review. Annals of medicine, 45(7), 467-473.

Ruzaike, A., Muizniece-Brasava, S., & Kovalenko, K. (2015). Facultative thermophilic microorganisms in potato products in retort packaging. Chemical Technology, 66(1), 19-23.

Vision 2050, ICAR-CPRI, Shimla, Page, p. 3.

Fig.1: Potato based gluten-free cookies

Fig. 2: Low-fat potato halwa

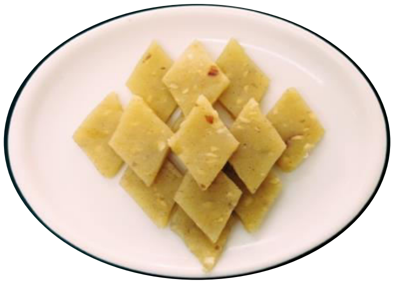

Fig. 3: Gluten-free potato burfi

Fig. 4: Potato porridge

Fig. 5: Potato semolina

Fig. 6: Dehydrated potato cubes

Fig. 7: Dehydrated potato shreds

Chapter -08

SEED PLOT TECHNIQUE: AN IDM APPROACH FOR QUALITY POTATO SEED PRODUCTION

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The third most important technology that revolutionized potato cultivation in India is the innovative technique of producing healthy planting material in the sub-tropical plains of India that is popularly known as "Seed Plot Technique". Unlike most crops where 'true' seed is used for raising a crop, potato is usually propagated through tubers. This vegetative mode of propagation is beset with many problems; the most important of which is a progressive and significant decline in the yield potential of seed tubers over the years. This phenomenon was first noticed by the farmers of European countries during last quarter of 18th century. It was termed as 'degeneration', 'running out' or 'senility' of potato in 1792 by Dutch framers. The problem of degeneration is much more acute whenever potato is grown in the sub-tropical plains. As described earlier, the yield potential of most of the imported European varieties became uneconomical within 2-3 years of their introduction largely because of high rate of degeneration in Indian plains. This problem even prevented development of indigenous varieties since the genetic stock used to rapidly degenerate during selection in the plains. As a consequence, no useful variety could be developed during early breeding efforts from 1935 to 1968. The strategy of making crosses at high altitude and selection in plains became counterproductive. The problem became so frustrating, that during 1959 when Dr. Pushkarnath took over as Director of CPRI, the priority of breeding indigenous varieties was subordinated to the problem of tackling the degeneration in the plains of India. Though it was initially believed that the problem of degeneration was a direct consequence of asexual propagation of potato, it soon became clear that the main reason was infection of seed tubers with virus diseases. Viruses are systemic in nature and once they enter the seed tuber, they remain and multiply within the tuber for generations. Since the condition for virus infection and spread is most congenial under warmer subtropical climate, rate of degeneration was very high in Indian plains.

The usual practice, therefore, was to regularly import seed potato primarily from Italy, Kenya Colony or Australia. Seed import came to a halt during 1939 due to World War II and as a result the Indian potato sector suffered a jolt. In the mean time, extensive survey of potato virus diseases in India demonstrated that Indian high hills are ideal for seed potato production. In fact, the concept of growing seed crop in high hills was developed in early forties in Europe and extended to the colonial India. Very high hills (above 2,500 MSL) with humid climate, high wind velocity and low temperature (14-25 °C) during summer were found ideal for quality seed production because those conditions did not favour multiplication and movement of aphids, the carriers of potato viruses. Consequently, crops grown in high hills had very low incidence of aphid transmitted viruses and had slow rate of degeneration. Therefore, certain locations in the high hills of Himachal Pradesh (Fig. 1), Uttar Pradesh (UP), Jammu and Kashmir and North-eastern hills became focal points of seed production and supply of comparatively healthy, good quality seed both for the hills and the plains. However, it was soon realized that the system of seed production in hills would not be able to sustain the growing potato cultivation in India. Normally, 2.5 to 4 metric tonnes of seed potatoes are required to plant one ha area. Thus, a large quantity (running into lakhs of tonnes) of healthy seed tubers is required every year. The plan of producing seed tubers in hills proved to be insufficient due to: (i) non-availability of varieties adapted to both long days of hills and short days of plains; (ii) dormancy of hill seed which degenerated very fast due to high vector pressure during spring in the plains and, (iii) limitation of land in the hills. A need, therefore, was felt to have a technology for producing healthy seed potatoes in the vast Indo-Gangetic plains.

An innovative approach for maintaining seed potatoes in a healthy state in the plains of India was suggested in 1959. This technology popularly known as **'Seed Plot Technique'** was based on a simple but profound observation on population dynamics of the virus vector. A detailed survey of a number of locations in the plains was undertaken during 1956-60 to study the population dynamics of the aphid vector *Myzus persicae* during the cropping period. It was found that the vector population in the North Indian plains (Indo-Gangetic plains) remained either absent or very low during October to December which was sufficiently long a period to grow healthy seed crop in the plains (Fig. 2). This simple observation formed the basis of seed production in the plains through the pioneering 'Seed Plot Technique'. Initially, the technology did not attract much attention, but with the first pilot experiment undertaken in Jalandhar at the farm of Mr. Iqbal Singh Dhillon, a progressive farmer, the entire situation changed. Hundreds of ha of uniform healthy and vigorous crops of potato completely changed the old conceptions and the plains of India emerged as the most favourable place for the production and propagation of healthy seed potatoes. The seed stocks proved to be healthier than the best produced in Europe. This development marked the beginning of the placing of potato on the agricultural map of the country. It revolutionized the production of potato seed for which dependence was on hills, and also changed the cropping pattern in Punjab, Haryana and Western Uttar Pradesh. The credit for the innovation of the 'Seed Plot Technique' goes to Dr. Pushkarnath and his colleagues. Dr. Pushkarnath was awarded the coveted Rafi Ahmed Kidwai award of ICAR in 1963 for this unique contribution.

Fig. 1. View of seed production station at Kufri

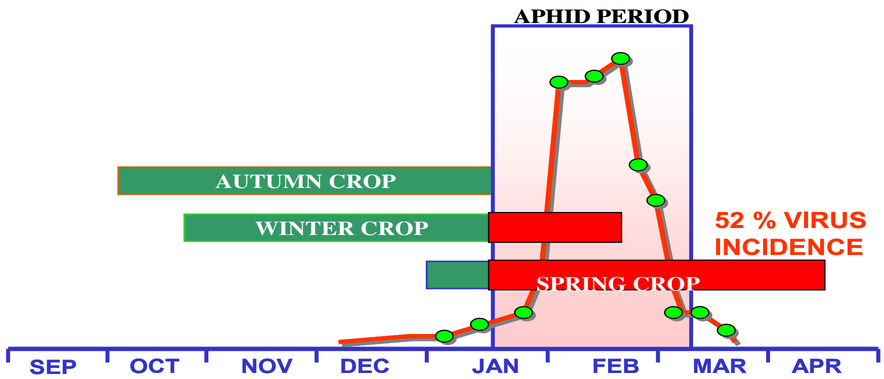

Fig. 2: Aphid population curve in northern plains of India (average of ten years data)

The Technology:

The 'Seed Plot Technique' was based on the basic principles of low aphid period of at least 70-75 days for growing seed crop. The pre-requisites for success of this technology were (i) the soil should be free from serious soil-borne pathogens like wart, cyst nematodes, bacterial wilt, black scurf, and common scab, (ii) there should be a low aphid or aphid free period of 70-75 days after planting the crop, (iii) the minimum and maximum temperature should be 8-28 °C during crop season, and (iv) the varieties used should have slow rate of degeneration. Initially, the 'Seed Plot Technique' was restricted to Punjab and comprised planting of seed crop during September end to mid-October, planting at a close spacing in not too rich a soil to ensure large percentage of seed-sized tubers, two inspections of the crop to remove off-types and virus infected plants, restriction of irrigation from mid-December onwards and dehaulming (cutting the above ground foliage) the crop in the end of December or when the critical level of 20 aphids/100 compound leaves are observed. The self-set plants from left over tubers in the fields which were foci of spread of virus diseases and were general menace for varietal mixture did not survive in the plains because of the high summer temperatures. The seed produced under low aphid period was found to develop more sprouts as a result of good physical condition of tubers due to 6-7 months storage at low temperature (2-3^{O}C) compared to traditionally grown hill seed. Incidence of various virus diseases in crop raised as per the above scheme at Jalandhar was less than 1.5% even after 3 to 4 years of propagation. The technique was further refined keeping in view the appearance and subsequent build up of aphids from North-western to North-eastern regions of the Indo-Gangetic plains (Fig. 3). In the areas where aphids appear early during crop growth period, such as parts of Madhya Pradesh, Gujarat and Maharashtra, use of systemic insecticides was found useful in controlling vectors and fairly good quality seed could be produced in those regions. Suitable time slot for production of healthy seed potato has been worked out for almost all the regions of Indian plains (Table 4). Agrotechniques for seed production by the 'Seed Plot Technique' was standardized and refined continuously. The current agrotechniques for seed production is described below.

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 pest 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: 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 control 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 aculeata*) during rainy season at least one month before potato planting for proper decomposition is beneficial in reducing pest and disease incidence**.** It also 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.

***Isolation of seed plots*:** The seed crop is separated from crops meant for "ware' purpose by a distance of at least 5 meters to avoid mixture and spread of viral diseases. Isolation is also required between different varieties of the seed crop.

***Healthy seed source*:** For on farm multiplication of quality seed by the farmers, it is essential to obtain healthy, disease free, true to the 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 the stocks should be replaced every 3-4 years.

Pre-sprouting: The pre-sprouting treatment of the seed tubers before planting ensures growth of multiple, stout and healthy sprouts, which helps in quick emergence, 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 the cold store for 24 hours. Spread the seed tubers in the 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 planting, care should be taken to avoid damage to the sprouts.

***Planting time*: ** Optimum planting time for potato crop is the period having temperature maximum 30-32^{O}C and minimum 18-20^{O}C. In seed crop the aphid free period of growth is also an important consideration. Planting must be completed by such time to ensure 75-85 days of low aphid period. The optimum planting time in North-western, West-central and eastern plains for seed crop is first week of October, second to third week of October and last week of October, respectively.

Planting method and seed rate: Use of cut tubers for seed crop is prohibited. Only whole tubers at spacing according to size 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 60 cm, respectively. Planting of seed-sized tubers of 30-40 g at 60 cm inter- and 20 cm intra-row spacing is best for seed potato production. However, for best results in terms of net yields (total yield/seed used), returns and optimum proportion of seed-sized tubers in the produce the adjustment of spacing according to the size of seed tubers is essential. The objective is to keep the seed rate reasonably within limits (32-35 q/ha) without sacrificing the total tuber yield. A plant population of about 1 to 1.1 lakhs hills/ha to ensure a stem density of 40-45/m^2 is adequate for best results. 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 >100 g seed size is 15, 20, 25 and 30 cm with inter-row spacing of 60 cm, 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. Fertilizer N 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. Masking of symptoms makes detection of infected plants difficult during rouging to the detriment of quality of seed produced. The crop requires a basal dose of 75 kg N, 60-80 kg P_2O_5 and 100-120 kg K_2O/ha at planting. Split dose of 75 kg N/ha given through urea is adequate. The basal dose of N can also be applied through urea by incorporating into the soil at least 48 hrs before planting during field preparation. This removes any constraints in using costly nitrogenous fertilizers of ammonium sulphate (AS) and calcium ammonium nitrate (CAN).

***Intercultural operations and weed control*: ** The objectives of intercultural operation in potato are weed control, earthing up for firming up the ridges to prevent exposure of growing tubers and application of split dose of N 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, when foliage cover is still small. The split dose of Nitrogen and Thimet should be applied at hoeing and earthing up about 5 cm away from the plants. The hoeing must not be delayed beyond 30 days 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 @ 1.5 kg/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 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 yields. 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 season potato 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. The chemical dehaulming is also more effective under moisture stress conditions.

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 @ 10 kg/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. @ 0.002% may be repeated at an interval of 12-15 days depending on duration of the crop and infestation. Drenching of the ridges with Chloropyriphos 20EC @ 2.5 litres/ha effectively controls cutworm attack during the early stages of the crop. In white grub prone areas, Chlorpyriphos 20EC @ 2.5 litres/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 @ 0.2% 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 or Ridomil @ 2.5 kg/ha may be given and repeat the spray after 7-10 days if required.

Inspection and rouging: Inspection of the seed crop to remove or rouge out the off type and diseased plants showing mosaic, mottling, veinal necrosis, crinkling and rolling of leaves, marginal flavescence and purple top roll symptoms is essential. The first rouging is done 25-30 days after planting before earthing up. Second rouging is done after 40-45 days of planting and the third is done 3-4 days before dehaulming. At each rouging, makes it sure to remove the tuber and tuberlets of rouged plants.

Dehaulming operation: Removal of haulms of the seed crop is essential by 5-15 January in the plains when aphids (*M. persicae* and others) population reaches the critical level of 20 aphids/100 compound leaves on unsprayed crop in the area. Dehaulming is done by manually cutting with the sickle close to the ground or by spraying non-selective herbicide Paraquat @ 0.5 kg/ha. If the 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. Regrowths 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: In the Indo-Gangetic plains potato digging should be preferably completed by 15th February. Delayed digging beyond February promotes rotting due to soft rot and charcoal rot. Start digging in the plains 10-15 days after dehaulming, when peel is firm to withstand handling operations. 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 tuber surface. Heaps of about 1.5 m high and 3.5 m 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. The graded tubers command premium in the seed market. Secondly, the graded tubers even if used for own planting 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 (<25 g), medium (25-50 g) and large (50-100g) and extra large (>100 g). Seed tubers should be dip-treated with boric acid (3%) solution against tuber borne diseases of common scab and black scurf for 30 min. 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, Emisan 6 @ 0.25% for 20 min is also effective, but 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 (4^0C) latest by the end of February. The treated seed bags should be properly sealed and labeled "Poisonous" to avoid human consumption mistakenly.

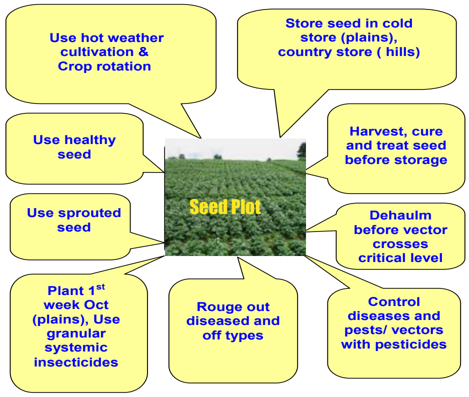

Fig. 3. A schematic re presentation of the refined Seed Plot Technique

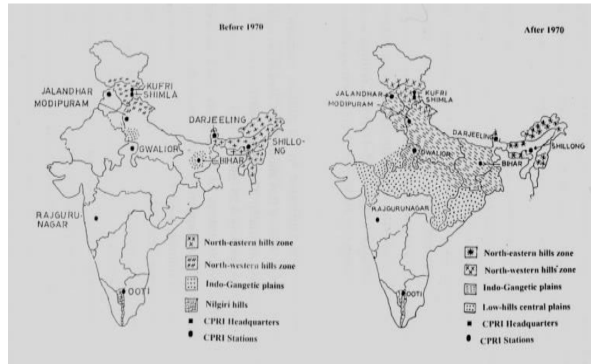

Fig. 4: Pattern of seed production before and after 1970.

Table 1: Suitability of potato seed production in different region of India.

State	Zone	Suitability for type of seed	Reasons for suitability
Himachal Pradesh	Northern high hills	All categories of seed	Low vector pressure No serious soil borne pest
	Lahaul Spiti Valley	Foundation & certified	Higher vector pressure Some soil borne pests
Jammu & Kashmir	Northern high hills	Foundation & certified	Low vector pressure Soil borne diseases
	Plains	Foundation & certified	Higher vector pressure
Arunachal Pradesh, Sikkim, Meghalaya, Manipur, Nagaland, Mizoram, Tripura	North-eastern high & mid hills	Foundation, certified & quality seed (for regional use)	High vector pressure Presence of brown rot & wart.
Darjeeling hills	Quarantine area	Quality seed for local use	Wart disease
Punjab, Haryana, UP, Western MP, Bihar	Indo-gangetic plains	All categories of seed	Low vector pressure No serious soil borne pest
West Bengal, Orissa, eastern MP	North eastern plains	Foundation & certified seed (for local use)	High vector pressure Presence of brown rot
Maharashtra, Karnataka, Andhra Pradesh	Plains & plateau area	Quality seed (for local use)	Very high vector pressure Soil borne brown rot
Tamil Nadu	Nilgiri hills (Quarantine area)	Quality seed (For local use)	Presence of cyst nematode Presence of brown rot

Adoption and Impact:

The technique for production of healthy seed under sub-tropical plains was primarily responsible for the phenomenal increase in area, production and productivity of potato in India after independence. The 'Seed Plot Technique' alone led to >62.7% increase in area and 51.2% increase in production. This technique led to the development of a robust national seed production programme to maintain high quality of nucleus and breeders' seed of improved varieties. This technology also enabled participation of many farmers in production of healthy potato seed. Adoption of these techniques by the farmers for own grown seed crop increased the local availability of quality seed enormously resulting in improved tuber yield and expansion of potato crop in the northern plains. The major centre of disease free seed production shifted from the hills to the plains (Fig. 4) as a direct consequence of 'Seed Plot Technique'. The seed produced in the plains not only gave 30-40% higher yields but also was free from many soil and tuber borne diseases and pests. This, in turn, prevented spread of seed and soil borne diseases from the temperate zones to sub-tropical plains. All these advantages led to rapid development of seed industry in Punjab and western Uttar Pradesh. Integration of seed plot technique with the advanced virus diagnostic techniques, plant protection measures and agronomic practices has laid the sound foundation of the Breeder Seed Production programme of the Institute. New generation, short to medium duration cultivars, like Kufri Chandramukhi, Kufri Bahar, Kufri Jyoti, Kufri Badshah, Kufri Sindhuri and Kufri Lalima could be promoted largely because of Seed Plot Technique. It also eliminated the need for import of costly seed from abroad to save valuable foreign exchange. Earlier, imports of potato seed from Europe was a regular practice, which continued for some time even after independence. In contrast, all neighboring countries of Pakistan, Bangladesh, Nepal and Sri Lanka and the West Asian countries and even China continue to depend on annual import of seed potato from Europe.

The salient features of the refined 'Seed Plot Technique' is given in the box below.

- Adoption of 2-3 years crop rotation to avoid build up of soil borne pathogens like black scurf and, common scab in the soil.
- Isolation of minimum 25 m of the seed crop from the ware potato crop.
- Use of disease free seed stocks selected by employing latest diagnostics like ELISA, RT-PCR, immuno electron microscopy and NASH.
- Use of correct physiological age cold-stored seed.
- Planting of seed crop by 15th October in Punjab, by 25th in Haryana, Rajasthan, western Uttar Pradesh and first week of November in eastern UP and Bihar.
- Use of systemic granular insecticides such as Thimet 10-G at the time of planting and earthing up against sucking insects and white grubs.
- Use of pre-sprouted large sized healthy tubers (40-80 g) with multiple sprouts to ensure a large proportion of seed sized tubers. Pre sprouting ensures quick and uniform emegence, early tuberization and maturity.
- Full earthing at planting and use of herbicides for control of weeds and prevent spread of contagious viruses.
- Inspection of seed crop 3 times at 50, 65 & 80 days during growing season to remove the off type and diseased plants.
- Protection of crop from late blight disease to prevent seed borne infection.
- Protection of crop from vectors towards the maturity of the crop.
- Withholding irrigation in the 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.
- Killing of haulms with Grammaxone @ 2.5-3.0 lit/ha or mechanically pulling for their proper them to kill.
- Harvesting of crop 15-20 days after haulm killing when the fields are in workable condition and tuber skin is hardened.
- Curing of produce is by keeping in heaps in a cool shady place for about 15-20 days.
- Treatment of produce with commercial grade 3% boric acid to prevent surface borne diseases.
- Drying of treated seed in shade and then filling in the bags, sealing, labelling, and cold storing.

Chapter -09

ADVANCES IN MANAGEMENT OF WEEDS: MANAGEMENT AND PRACTICES OF WEED CONTROL

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Crop production provides about 84% of global food, feed and fibre requirements and virtually all other human endeavours depend on food security. Yield of underground crops remain a mystery until harvest, along with the pests and diseases that could lurk just under the surface. The potato, for example, is a major crop in about 130 countries. According to the FAO, root and tuber crops including potatoes are second only to cereals as the leading worldwide source of dietary carbohydrates.

Crop losses due to pests: It is estimated that food plants of the world are damaged by more than 10,000 species of insects, 30,000 species of weeds, 100,000 diseases (caused by fungi, viruses, bacteria and other microorganisms) and 1000 species of nematodes (Dhaliwal et al., 2007). However, less than 10% of the total identified pest species are generally considered major pests. Among different pests, weeds cause highest loss to field crops. Weeds compete with crops, ultimately converting productive land into unusable land. Weeds may be poisonous, distasteful, produce burrs, thorns or interfere with the use and management of desirable plants by contaminating harvests or interfering with livestock. Weeds compete with crops for space, nutrients, water and light. Smaller, slower growing seedlings are more susceptible than those that are larger and more vigorous. On an average losses due to weeds 45%, disease 20%, insects 30%, and others 5%. Crop losses due to weeds range 10 - 28% in wheat, 25 - 41 % in rice , 20 - 41% in maize, 8 - 21% in potato, 11 - 32% in soybean.

Weeds of Potato Crop: Weeds prevalent in potato crop vary from region to region and have been grouped mainly into two sub-groups *i.e.* weed species found in plains and in hills. The knowledge of dominant and invasive flora is of paramount importance for controlling weeds efficiently in different potato growing zones. The dominant weeds of potato crop in Indo-gangetic plains are *Cynodon dactylon* L.(Pers.) , *Cyperus rotundus* L., *Trianthema monogyna* L., *Chenopodium album* L. *Poa annua* L. *Anagallis arvensis* L., *Melilotus spp*., *Sonchus arvensis* L. and *Vicia sativa* L. Major weeds of hills are *Amaranthus viridis* L., *Chenopodium* spp., *Oxalis* spp., *Digitaria sanguinalis* (L.) Scop. *Setaria glauca* (L). Beauv., *Spergula arvensis* L. and *Melilotus spp*. (Lal 1993). The occurrence and intensity of weeds vary under various agro climatic regions, cropping systems and management conditions. In Assam, a total of 33 weed species belonging to different families have been reported in potato crop, where *Chenopodium album* L., *Axonopus compressus* and *Cynodon dactylon* L. (Pers) were the dominant weeds (Baruah and Sarma, 1994). In Meghalaya forty-two weed species in potato fields have been registered with dicot/monocot ratio of 2.4:1 (Laloo, 2004). In Nilgiris hills (Tamil Nadu), the most dominant weeds in potato fields were *Polygonum nepalense*, *Coronpus didymus* and *Spergula arvensis* (Manorama, 2004) and observed a total of 23 species, out of which three were grassy, sixteen broad leaf and one sedge weeds.

Cyperus rotundus, Chenopodium album, Anagallis arvensis, Phalaris minor, Poa annua, Melilotus indica, Polypogon monspliensis, Coronopus didymus and *Medicago denticulata* were the major weeds of potato crop. Major weed species infesting potato crop in central Uttar Pradesh were *Chenopodium album, Anagallis arvensis, Melilotus indica, Vicia sativa* and *Cyperus rotundus* (Tripathi and Tripathi, 2008). Biology of important weeds of potato crop in the country has been described separately in chapter of Biology and control of weeds of potato crop.

***Critical Period of Crop - Weed Competition in Potato*:** Potato crop is usually raised in wider geometry with liberal use of manures and fertilizers. Further, irrigations are frequent in plains and generally rains are heavy in hills during crop growth season. All these practices are advantageous for early and faster growth of weeds even before the crop emerge out. It provides ample opportunity for weeds to flourish and dominate the crop if not managed timely. This would culminate into reduction in tuber productivity particularly due to initial takeover of weeds rather than late in the season. Gupta *et al.* (1977) found that irrigated crop responded well to initial weed management. Early coverage of crop canopy by weeds or their allelopathic effect was speculated as major factor in crop-weed competition. Thakral *et al*., (1985) reported that the most critical period of crop-weed competition is 25-30 days from planting. At Kufri, tuber yield reduced indicating the criticality of this period (Lal and Jaiswal, 1989-90).

Lal (1990 and 1993) concluded that the initial period of 20-40 days after planting of potato crop was the most critical period for competition in western Uttar Pradesh. Singh (1982) suggested that weeding should not be delayed beyond four weeks of planting as delay in weeding would adversely affect potato productivity. In Nilgiris (Tamil Nadu) the most critical period for crop-weed competition was 4-6 weeks after planting in the plains and 5-7 weeks after planting in the hills (Manorama, 2004). The potato crop should remain weed free up to 40-50 days depending upon farming situation. However, towards maturity, potato plants tend to drop between ridges after 65-70 days of planting and at this stage second flush of weeds come up. These weeds do not cause significant damage to tuber productivity but play a major role in increasing weed seed bank and cause hindrance in crop harvesting. Weeds emerging at this stage are main source of seed working as seed bank in the field. Hence, control of weeds at this stage not only reduces weed problem of current season but of subsequent years also. Therefore, weeds in potato crop have to be managed in such a way that these do not dominate at any stage of growth.

***Cultural weed control*:** Weeds are suppressed out specifically in initial phases of crop growth by way of crop competition through adoption of best crop production practices and making major components of crop growth in favour of potato crop. It includes vigorous and faster growth of potato plants and having crop environments such that it always smothers weeds. The weeds emerging out under better crop canopy are generally frail and will not be much harmful to tuber productivity. Further, these can be managed without much difficulty by adopting inter-cultivation or chemical methods. The potato cultivars having vigorous and rapid growing habits may prove better competitors for weeds as they cover fields quickly and overwhelm these undesirable plants. Studies of crop weed competition versus chemical weed control in potato crop suggested that comparable yield could be achieved by achieving optimum plant density and inter-cultivation

(Channappagoudar *et al*., 2007). Adoption of suitable agronomic practices can reduce dependence on chemicals.

Crop rotations: Well-planned cropping systems can be quite useful in controlling weed density in long run. This may be done following at least two-year crop rotation in a particular field or having green manure crops like dhaincha, cowpea etc. for smothering weeds. Two-year crop rotation will assist in reducing weed seed bank in field, while in green manuring even for a shorter period (45-50 days), weeds get buried along with the green manure crops and are decomposed, which also add to the soil organic carbon. Thus, this operation also facilities better potato growth for posing tough competition to these detrimental plants.

Hot weather cultivation and soil solarisation: Advantage of hot and dry summer season should be harnessed in a cropping system for desiccating the weeds. Two-three deep field cultivations in this period are very useful for the control of annuals and also for perennials like *Cynodon dactylon* L. Similarly, soil solarisation may be quite useful in specific situations or for premium potato crop like seed *etc*. Soil solarisation done using transparent polyethylene (TPE) film of 0.05 and 0.10 mm thickness for 30 and 40 days with and without conventional weeding or chemical weed control in potato crop after groundnut recorded lowest mean total weed count and weed dry weight (Soumya *et al*., 2004).

Proper seed bed preparation: Seed bed should be prepared thoroughly depending upon soil type of a region. Pre-plant tillage operations for making a proper soil tilth not only accelerate faster emergence of potato plant, but also destroy the weeds and give an edge to the crop.

Proper planting: A competitive edge is given to potato crop by way of optimized planting time. First of all, a variety should be planted at an optimum date, where soil bed is prepared properly and contains sufficient moisture. Well-sprouted seed tubers should be planted at optimum crop geometry at a proper depth. This will help in faster emergence and growth of potato plant. At Jabalpur, ridge planting significantly reduced the population of *Phalaris minor, Medicago hispida, Cichorium intybus* and *Vicia sativa* at 40 days over other methods like flat planting (Mishra *et al*., 2002).

Placement of manures and fertilizers: At planting, manures and fertilizers should be precisely placed in bands 5-6 cm below seed tubers, so that these inputs remain in root zone of the crop. Thus, the plants will be able to harness nutrition efficiently in comparison to weeds, which will accelerate the vegetative growth. Faster coverage of fields of potato canopy would deprive weeds from uptake of nutrients and thus assist potato crop in reducing their intensity more specifically in initial phase of plant growth.

Mechanical weed management: Hand pulling, chopping, and hoeing weeds are simple forms of weed control used on smaller farms where weed control options are limited, particularly in less developed countries or those growing potatoes organically. Most commercial farms, however, use tractor tillage for mechanical weed control. Tillage is an important component of weed control in potatoes, regardless of region or production system. Some of these methods are as old as human beings started the farming. Mechanical weed management is very significant in modern era due to concerns for the environments and emphasis on avoidance of chemicals.

Manual weeding: Removal of weed plants simply by hand or by manual implements like Khurpi, hand hoe, spades *etc* is an old practice and still followed in many parts of India in potato crop. This may be a feasible and efficient method for controlling the undesirable vegetation provided manual labour is available and cheap. Further, it is quite effective against annuals and biennials, as they do not re-generate from the pieces of vegetative parts left in soil after such operation. This method is particularly better as it destroys weeds within the rows, which are generally not controlled by the cultivation. Hand weeding produced higher tuber yields and net returns than the herbicide in potatoes (Sharma, 1994). Prasad and Singh (1995) concluded that weeding at 30 days + earthing up was comparable with pre-emergence applications of atrazine and fluchloralin for reducing weed dry weight, increasing weed control efficiency and also better tuber yield. Pandey (2001) recorded comparable tuber productivity in treatments of hand weeding + earthing up, isoproturon, metribuzin and pendimethalin. Integration of hand weeding with earthing up had lowest weed population and biomass with 65.8-94.3% weed control efficiency. Maximum tuber yield was also observed with hand weeding + earting up followed by Prometryn @ 1.00 and 0.75 kg ha^{-1} (Mukhopadhyay, 2002 and Nandekar, 2005).

Mechanical methods: These methods mainly include two options i.e. animal drawn or tractor drawn implements for the potato growers depending upon their farm size. Animal-drawn three-tine cultivators are quite efficient and cost effective implements for inter-cultivation in potato crop (Shyam and Singh, 1979). Narrow shovels are better for weeding operation as it will not damage roots and stolons of potato plants growing over ridges. One pair of bullocks per day can cover approximately one hectare of land. After inter-cultivation, animal-drawn single bottom ridger is better for earthing up of the crop. Tractor operated machines are very efficient and can cover larger fields in a day. Spring tine cultivars consisting of spring tines with narrow reversible shovels fitted to a tractor tool bar may cultivate three or more potato rows at a time. As each tine is hinged at its base so the lateral position on shovels can be changed easily with a mild foot below, to reduce root and stolon damage if crop is cultivated at different stages of growth. Later on ridgers consisting of three or more bottoms do the earthing up operation in potato crop. Tractor based mechanization can cover 3-5 hectrare of crop field per day.

Potato crop has critical period of crop-weed competition, so timely inter-cultivation and weeding are very pertinent for maintaining better crop growth and high tuber productivity. First four to six weeks after crop emergence are very crucial for canopy development and covering the fields to give potato crop an edge over undesirable vegetation in fields. Inter-cultivation is better 20-25 days after planting when the plants are about 10-12 cm in height. Earthing up should immediately be done after inter-cultivation and weed removal otherwise soil moisture will deplete and proper ridges will not form. In Punjab, blind hoeing proved advantageous in early potato crop where *Trianthema monogyna* L. germinated much earlier and covered the entire field before the emergence of potato plants (Singh and Saini, 1980). Mechanical weed control proved comparable to chemicals in terms of crop growth, yields and economics of weed management in potato crop in a field trial conducted on red sandy loam soil.

Mulching: Though it is very old practice but it is a very efficient way for smothering the weed growth during crop season and more specifically for annuals. Main objective of mulching is to deprive weeds of solar radiation and thus inhibition of weed growth. Germination of weeds is also hampered and this practice helps in conserving soil moisture, which facilitate quick emergence of potato plants. Crop residue, dry straw, dry grasses, pine needles and other vegetative material may be utilized in this operation. Recently plastic mulching has also come up as a promising technique for weed control. However, mulching cost has increased due to increase in cost of residues and labour. Lal (1990d) observed effective weed management in potatoes with the mulching of paddy straw in Uttar Pradesh and pine needles in Meghalaya. Tuber productivity of mulching treatments was comparable with conventional weed control. It was also concluded that mulch should be thick enough (5-10 cm) to prevent light interception by weeds so that photosynthesis is hindered. At Bangalore, mulching with straw and polyethylene films reduced weed dry weight from 12.7 g m^{-2} (no mulch) to 5g and 3 g m^{-2}, respectively. Mulching with straw and polyethylene also increased tuber yields from 14.3 t ha^{-1} (no mulch) to 16.7 t and 18.2 t ha^{-1}, respectively thereby enhancing cost : benefit ratios (Khalak and Kumaraswamy, 1993). In West Bengal, potatoes cv. Kufri Jyoti recorded better tuber productivity with *L. leucocephala* mulching followed by FYM, rice husk ash and mustard oil cake incorporation (Datta and Chakraborty, 1995).

Efficient Use of Herbicides: Weeds have to be controlled for successful crop production to occur. Herbicides are the key to sustainable crop production throughout the world and will remain the mainstay for weed control for the foreseeable future. About 30% crop yield is lost due to pests weeds, diseases etc which in terms of quantity is 30 million tonnes of foodgrains. Selection of proper herbicide by judging the crop stage, presence of various weed species and their intensity, soil type and weather conditions is very important, which determines the effectiveness of the chemical applied. It is mandatory to provide chemical details and composition of any product by an organization in the market, so active ingredient (ai) is used in computing the quantity of chemical for a given farm area by adopting following formula:

$$\text{Dose of commercial product} = \frac{\text{Weight of chemical required per ha x 100}}{\text{Active ingredient in a product (\%)}}$$

Pre-emergence herbicides lebeled for use in potato include EPTC, linuron, metribuzin, s-metolachlor, pendimethalin, rimsulfuron etc. metribuzin is currently the most widely used pesticide in potato production. Metribuzin, an s-triazine or triazinone, is one of the oldest potato herbicides and is still widely used in potato production. Metribuzin controls a range of broadleaf weed species and suppresses many additional grasses. Resistance to triazine herbicides has developed in 69 species worldwide, limiting activity and requiring a combination of control practices for these weeds.

Biological weed control: Biological weed control is divided into two groups where first is crop competition and second one is use of parasites, predators and pathogens. Second option is in focus now to bring the weeds of a given crop or cropping system below economic threshold level by utilizing natural enemies of specific weed species. Prashanthi and Kulkarni (2005) isolated organisms from the diseased parts of Eupatorium (*Chromolaena odorata*) an alien aggressive weed and eighteen isolates belonging to nine genera were obtained. Among them fungus *Aureobasidium pullulans* was found potent for probable use on various target weed plants. Similarly, an attempt was made by Paijwar *et al.* (2005) to collect and identify fungi associated with the infected parts of *Lantana camara* for further exploitation as biological control agents. They were able to isolate two fungi in pure culture (*Alternaria* sp. and *Fusarium sp*) for potential use in biological control strategies.

***Intercultural operations and weed control*: **The objectives of intercultural operation in potato are weed control, earthing up for firming up the ridges to prevent exposure of growing tubers and application of split dose of N and 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, when foliage cover is still small. Rotating herbicides with different modes of action from year – to - year and/or tank - mixing herbicides with different modes of action and overlapping weed control spectrums can help prevent or delay the development of herbicide - resistant weed populations.

Pre - emergence herbicides like Metribuzin @ 0.75 kg/ha, Oxyfluorfen @ 0.15 kg/ha, Linuron @ 0.5 kg/ha, Alachlor @ 1.5 kg/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. Herbicide Metribuzin @ 0.75 kg/ha mixed with 1000 litre of water can be applied just after planting under dry soil which should be followed by irrigation also control weeds effectively. 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.

Fig : Chemical weed control using metribuzin as pre - emergence followed by hoeing

Suggested References

Kushwah, V.S. and J.S. Grewal. 1992. *Agro Techniques for Seed Potato Production*. Technical bulletin No.37. Central Potato Research Institute, Shimla, India 32 p.

Pushkarnath and K.K. Nirula. 1970. Aphid-warning for production of seed potato in subtropical plains of India. *Indian J. Agric. Sci. 40*: 1061-70.

Pushkarnath. 1959. Producing healthy seed potatoes in the plains: A new approach. *Indian Pot. J.* 1: 63-72.

Singh, Sarjeet, V.K. Garg, Shiv Kumar and G.S. Shekhawat. 2000. *Seed Potato Production Manual.* Central Potato Research Institute, Shimla, India. 91p.

SP Singh , S Rawal, VK Dua, S Roy, MJ Sadaworthy, SK Charkrabarti (November 2018) Weed management in conventional and organic potato production *International Journal of Chemistry Studies*. 2(6): 24-38

SK Pandey and SK Chakrabarti 2008 Twenty Steps Towards Hidden Treasure *Technologies that triggered potato revolution in India*, Central Potato Research Institute, Shimla.

S Rawal, MA Khan, VK Dua, SP Singh, SK Yadav, SS Lal, and BP Singh (2014) Weed Management in Potato Technical Bulletin No 99, Central Potato Research Institute, Shimla. 32 p

Chapter -10

IDENTIFICATION OF VIRAL DISEASES OF POTATO AND THEIR MANAGEMENT

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Introduction

Viral infection cause enormous economic losses particularly in the areas of tropics and semi tropics which provide ideal conditions for the perpetuation of viruses and their vectors. These diseases cause heavy losses to the crop and prove a limiting factor in its successful cultivation. So, any attempt to minimize the losses caused by these diseases must be, always, preceded by a correct and precise detection and diagnosis of the causal agent. Initially, critical visual inspection of disease symptoms (Fig. 1) constituted major step in virus detection. But, it is very difficult to diagnose the plant virus infections as the symptoms may vary depending upon the plant variety involved, the environmental conditions, strain of the virus. Sometimes different viruses can cause similar symptoms in the same plant species and sometimes the disease could result from the synergistic effect of infection caused by two or more different viruses. Therefore, techniques based on serology and molecular tests were developed for identification/ detection of viruses infecting potato.

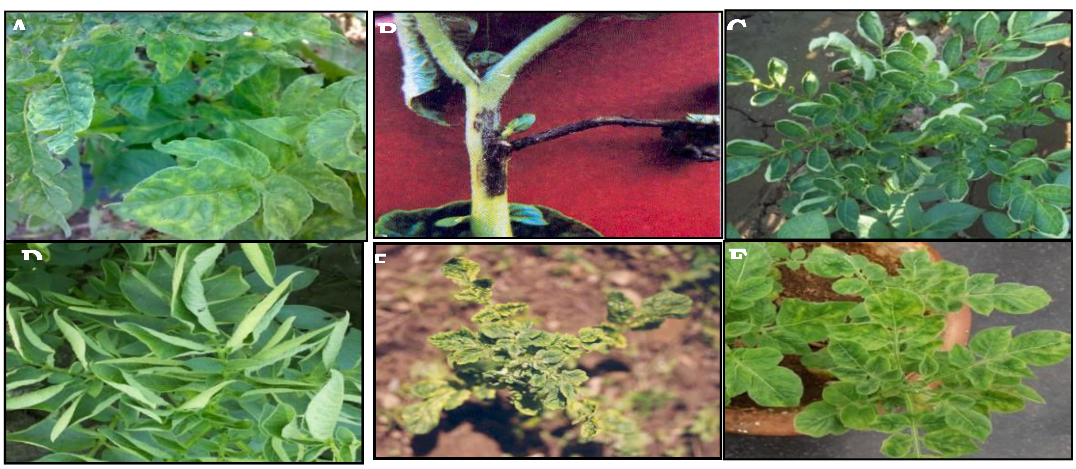

Fig. 1. Mosaics symptoms due to PVA, PVS, PVX and PVY (A); stem necrosis caused by GBNV (B); Spoon shaped leaves due to PVM (C); Leaf roll caused by PLRV (D); and apical leaf curl caused by ToLCNDV under field conditions (E) and in glass-house (pure cultures) conditions (F).

Viral diseases of potato

Potato Mosaics

In general majority of the potato viruses like PVY, PVX, PVA, PVM, PVS, PAMV and PSTVd (viroid) causes mosaics mottling/crinkle, necrosis, etc., either individually or in different combinations. Overlapping symptoms are invoked by different viruses individually and/or in different combinations, such as typical greening or yellows, mild or severe/rugose mosaics, faint mottle, chlorosis of plants and discolouration or distortion of foliage. Rugosity of leaves is accompanied by interveinal chlorosis and/or interveinal puckering. Besides, there can be necrosis of the veins (lower side), petioles and even inward curling of lamina which may lead to premature defoliation. Mosaics and mottle are prominent in cool and dull weathers.

Latent Mosaics

Potato virus X (PVX): It's latent in many of the cultivars whereas the severe strains can cause mosaic symptoms and the appearance of mosaics is limited by the veins. Bright day light generally affects visual symptoms, which can be observed under low light or placing a white card below the leaf.

Potato virus S (PVS): Usually latent or very mild or barely perceptible mottle and faint vein banding. Some cultivars develop mild rugosity while few strains invoke bronzing of leaves and in few cultivars tiny necrotic spots can also be seen.

Mild Mosaics

Potato virus A (PVA): Slight and transient mosaics that are particularly visible in cloudy weather. Mosaic faint mottling, slight crinkling of leaves and inter-veinal and veinal chlorosis. These symptoms can be reinforced by placing a sheet of white paper under the leaf.

Potato virus M (PVM): Spoon-shaped leaves corresponding to a soft curling of the leaves (while the potatoleaf roll virus produces "cracking" of the roll). Called leaf rolling mosaic or para crinkle. It occurs on developed plants, preferentially on the topmost leaves.

Potato spindle tuber viroid (PSTVd): The symptoms of PSTVd are very obscure and unusual. Generally the plants are slightly stunted, erect, often with curling leaves darker green than healthy. Eyes are numerous in number with distinct eye brows. Tubers are cylindrically longer than normal with tapered ends with cracks upon infection with severe strain of PSTVd.

Severe Mosaic and complex Diseases

Potato virus Y (PVY): Generally the symptoms vary with the strains of the virus or variety of potato *i.e.,* plants will be stunted with mild or severe mosaic, veinal necrosis. Ordinary strain (PVYO) and stipple-streak strain (PVYC) causes necrosis, yellowing of leaflets and premature leaf drops. PVYNTN strains cause mild mosaic and clearly visible raised necrotic ring spots on the tuber surface which later become sunken and skin cracking.

Crinkle (PVX+PVA): Infection of PVA and PVA may lead to heavy blotching of distorted, erect leaves with wavy margins, severe stunting, mottling, necrotic spotting and streaking of leaflets.

Rugose (PVX+PVY): The primary cause of rugose mosaic is due to the infection by PVY but in combination with PVX may result in severe rugose symptoms, stunted growth and leaf drop or curling with veinal necrosis in lower leaves and severe mosaic in upper ones.

Rosette (PVX+PVS+PVM or PVX+PVA+PVY+PVM): Severe stunting of the infected plants with single or afew stems per hill, puckered, roughened leaflets with inward and yielding a few small tubers.

Potato Leafroll

Potato leafroll virus is one of the most prevalent viral diseases of potato in India. Infected plants produce only a few, small to medium tubers. It is the type species of the genus *Polerovirus*, inthe family *Luteoviridae*. PLRV has small, isometric virions (23-25 nm dia) which are primarily confined to thephloem of the infected plants. The primary symptoms are confined to top young leaves, which usually stand upright, roll and turn slightlypale in certain cultivars. Most varieties, however, develop reddish/pink colour in top leaves starting at themargins, sometimes accompanied with slight rolling of the leaflets. Secondary symptoms develop when theplants are grown from infected seed tubers. Such symptoms are rather prominent in older leaves, *i.e.*absent or less pronounced on younger top leaves. Infected plants have characteristic pale, dwarfed, andupright appearance with rolling of lower leaves that turn yellow, brittle and are leathery in texture. In somecultivars, a reddish or purple discolouration develops on the margins and underside of the leaves.

Apical Leaf Curl Disease

Apical leaf curl disease has recently emerged as one of the most devastating viral disease of potato in India.It was first observed during 1999 in northern India and the association of a begomovirus with this diseasewas confirmed through electron microscopy in the year 2001. Further the virus was confirmed as a strainvariant of *Tomato leaf curl New Delhi virus* (ToLCNDV) on the basis of nucleotide sequence of genomiccomponents (2003). The incidence of apical leaf curl disease has been observed to be higher in early plantedcrop when temperature is high in October, than in November planted potato crop.It is transmitted through whitefly. Infected potato leavesshow chlorosis, crinckling, mosaic, curling of apical leaves, pinkish tinge on leaf margins, latter entire plantappears bushy and stunted due to reduced internodal distance.

Stem Necrosis Disease

Potato stem necrosis disease (PSND) has become a serious problem of the early crop in the central andwestern parts of India. Initially, it was thought to be fungal disease due to necrotic symptoms but later after detailed investigations,revealed the presence of enveloped spheroidal virus-like particles measuring ca 10 to 110 nm in diameter; particles being enclsoed in endoplasmic reticulum-like membrane. Characteristics of the virus like particlesshowed it to be *Groundnut bud necrosis virus* (GBNV).It is caused by *Groundnut bud necrosis virus* (GBNV), which is spherical, enveloped particles, ranging from70-110 nm in diameter and enveloped with glycoprotein. Under field conditions the virus is transmitted byviruliferousthrips in persistent manner. It acquires at nymphal stage and transmits in adult stage. The virusinduces necrotic and chlorotic spots on leaves and stem, veinal-necrosis, leaf droop and hanging, blackeningand cracking of stem. Distinct wavy concentric patterns with ligh and dark brown necrotic region cover thestem. In extreme cases of infection, cracking and blackening of stems also occur.

Identification of viral diseases of potato

Viruses and viroids, are very small, sub-microscopic and nucleoprotein macromolecules. Therefore, we need to have detection/ diagnostic techniques for specific detection/ identification to diagnose the cause of viral disease. The techniques used for identification/ detection of potato viruses/ viroids have been listed below.

Biological techniques: Specific plant species are inoculated with the virus that produce either necrotic local lesions on inoculated leaves or systemic symptoms, which are sometimes characteristic of a specific virus. These plant species are called indicator hosts. In fact, the earlier plant virologists employed only indicator hosts for virus detection and virus differentiation based on the spectrum of symptoms produced. Most of the indicator host species belong to *Solanacae* and *Chenopodiacae*. Though indicator hosts are not for identification of a virus, they are useful in the differentiation of strains of a known virus and for ascertaining virus infection in a test sample.

Serological/ Immunological techniques: These techniques are indispensable for the speedy, sensitive and reliable detection of viruses. There are a great variety of serological techniques ranging from the less sensitive and less reliable ones like chloroplast agglutination to the highly sensitive, reliable, quick and efficient ELISA (enzyme-linked immunosorbent assay) and immuno electron microscopy (IEM).

Enzyme-linked immunosorbent assay (ELISA): Commonly used format is double antibody sandwich ELISA (DAS-ELISA). It involves trapping of virus particles on antibody-coated wells of ELISA plate followed by reacting the bound particles with enzyme-antibody conjugate. In case of positive sample, enzyme-antibody conjugate will bind the trapped virus particles. It is confirmed by adding the enzyme substrate; positive sample will produce colour in the well as in the case of alkaline phosphatase-antibody conjugate (Fig. 2).

Fig. 2. Automated ELISA facility with robotic plates washer (A), plate reader (B) and visual observation ELISA plate with yellow coloured wells indicating positive for virus (C).

Immuno Electron Microscopy (IEM): It employs catching of virus particles from virus extract on antiserum coated electron microscope grid. Presence of antibodies on the grid inhibits non-specific binding of other host proteins but promotes binding of the homologous virus particles. As a result, a sort of immunopurification of the virus occurs on the grid seen as enhanced binding of virus particles with clean background. This step of IEM is called as 'trapping' and enhanced trapping of virus particles is indicative of the presence of the target virus. If the trapped virus particles are again made to react with homologous antiserum, antibodies bind to the virus particles and are readily seen in the electron microscope confirming the identity of the target virus (Fig. 3B). This process is called 'decoration'. When virus particles are allowed to interact with homologous antibodies, it results in the formation of clumps of virus particles due to cross-linking of virus particles with antibodies readily seen in the electron microscope.

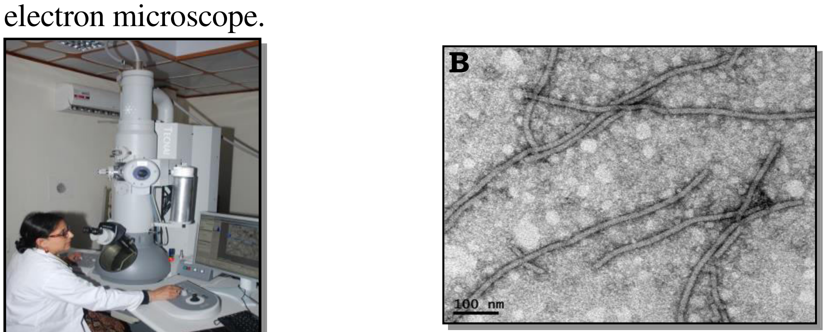

Fig. 3. Transmission Electron microscope (TEM) facility, 120kV TEM (A). TEM images of Potato virus A (B) particles.

Lateral flow immune assay (LFIA)/ dips sticks: The assay is based on the interaction between the target virus, antibodies and their conjugates with colloidal particles applied on the membrane carriers (test strips). When the test strip is dipped into the sample, the liquid flows through membranes and triggers immunochemical interactions resulting in visible coloration in test and reference lines (Fig. 4). The assay can be performed in 10-15 min. The greatest advantage of this technique is, it can be used in fields by an unskilled person.

Fig. 4: Development of Lateral flow immune assay for detection of potato viruses.

Molecular techniques: Polymerase chain reaction (PCR) is the most popular assay used for detection of specific virus. Since majority of the potato viruses possess RNA genome, a complementary DNA (cDNA) need to be synthesized and used in PCR amplification.

Uniplex and Multiplex RT–PCR: Uniplex RT-PCR employs a single set of primers whereas, multiplex RT-PCR employs more than one set of primers for detection of number of viruses simultaneously. Re-optimization of PCR conditions and reagents is necessary with increasing number of targeted viruses for specific detection. It is important that the amplicons should be of different lengths. The amplified DNA is detected through gel electrophoresis (Fig. 5).

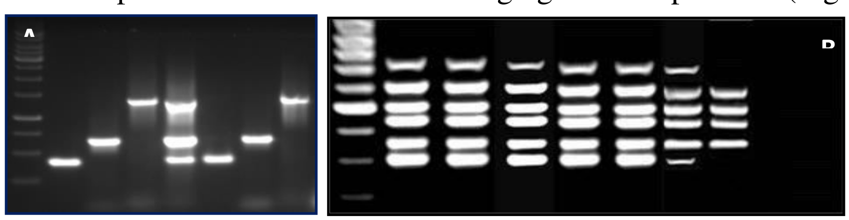

Fig. 5. Uniplex (A) & multiplex (B) RT-PCR assays for detection of potato viruses.

Quantitative PCR/ RT-PCR (qRT-PCR): The assay is being used for real-time quantification of the target DNA in a given sample. Two common methods for detection of products in real-time PCR are: (1) sequence-specific DNA probes consisting of oligonucleotides that are labelled with a fluorescent reporter which permits detection only after hybridization of the probe with its complementary DNA and (2) target non-specific fluorescent dyes such as SYBR green I that intercalate with any double-stranded DNA (Fig. 6).

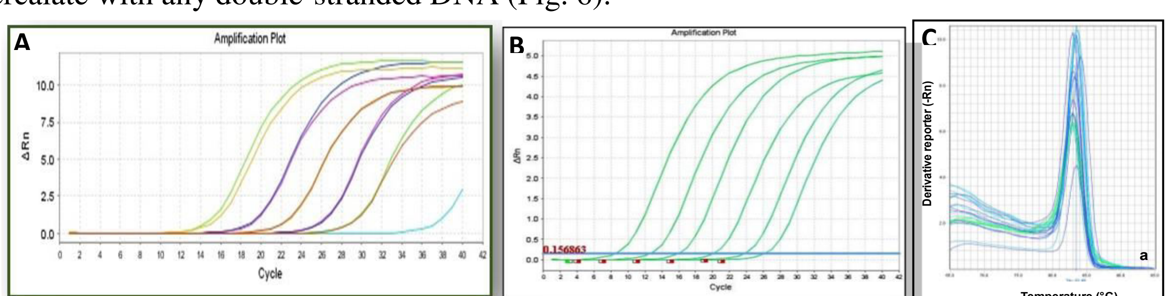

Fig 6. SYBR green based qRT-PCR detection of potato virus, amplification plot (A & B) and melt-curve analysis (C).

Loop mediated isothermal amplification (LAMP): Recently, a technique called loop-mediated isothermal amplification (LAMP) of DNA has been developed. The technique uses four to six primers that recognise six to eight regions of the target DNA, respectively, in conjunction with the enzyme *Bst* polymerase, which has strand displacement activity. The simultaneous initiation of DNA synthesis by multiple primers makes the technique highly specific. The LAMP test is carried out under isothermal conditions (60–65°C) and produces large amount of DNA (amplified 10^9–10^{10} times) in 15–60 min. Alternatively, gene amplification can be visualized by the naked eye either as turbidity or in the form of a colour change when SYBR Green, a fluorescent dye, is added (Fig. 7).

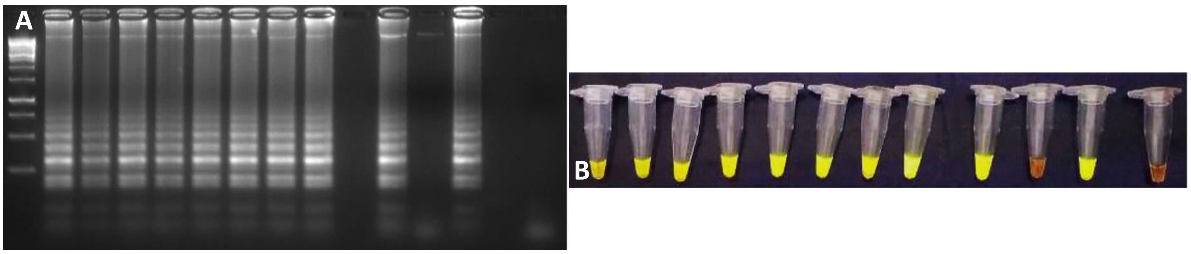

Fig 7. LAMP based detection of potato virus. Agarose gel electrophoresis (A) and visual detection by adding SYBR nucleic acid staining dye (B).

III. Management of viral diseases of potato

Diseases caused by viruses cannot be easily controlled by chemicals alone. Therefore, it has to be managed byadopting the following measure on co-operative basis and in an integrated approach:

1. Essentially plant the disease-free seed stocks from approved or reliable sources.
2. Apical meristem culture to produce pre-nucleus/mother seed stocks.
3. Yellow trap (15X30cm2) just above the canopy height @ 60 traps/ha at equidistance fromeach other.
4. Manage the weeds at regular interval and avoid/remove the reservoir plants like okra, brinjal and datura.
5. Rogue out the infected plants carefully along with their tubers at regular intervals.
6. Observe strict sanitation in the field and also in stores as they can spread through contaminated hands, clothes of workers, farm machinery/ tools etc.
7. Disinfect all field equipment's by dipping in or washing them either with 3% trisodium phosphate or calcium hypochloride (1%) solution to avoid the spread of virus.
8. Seed treatment with imidacloprid (17.8% SL) @ 0.04% (4ml/10 lit) for 10 minutes before planting.
9. First spray with imidacloprid (17.8% SL) @ 0.03% (3ml/10 lit) at the time of emergence of crop.
10. Second spray with thiamethoxam (25WG) @0.05% after 15 days of crop emergence.

Suggested References

Chandel RS, Banyal DK, Singh BP, Malik K, Lakra BS. Integrated Management of Whitefly, *Bemisiatabaci* (Gennadius) and *Potato Apical Leaf Curl Virus* in India. *Potato Research* 2010; 53(2), 129-139.

De Bokx, JA and JPH van der Walt. 1987. Viruses of potatoes and seed potato production, Pudoc,Wageningen (Netherlands), 259 pp.

Garg ID (2005). Virus *and virus-like diseases of potato and their management*. *In: Challenging Problems in Horticultural and Forest Pathology,* (R.C. Sharma and R.N. Sharma, Eds.), pp. 200-22, Indus Publishing Co., New Delhi, India.

Jeevalatha A, Ravinder K, BaswarajRaigond, S. Sundaresha, Sanjeev S and B. P. Singh(2015). Duplex realtime RT-PCR assay for the detection of *Potato spindle tuber viroid* (PSTVd) along with *ef 1-α* gene of potato. *Phytoparasitica*, 43:317–325.

Khurana, S.M. Paul. 1999. *Potato Viruses and Viral Diseases*. Technical Bulletin No. 35 (Revised). Central Potato Research Institute, Shimla, India. 94p.

Khurana, SM Paul, SK Pandey, RB Singh and Usha Bhale. 1997. Spread and control of the potato stem necrosis. *Indian J. Virol.* 13:23-28.

Raigond B, Ambika V, Shivani R, Tarvinder K, Shilpa, Jeevalatha A, Ravinder Kumar, Sanjeev Sharma and SK Chakrabarti (2018). One-step reverse transcription loop-mediated isothermal amplification: A simple, sensitive and rapid assay for detection of Potato Virus X in potato leaves and tubers. *Indian Phytopathology* 72: 321–328.

Raigond Baswaraj, Jeevalatha A, Ravinder K, Tarvinder K, Priyanka K, Shivani R, Rajender K and BP Singh (2016) Gold nanoparticles for improved electron microscopic detection of *Potato virus M* in potato leaves and tubers. *Potato J* 43(1): 22-29.

Singh, RB, SMPKhurana, SK Pandey & KK Srivastava 2000. Tuber treatment with imidacloprid is effective for control of potato stem necrosis disease. *Ind Phytopath*. 53:142-145.

Chapter -11

BIO-SECURITY ISSUES FOR IMPORT OF POTATO

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Potato is the most popular non-cereal food crop of the world and produces substantially more edible energy, protein and dry matter per unit area and time than many other crops. These virtues make potato as a good candidate crop for providing food and nutritional security to the developing world. Keeping this in view, FAO has declared it as the "food for future". There are many threats to potato that put sustainability at risk. Challenges like population growth, globalization, climate change, bioterrorism and changing agribusiness infrastructure hamper plant bio-security at the local, regional, and global levels. It is important for each nation to develop a plant bio-security infrastructure that ensures a safe and constant supply of food, feed, and fiber. It is equally important to develop an international framework for cooperation that maintains plant bio-security without compromising trade. The devastating effects resulting from diseases and pests introduced along with international movement of planting material, agricultural produce and products are well documented. Movement of plants and plant products between bio-geographical zones by human activities is now generally accepted to be the primary mode of introduction of exotic pathogens and pests.

Bio-security: Safeguarding of Resources from Biological Threats

Bio-security is a strategic and integrated approach that encompasses the policy and regulatory framework to analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risks. It covers i) the introduction of plant pests, animal pests and diseases, and zoonoses, ii) the introduction and management of invasive alien species and genotypes, and iii) the introduction and release of genetically modified organisms (GMOs) and their products. It encompasses the full spectrum of biological risk whether naturally occurring harmful organisms, or introduced by accidents and/or negligence through their deliberate use as biological weapon. Bio-security has wider implications in biological warfare and bio-terrorism. Thus, bio-security is a holistic concept of direct relevance to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity.

Need for Bio-security in Trade and Exchange Programmes

The introduction of pests into a new locality is brought about in various ways namely: i) the host may be the carrier; ii) inert materials such as packing material may carry resting stages of the organism; iii) insect vectors and birds may transport it; iv) air currents may carry the pest over long distances; or v) there may be deliberate, illegal introductions to use them as bio-weapons. The first two modes of distribution lend themselves to curtailment by quarantine measures. The next two are by and large beyond human control and are a major limitation in the control of pest by exclusion. A different degree of alertness and preparedness is required for the last category.

The global trade in agricultural commodities and transboundary movement of genetic resources of plants and animals has led to situations in the past which warranted legislative measures to regulate such trade/exchange. Plant quarantine is the government endeavour of planting materials, plant products, soil, living organisms, etc. in order to prevent inadvertent introduction of pests harmful to the agriculture of a country/state/region, and if introduced, prevent their establishment and further spread.

The devastating effects resulting from diseases and pests introduced along with international movement of planting material, agricultural produce and products are well documented. The historical Irish famine of 1845, caused by late blight of potato introduced from Central America; coffee rust introduced in Sri Lanka in 1875 and its subsequent introduction in India in 1876; fluted scale on citrus introduced from Sri Lanka in 1928; San Jose scale in apple introduced into India in 1930s; bunchy top of banana introduced from Sri Lanka in 1943; the dreaded Golden nematode infesting potatoes introduced in 1960s from the UK; wart pathogen introduced from Denmark in 1953 and the noxious weed *Lantana camara* introduced in 1809 from Central America are glaring examples that clearly demonstrate that introduction and establishment of quarantine pests including weeds into new areas can severely damage the crop production and economy of a region/country. Movement of plants and plant products between bio-geographical zones by human activities is now generally accepted to be the primary mode of introduction of exotic pathogens and pests.

After the Second World War, FAO convened an International Plant Protection Convention (IPPC) in 1951, to which India became a party in 1956. This convention helps in developing international cooperation among various countries to prevent the introduction and spread of regulated pests that may accompany international movement of plants and planting material (http://www.ippc.org). The IPPC requires that each country establish a national plant protection organization to discharge the functions specified by it.

Risk Associated with Imports

Based on the quantity, plant/planting material are either imported as bulk material for sowing/planting or for consumption while small samples of trial and germplasm are required for research work. Of these, bulk imports for sowing/planting carry maximum risk as thorough examination and treatment becomes difficult and the planting area required is also too large. However, certain small samples meant for research purposes are of immense quarantine importance. These samples usually comprise of germplasm material or wild relatives or landraces of a crop, and are thus more likely to carry diverse biotypes/ races/ strains of the pest. Besides, in case of true seed, generally risks are more due to deep-seated infections than with surface-borne contamination. However, the import of vegetative propagules presents a much higher order of risk than true seeds.

The Darjeeling hills of West Bengal were one of the important potato seed producing area in India prior to 1958. The seed produced in these hills were used to be sold to states like Bihar, Uttar Pradesh and Punjab. With the introduction of variety Furore from Denmark in 1953, the wart pathogen was also introduced which made Darjeeling hills unfit for quality seed production forcing Government of India to impose a legal ban on movement of potatoes from the state of West Bengal to other parts of the country through legislation. Thus, the country lost a potential seed producing area. Similarly, with the introduction of cyst nematodes (*Globodera pallida* and *G. rostochiensis*) from Scotland (UK) in the Nilgiri hills, Government of India had to impose domestic quarantine for the movement of potatoes and the farmers are unable to export seed potatoes to nearby countries like Sri Lanka. Thus, the country lost another potential seed production area. Similarly, common scab pathogen (*Streptomyces scabies*) was introduced through bulk import of potato seed from Burma.

Potential Threats to Potato

The potential for dangerous pests not reported from India being misused or mishandled and thereby threatening the ecosystems on a large scale is also an issue of national concern. Potato is usually propagated through tubers and this vegetative mode of propagation is beset with many problems; the most important of which is a progressive and significant decline in the yield potential of seed tubers over the years and this is called 'degeneration'. It is now unequivocally accepted that degeneration is due to viruses, phytoplasmas and viroids that multiply during successive clonal generations. Though potato is generally infected by more than three dozen plant viruses worldwide but all these viruses are not present everywhere. Hence, there is continuous threat of their introduction into new areas with planting material. The potato is vulnerable to threat from exotic pests/diseases that have the potential to be used as bio-weapons. Besides, a large number of destructive pests have strains/isolates/biotypes reported which also have potential for use as bio-weapons.

Development of 'Seed Plot Technique' in early seventies made it possible to produce potato seed in sub-tropical plains as a result bulk import of potato seed was terminated. The pathogen profile remained more or less constant till 1990. During mid nineties, potato was put under OGL as a result huge quantity of potato was imported into the country. But, realising the threats posed by the bulk imports, the relaxation of its import was withdrawn within six months. However, by that time a huge quantity of potatoes had already been imported into country. This led to a change in the pest and disease scenario in the country. The hitherto unknown viruses (exotic) like, Potato Yellow Dwarf Virus (PYDV), Tomato Spotted Wilt Virus (TSWV), Tobacco Streak Virus (TSV), Potato Yellow Vein Virus (PYVV), Potato Spindle Tuber Viroid (PSTVd), were introduced, which are now being intercepted during routine tests. This has put immense pressure on maintaining the potato seed health in the country.

Currently, potato seed production programme in India is based on eight viruses only which are prevalent in the country (PVX, PVS, PVA, PVM, PVY, PLRV, GBNV and Potato apical leaf curl virus), whereas 19 viruses/pathogens/pests are exotic in nature. If the bulk import of potato is allowed there is every likely chance of introduction of quarantine pests and pathogens like Potato tuber nematode (*Ditylenchus destructor*), Stem and bulb nematode (*Ditylenchus dipsaci),* Potato cyst nematodes (*Globodera rostochinensis, G. pallida*), Gangrene (*Phoma exigua* var. *foeta*), Potato wart (*Synchytrium endobioticum*), Potato smut (*Theccaphora solani*), Bacterial ring rot (*Clavibacter michiganensis* ssp. *sepedonicus*), Colorado potato beetle (*Leptinotarsa decemlineata*), Andean potato weevil (*Premnotrypes* spp.) and viruses (Andean potato latent, Andean potato mottle, Arracacha B virus, Potato deforming mosaic, Potato T, Potato yellow dwarf, Potato yellow vein, Potato calico strain of tobacco ring spot virus, Potato strains of tobacco streak virus and Potato purple-top wilt & stolbur *Phytoplasmas*), which might establish in the country and hamper potato production programme. If new viruses/pathogen enters into the country the entire seed production programme will become infructuous. It will take years to put it back on rails which country cannot afford. Therefore, it would be in the interest of the country that bulk import of potato from any country is not allowed and all appropriate steps are taken to avoid such a situation. Another lapse of similar nature may completely jeoparadize the indigenous potato seed production system in the country and we would end up importing potato seed from outside which our poor farmers cannot afford.

Ensuring Bio-security during Trade and Exchange

Legislation: The Government of India legislated the Destructive Insects and Pests (DIP) Act in 1914. This Act has been amended through various notifications issued from time to time and also has provision for domestic quarantine to restrict the movement of certain planting material from one state to another state. In 1984, a notification was issued under this Act, namely Plants, Fruits and Seeds (Regulation of Import into India) Order popularly known as the PFS Order which was revised in 1989 after the announcement of the New Policy on Seed Development by the Government of India in 1988, proposing major modifications for smooth quarantine functioning. This order has now been superceded by the Plant Quarantine (Regulation for Import into India) Order 2003 as there was an urgent need to fill the gaps in the existing PFS order regarding import of germplasm/ genetically modified organisms (GMO's)/ transgenic plant material/ biocontrol agents, etc. to fulfill India's legal obligations under the international Agreements.

Infrastructure: The Directorate of Plant Protection Quarantine and Storage (DPPQS) of the Ministry of Agriculture & Farmers Welfare is the apex body for implementation of plant quarantine regulations. It has a national network of seven Regional Plant Quarantine Stations and 42 Plant Quarantine Stations spread over seven regions of the country at airports, seaports and land frontiers. In all, two categories of materials are being imported under the PQ Order, 2003: i) bulk consignments for consumption and sowing/planting, and ii) samples of germplasm in small quantities for research purposes. The Plant quarantine Stations under the DPPQS undertake quarantine processing and clearance of consignments of the first category (http://www.plantquarantineindia.org). The ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR) undertakes the quarantine processing of all plant germplasm and transgenic planting material under exchange. As per the PQ Order 2003, the ICAR-NBPGR is responsible for ensuring that imported transgenic material is free from pests and terminator gene technology.

In the light of above discussion, a holistic concept to address the issue of bio-security needs to be evolved. Under the present international scenario, the plant protection specialists have a major role to play in promoting and facilitating export and import in the interest of the nation but also in protecting the environment from the onslaughts of invasive alien pests and unforeseen ill-effects of the introduction and trading in GMOs. Besides, the threat to national bio-security from the use of such instruments as bio-weapons to create agro-terrorism is a possibility that requires preparedness. The holistic approach to ensure bio-security seeks to use the synergies of various existing sectors at the national level and there is a need for integration of various aspects of bio-security and the institutions involved.

Chapter -12

NON-SUCKING PESTS OF POTATO AND THEIR MANAGEMENT

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Potato crop is attacked by a number of pests that can completely destroy the crop if left unattended, few of them can damage tubers, making them unfit for seed as well as for human consumption. Some can damage the leaves by chewing them and affecting the yields in turn. In potato production many need based suitable IPM programmes are there to control the insect/pests but they can be different in different geographical areas depending upon the kind of insects prevalent in that particular area.

WHITE GRUB: These are polyphagous beetle whose larvae live in soil and these larvae are called 'white grubs'. White grubs are widely distributed world over hence they are cosmopolitan in nature. The number of grubs can be more in light soil with high organic matter content. This had been most destructive insect threatening potato production in hilly regions, now it is becoming a problem in potato producing areas in plains too. In plains, white grub has long been associated with sugarcane crop and now causing the damage to potato crop. Out of many, *Brahmina coriacea, Holotrichia seticollis*, *H. Longipennis, Anomala dimidiata* and *Melolontha indica* are most destructive in north western hilly region and many others are found in different parts of the country. White grub, *B. coriacea* was first reported to cause serious damage to potato in 1980 and the damage ranged from 10-90 per cent in variety Kufri Jyoti.

Seasonal biology: In India, adult beetles emerge from the soil during April to June in response to pre monsoon showers. The second fortnight of June observed as the peak period of emergence of beetles, adults mate in the evening and at dawn. Females return to the ground to deposit the eggs in the soil depending upon the softness of the soil.The beetles are strong fliers, in the evening of warm sunny days they come out of the soil and fly to nearby trees/shrubs at dusk. The damage is done by second and third instar grubs (larval stage) which feed on underground part of the plant by making large shallow and circular holes in the tubers. The grub stage which can be easily identified is creamy white in colour with dark brown head and attains 'C' shape of English letter when disturbed.

Adult beetle management: Light traps can also be useful to catch the adults as soon as they emerge and kill them in water mixed with kerosene. For chemical control, damage can be minimized by the application of soil insecticide at the time of planting or at the time of earthing-up. Spray of chlorpyriphos 20 EC (0.1%) immediately after first monsoon showers on weeds and bunds around the field will reduce the number of grubs emerging out of eggs. Spray the crop (ridge portion) with chlorpyriphos 20 EC@ 2.5 l/ha after earthing-up to kill the larvae.

Grub management: Deep ploughing after harvest of potato is the best way to expose white grubs to high temperature and natural predatory birds. Similar ploughing should be done at the time of planting also. Only well rotten Farm Yard Manure should be applied to the fields as this acts as attractant for grubs to feed on if not fully rotten.

Natural enemies: In nature white grub population is kept low by predatory birds like, Indian myna and jungle crow. Wild boars and dogs prey on big sized grubs but they destroy the crop too. In India and Nepal, *entomopathogenic fungi* are being used against white grub. Entomopathogenic nematodes (EPN) are effective in management of white grubs in potato crop in mid and higher hills of Himachal Pradesh.

CUTWORMS: Cutworms are polyphagous and most destructive insects. *Agrotis segetum, A. Ipsilon and A. flammatra* are reported to occur on potato. In India, cutworms are more serious in northern region than south. Peak activity occurs during May-June in Shimla hills, in August in peninsular India and in March April in Bihar and Punjab.

Seasonal incidence: In plains of country, the population of cutworm *A. ipsilon* is able to attain the first peak in mid of December, second peak will be observed during third to fourth week of March, type of the soil has a large influence on the rate of infestation. Cutworms tend to be more frequent in soil with plenty of decaying organic material. Damage is worse where cutworms are present in and around the field in large number before planting.

Biology: The eggs are small (about 0.5 mm in diameter). The freshly laid eggs are cream coloured and turn reddish-yellow to blackish before hatching. They are laid singly or in clusters. Eggs are laid on vegetation, on moist ground around plants, or in cracks in the soil. Eggs hatch in 10 to 28 days. Young caterpillars are smooth, stout, cylinderical with blackish brown in colour dorsally. Fully-grown caterpillars are 4 to 5 cm long. The larvae curl into a C shape when disturbed and remain motionless for a short period. They commonly hide just under the soil or litter by day. 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 construct burrows or tunnels in the soil 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 life cycle can be completed in 6 weeks under warm conditions.

Nature of damage: Crop damage is caused by caterpillar (larva) stage only. They cause damage by- (i) young larvae feeding on leaves (ii) mature larvae by cutting the stem of the plant just near the ground and (iii) making irregular holes in the tubers. Larvae also feed on roots also. Smooth, grayish-brown, greasy and plump looking caterpillars are found hiding in the soil near to the stem of the plant during day time. After tuber formation, they starts feeding on tubers and roots resulting in a variety of holes, ranging from small and superficial to very large deep ones so it directly affects the tuber yield and its market value. Tuber damage can be from 9.0-16%.

Management: Deep summer ploughing in potato fields to exposes immature stages to predators and sun. Fields should be prepared and vegetation and weeds destroyed 10 to 14 days before planting the crop in the field. Flooding of the field for a few days before planting can help to kill cutworm caterpillars in the soil. Exposing the larvae to bird predators is the best way. Light traps installed in/around potato fields attract the adult moths.

For effective chemical control, the chemical should be sprayed at the appropriate time.The best time is when caterpillars are small and still feeding on the haulms. Chemical control would be more effective when soil is dry and weather is warm. For efficient chemical control thorough coverage of foliage with good amount of water is needed. Chlorpyriphos 2.5lit/ha, cypermethrin and triazophos are used to control cutworms on potato.

POTATO TUBER MOTH, *Phthorimea operculella*: The potato tuber moth also referred as PTM, is the most significant insect pest of the potato and three species are most important, common potato tuber moth, *P. Operculella*. The common PTM today it has become a cosmopolitan pest. It has been reported from more than 90 countries worldwide. The moth occurs in all tropical and subtropical potato producing systems. The damage has been reported from Maharastra, Bihar, Madhya Pradesh, Uttar Pradesh, Kangra valley (Himachal Pradesh), Tamil Nadu, North Eastern hill states and plateau region and Karnataka. The range of infestation can be 30-70% in stored potato.

Alternate hosts: tomato, egg plant and few solanaceous weeds, *Solanum nigrum*.

Nature and symptoms of damage: The adult moth prefers to lay eggs on green foliage than on tubers. Eggs are laid on underside of the leaf in the field the young larva feed inside the tunnel between two layers of leaf tissue and later on to leaves. The larvae destroy the crop by injuring the leaves and boring into petioles and terminal shoots causing wilting. After tuberization, the eggs are laid in the eyes of tubers through cracked soil or if tubers are exposed. The larvae feed on them causing mines. Because of the heat produced by the activity of larvae in the heaps the losses become huge due to tuber rottage also. In country store the larvae bore into stored potatoes causing 18-83% tuber damage in NEH hills.

Biology: Life cycle of PTM is completed in 21-30 days at 27-35^{o}C. Upper and lower threshold temperatures for PTM are 40^{o}C and 5.0^{o}C.

Management of Potato Tuber Moth (PTM)

Storage of healthy, un-infested potato tuber is the best way to control potato tuber moth. Cultural practices can contribute significantly to reduce PTM infestation at harvest.

Use of botanicals/biopesticides: Covering of potato heaps with 2.5 cm thick layer of chopped dried leaves of Lantana/ Eucalyptus can prevent tuber infestation. Use of Granulosis Virus (GV) is extremely effective in reducing PTM damage. Use of sex-pheromones can be made by mass trapping PTM male adults.

Chemicals/Semiochemicals and Attract and kill approach: Dusting of the tubers with 5% Malathion or 1.5% quinalphos (125g dust/100 kg potato) will result in good control of PTM but these potatoes should not be consumed. Sex pheromones are available for all the PTM species. Attract and kill product (attracticide) consisted of pure pheromone, cyfluthrin as contact insecticide, formulated with plant oils and ultraviolet screens was successful in both laboratory and field experiments.

TERMITES: Common termites are- *Microtermes obesi, Odontotermes* obesus, and *Eromotermes* spp. The damage done by termite is more in rain fed crops than to frequently irrigated crops.

Nature of damage: They can be easily identified with brown head and dirty white soft body. It is the worker caste of the termite which damages the crops by damaging the roots as a result the leaves of the plant turn yellow and plant starts wilting and ultimately dries. Tunnels can be made into the tubers. The tubers become hollow and filled with soil and that is the typical symptom of termite.

Life cycle: These insects are social insects. Most of the individuals perish but the remaining few will mate, shed their wings and burrow in the soil to form new colony of which they become king and queen, the queen lives 5-10 years and lays large number of eggs 70,000-80,000 per day. Crop residues should not be left in the field as they provide food to the termites.

RED ANTS: Red ants, *Dorylus orientalis* and *D. Labiatus* are reported as a pest on potato, cauliflower, cabbage, groundnut, sugarcane, coconut seedlings.

Nature of Damage: They also have a habit of attacking the underground parts of the plant but do not avoid light. They can be seen in large numbers in the field. The ants seen in the fields are workers. It is a pest of warmer climates (> 26°C), high temperature and dry weather favours the population build up. Workers of red ant feed on tubers by nibbling and making small but deep circulars holes. The damaged plants wilt in sunlight and eventually dry up.

Chemical control: The pest is very difficult to eradicate. Spraying of the crop and drenching of the ridges with chlorpyriphos 20EC @ 2.5 l/ha helps.

WIREWORMS: Wireworms are the larvae of click beetles (*Drasterius* spp., *Agronichis* spp., *Lacon* spp). They are becoming important worldwide and are generalist herbivores in nature mostly. The crops include grains-wheat, barley, oats; forage crops-corn and maize; many vegetables, tobacco, sugarbeets, sugarcane, sweet potatoes and potatoes.

Nature of damage: The major damage occurs from the time of tuber initiation until harvest and reduces the marketable quality of potatoes. Wireworms bore into the tubers making cylindrical holes and bigger larvae do more damage. The economic threshold is low. The treatment may be initiated if wireworms are detected in a pre-planting soil sample.

Life cycle: *Agriotes* spp. have very long life cycle may several years to complete their larval period. The presence of wireworms can be monitored by using baits.

Management: Mechanical methods of disturbing soil such as ploughing, harrowing, disking and rotavating can reduce wireworms. Soil application of chemical insecticide used at the time of planting takes care of these worms. Neonicotinoids (imidacloprid and thiamethoxam) seed treatment can reduce them. The phenyl pyrazole, fipronil is the most effective wireworm insecticide, it kills wireworm at much lower dose and takes care for months after exposure

MOLE CRICKETS: This is sporadic in nature and reported from Bengal in India. It can damage mostly all crops and common species are- *Gryllotalpa africana and Gryllotalpa orientalis.*

Nature of damage: Young plants/seedlings are attacked more. The damage can be 5-6% in plants and 10-15% in tubers. Eggs are laid in rainy season deep in the soil, nymphs live underground in branched burrows and feed on roots of cultivated wild plants. They can also damage newly planted seed tubers by tunnelling inside. Both nymphs and adults come out in the night and feed on the leaves of the plants. This can be controlled by applying chlorpyriphos.

Chapter -13

MANAGEMENT OF VECTORS/ SUCKING PESTS OF POTATO

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Potato is prone to attack by more than 100 insect pests which are one of the important limiting factor in raising productivity and production of potato in the country due to transfer of number of viral diseases, resulting in quick degeneration. Insect vectors like whitefly and thrips have given new dimension and challenges to IPM of potato in the country. Adoption of IPM is more relevant in potato because potato is often consumed directly as a vegetable. Still, there is a gap in available technology and the technology being adopted by the potato farmers. Doubling the income of potato farmers by 2022 is a real challenge to Indian farmers and scientists. Habitat management in potato crop through biological measures can be made more effective by adopting conservation and promotion of natural enemies in the ecosystem, beside proper insecticides and their doses based on pest biology and crop phenology will give the best results for potato insect management and double the economic returns of the farmers.

Beside other factors, foliar diseases and soil and tuber borne diseases, viruses, soil pests, foliage feeders, sap feeders and storage pests cause considerable damage at various stages of the crop and their severity and incidence varies from region to region. Amelioration in crop losses due to diseases and insect pests through scientific interventions is very critical and forms sound means of their management. In this article, Insect vectors in potato seed production and their management (IPM) have been dealt comprehensively. Its interventions should be suitably modified and validated according to the region before its implementation**.**

Insect pest scenario in potato: Insect pests cause direct damages to the crop by feeding on potato tubers in soil, feeding on foliage and on potato tubers in stores, while indirectly by sucking the sap and transmission of viral diseases in the crop resulting quick degeneration of seed stocks. The number of insect pest species causing serious damage to potato crop has been few in 70's to 10-15 in the last 5 years. Among the major vector pest, aphid *Myzus persicae* Sulzer is the most destructive. They inflicts severe losses in potato particularly by transmitting number of viruses like PLRV, PVY, PVA and PVM. White fly, *Bemisia tabaci* (Gennadius) now assumed significant importance in North Central India as; they are main vector of Gemini virus, which causes apical leaf curl disease in potato. Similarly, leafhoppers and mite are now serious problem in early potato crop in North-Western plains and Plateau region. These vectors are considered more important because they are responsible for significant decline in potato yields directly or indirectly across the country.

There are many vectors of regional significance among them, Thrips, *Thrips palmi* Karny in Madhya Pradesh (Gwalior & Chindwara), Gujrat (Deesa) and Rajasthan (Kota).

Sucking pests (sap feeders): The major sap feeders include aphids, whitefly, thrips, leafhoppers and mites. Among this group aphids are of the greatest economic importance as a vector of virus diseases in potato. Whitefly is assumed significant status as a vector in North Central India but high populations of these sap feeders can also cause direct damage to crop. Thrips, mites and leafhoppers are sporadic and restricted to certain potato growing areas. These sap feeders not only cause direct damage to potato crop but also transmit viruses, resulting degeneration of potato seed.

1. Aphids: Aphids are one of the most important insect vectors in the production of healthy seed tubers. Among the dozen species, *Myzus persicae* (Sulzer) and *Aphis gossypi* have been reported widely on potato crop in India. As a result of feeding the leaves curl downward, turn yellow, become wrinkled and ultimately die. Aphids transmit potato virus in two ways i.e. non persistent and persistent manner in potato crop. Potato leaf roll virus (PLRV) and potato virus (PVY) are estimated to 20 to 50% and 40 to 85% yield losses, respectively. In the North-Western and Central Indo-gangatic plains the population of aphids remained low from October to December. Aphids are crossed the critical limit (20 aphids/100 compound leaves) in these regions only after last week of December in North-Western plains and second week of January in North-Eastern plains. The maximum population is generally observed in February and March. The seed potatoes can be grown successfully by adjusting the planting time and cutting of haulms as per the activity of aphids. Reproduction of aphids is usually parthenogenetic and viviparous. The *M. persicae* feeds on several ornamental plants, weeds and vegetables crops.

Management

- Potato seed production area should be selected on the basis of population studies of aphids for the production of disease free potato seeds.
- Eliminate alternate host plants or infected diseased plants; use balanced fertilizer and good water management in potato fields.
- Haulm killing and harvesting should be completed as per the activity of aphids or before the population attaining 20 aphids/100 compound leaves.
- Monitoring of aphid population through aphid count on 100 compound leaves or use of water and yellow sticky traps.
- Only foliar systemic insecticides such as Dimethoate, or Imidacloprid are recommended for controlling aphids on seed crop. Granular insecticide applied at planting has also been found effective for 45-65 days.
- Conservation of natural enemies like *Coccinella septempunctata* L., *Chrysopa* .

2. Whitefly: *Bemisia tabaci* is tiny, soft, white winged insect, found mostly on the lower surface of potato leaves and sucking sap from succulent leaves. Whitefly is a newly emerging vector and transmit Gemini virus in potato, resulting apical leaf curl disease in North-Central India.

Management: As per aphids.

3. Thrips: Thrip is very small insect of 1mm with fringed wings, adhered on the apical portion of the foliage. *Thrips palmi* Karny is one of the predominant species responsible for transmission of disease in early potato in Central India. It will acquire tospo virus only at nymph stage and transmit throughout their life. The wide range of disease symptoms include leaf droop and hanging, blackening and cracking of stem and concentric ring spots in affected stems. Potato yield losses due to the disease vary greatly from place to place and year to year and may range from 15 to 30%.

Management

- Avoid early potato planting.

- Grow tolerant potato varieties for early planting like Kufri Sutlej, Kufri Badshah and Kufri Jawahar.
- Seed treatment Imidacloprid 17.5 SL @ 5ml/10 l of water for 10min. or spray with same insecticide just after the emergence of crop @ 4ml/10 l of water.
- Frequent irrigation reduced the activity of thrips on crop.

4. Mites: Mites cause severe damage (20-60%) to early potato crop in Indo-gengetic plains, part of Himachal Pradesh, Maharashtra, Karnataka, Gujarat, Madhya Pradesh and Western Uttar Pradesh. Mites suck the sap from leaves and in severe damage resulting wither and waxy lower surface. Mite is very minute insect and difficult to see through necked eyes.

Management

- Delay in potato planting.
- Spraying of Dicofol 18.5EC or Quinalphos 25EC @ 2.0 l/ha.

5. Leafhoppers: *Amrasca biguttula biguttula* and *Empoasca devastans* cause direct as well as indirect damage to potato crop. Both the nymphs and adults suck the sap from tender parts and in severe condition plants showed hopper burn, which is very common in case of early planted potato crop in northern plains. The nymphs are light yellow to pale yellow in colour with well developed head capsule Management As per aphids.

Challenges for the future: Among the various components of IPM, cultural practices are one of most practicable, eco-friendly approach in potato crop. It includes disease free seed, time and manner of planting, sanitation, balance use of fertilizers, haulm cutting, harvesting and proper storing of potatoes. These practices need to be modified and refined to make them more compatible to maximize the productivity and production of potato. Large number of natural enemies have been identified that could be conserved in potato fields. There is an urgent need to reduced application of harmful chemicals, only selective and need based application will be advocated on the basis of monitoring of insect pests. Monitoring and forecasting models of insect vector specially aphids should be up dated for different regions. Very little information is available on the effect of various plant extracts on major insect pests. However, neem and other plant formulation were evaluated and found promising, could be used as a component in IPM schedules. In the end, it may be concluded that there is still a gap in available technology and the technology being adopted by farmers. This gap can be minimized by convincing the farmers about benefits of IPM. This will given the ample opportunity specially potato farmers to double the income by 2022.

Suggested References

Bhatnagar A., Sharma V. and Singh B.P. 2016. Climate change and population buildup of whitefly on potato cultivars in North –Western India. *Int. J. Agri. Stat. Sci*., 12(1):199-203.

Bhatnagar A. 2008. Insect associated with potato in Madhya Pradesh. *Pest Management in Horticultural Ecosystems*, 13 (2):21-24.

Chandla V.K., Khurana S.M. Paul and Garg I.D. 2004. Aphids, their importance, Monitoring and Management in Seed Potato crop. *Tech. Bulletin* No. 61, CPRI, Shimla,1-12p.

Venkatasalam E.P., Pandey K.K., Singh V. and Singh B.P. 2011. Seed potato production technology, CPRI, Shimla, Publication, 1-57 p.

Chapter -14

NEMATODES AND THEIR MANAGEMENT PRACTICES USED IN POTATO CROP

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Introduction

The Potato cyst nematode (PCN) (*Globodera* spp.) and root knot nematodes (RKN) (*Meloidogyne* spp.) are amongst the most economically important nematode pests of potato. The earliest record of parasitic nematode infestation in potato crop was of the cyst nematode recorded in the year 1881 by Julius Kuhn from Germany. Whereas, RKN was recorded in 1889 by Neal from Florida in USA and ten species are reported to infect potatoes. Two species of PCN *viz., Globodera rostochiensis* (Woll) and *G. pallida* (Stone) also popularly called the Golden nematodes hindering the sustainable production of potato in many countries worldwide including India. They are subjected to stringent quarantine and/or regulatory procedures, wherever they occur and present a serious threat to domestic and international commerce in potatoes. In India, the RKNs infection in potato tubers was first noticed by Dr. Thirumalachar in 1951. He observed scab like warts on potato tubers from Shimla during 1950 which were caused by the root-knot nematodes.

1. Root knot nematode (RKN)

In India, the dominant RKN species affecting potato both in hills and plains has been *Meloidogyne incognita* while *M. javanica* infestation is in mid hills and plains of northern India. *M. hapla* is confined to hilly tracts of Uttar Pradesh, Himachal Pradesh, Jammu and Kashmir and Tamil Nadu. *M. arenaria* is reported form the plains of Uttar Pradesh. Till now, pathotypes belong to particular RKN species have not reported.

Host range and biology

Root-knot nematode species found to infect more than 2000 plants worldwide that includes many important cereals, pulses, vegetables, fruits and ornamental including potato. The vermiform second stage juveniles hatch out from the egg masses penetrate the young potato roots and starts feeding. This leads to the formation of specialized, enlarged cells called 'giant cells' which provide nourishment to the nematodes throughout its development. The second stage juveniles (J_2) undergo molting and pass through J_3 and J_4 stages and finally become adult females or males. The adult females are sedentary and pear shaped while males are migratory and vermiform or thread shaped. Males move out of the root to locate and mate the females. The females lay about 300 to 400 eggs in gelatinous matrix, usually adhering to the root galls. At the time of tuber formation, the juveniles usually enter the tubers since the root system would have started decaying. Life cycle is completed in 25-30 days during summer and 65-100 days in winter.

Symptoms and yield loss

The above ground symptoms include stunting and yellowing of plants with chlorotic leaves due to the hindrance in water and nutrient uptake by roots. In roots, the characteristic swellings called 'galls' are formed. The warty 'pimple-like' blemishes on the tubers due to nematode infection reduce the commercial value and keeping quality of potato (Fig 1). Brown spots are evident in the flesh of the cut tubers due to the presence of nematodes. An initial inoculum of 200 juveniles per 100 ml soil resulted in an overall yield reduction of 40% with 100% tuber infestation.

Fig 1. RKN symptoms in field and tubers

Management

Cultural control

Use of healthy seed tubers and avoiding seed tubers from infected areas. Deep ploughing during summer months exposes the infective juvenile stages of the nematode to direct sun, thereby killing them. Adopting good sanitation and keeping the field free of weeds which otherwise would serve as alternate hosts for root-knot nematode. Crop rotation with non-host crops like maize or wheat helps in minimizing the nematode damage. Early planting of spring crop in first week of January and late planting of autumn crop in second and third week of October reduce nematode infection in potato due to the lower temperature prevailing during crop period. Growing trap crops such as marigold, *Tagetes patula* in alternate rows with potato reduce nematode population in soil.

Chemical control

Application of carbofuran 3G@ 1-2 kg/ha will reduce nematode infestation and increased yield. The efficiency of pesticides will increase when applied in two split doses once at planting and then at the time of earthing up.

Integrated management

Since a single method of control is uneconomical and not adequate for better nematode management, a judicious blend of the above methods is always advisable for achieving higher production. Using of nematode-free seed tubers, crop rotation with maize or wheat and application of carbofuran 3G@ 1-2 kg/ha at the time of potato planting. A two-year adoption of INM for root-knot gives efficient and economical production system.

2. Potato cyst nematodes (*Globodera* species)

In India, Dr. F.G.W. Jones first detected the potato cyst nematode in 1961 from a field in Vijayanagaram farm in Udhagamandalam, The Nilgiris district, Tamil Nadu. Later on, their occurrence was reported from other parts of Nilgiri, Kodaikanal hills, adjoining hills of Karnataka, Idukki District in Western Ghats of Kerala and recently, in the hilly regions of Himachal Pradesh. Accordingly, Tamil Nadu Government imposed domestic quarantine during 1971 to ensure strict checking of seed potato for marketing from infested field of Udhagamandalam. In addition, Government of India restricted the movement of potato seeds from some areas of Himachal Pradesh, Jammu & Kashmir and Uttarakhand hills (Gazette Notification S.O.No 5642 (E) dated

2nd Nov, 2018). In India, the differential host reactions of PCN populations from The Nilgiris and Kodaikanal hills revealed that the pathotypes Ro1 of *G. rostochiensis* and Pa2 of *G. pallida* are the most prevalent forms. The other prevalent pathotypes are Ro2 and Ro5 of the former and Pa1 and Pa3 of the later.

Spread of PCN

The PCN normally spreads by the movement of infested soil containing cysts and larvae, movement of seed potatoes from infested fields to the clean fields, irrigation and rain water, raising of seedling from infested area and planting to clean area, movement of compost from infested area, use of agricultural implements first in the infested area and then in clean plots, through shoes of the workers and hoofs of cattle and through the use of old gunny bags in which the potatoes from infested plots were packed/stored previously.

Host range and biology

Potato (*Solanum tuberosum*), tomato (*Lycopersicon esculentum*) and eggplant (*Solanum melongena*) are the agronomic crops attacked by both species on PCN. Other host range of PCN includes mainly *Solanum* species *viz., Datura, Hyoscyamus, Lycopersicon, Physalis, Physoclaina, Salpiglossis* and *Saracha* and *Oxalis tuberosa* Molina, a native Andean tuber crop of economic importance, is also considered to be a host of PCN. he hatching of cysts is stimulated by the chemical substances called hatching factors present in the potato root diffusates (PRD) of the host plant roots. The second stage juvenile (J_2) coming out of the cysts moves actively in soil and invade the roots by rupturing with its stylet. It enters through the epidermal cell walls and eventually settles with its head towards the stele and feeds on cells in pericycle, cortex or endodermis by forming a feeding tube. This induces enlargement of root cells and breakdown of their walls to form a large 'syncytium' that provides nourishment for nematode development. The nematode molts and remains in the syncytium until its development is complete. The sex of the nematode is determined during J_3 stage. The females become sedentary, swollen and remain attached to the roots and posterior part of the body comes out by rupturing the root cells. Males retain their thread shape and come out of the roots to locate and mate the females. The immature females of *G. rostochiensis* are golden yellow in colour while *G. pallida* are white or cream in colour (Fig 2). The white PCN remain white or cream-coloured before finally turning brown whereas the yellow PCN passes through a prolonged golden-yellow phase before it also turns brown. After the female dies, the body wall thickens to form a hard brown cyst that is resistant to adverse weather conditions. Each cyst contains 200-500 eggs and is easily dislodged in soil at harvest. The cysts can survive in soil for 20-30 years even in the absence of a suitable host. The life cycle is completed in 35-40 days and generally, one generation is completed in one crop season.


Fig. 2. Infection of *Globodera* species

Symptoms and yield loss

The disease caused by this nematode is often referred to as 'potato sickness'. The presence of the golden nematode in soil is often unnoticed in lightly infested crop which does not show any above ground symptoms at all. This is because at low PCN population densities, most plants can tolerate nematode invasion and respond by developing more lateral roots as wound response, without affecting their growth and yield. However, as the degree of invasion increases, the plant is unable to compensate and ultimately exhibits a range of symptoms. When the infestation is sufficiently heavy and localized, small patches of poorly growing plants appear in the field wilting may occur during hot parts of the day (Fig 2). As the season advances, the lower leaves turn yellow and brown and wither, leaving only the young leaves at the top, the entire plant now presenting a somewhat 'tufted head' appearance. The browning and withering of the foliage gradually extends and ultimately causes the premature death of the plant. The root system is poorly developed and the yield and size of the tubers are reduced considerably depending upon the degree of infestation.

Globally, an average yield loss of nine per cent, which is about 43 million tonnes, has been estimated due to this nematode alone. In India, the tuber yield loss estimates vary from 5 to 80% depending on the initial inoculum level. The economic threshold level for crop loss due to PCN is usually around 20 eggs per g of soil, which may vary with the environmental interactions and host tolerance.


Fig. 3. Symptoms of field infected with potato cyst nematode

Management

Once established, PCN are very difficult to be eradicated from infested fields. As no single method of control is fully effective in giving desirable level of nematode suppression, an integrated nematode management package incorporating judicious blend of various management options such as host resistance, chemical, biological and cultural methods are being advocated to bring down the PCN population to levels that permit profitable cultivation of potato.

Cultural control

Crop rotation

Crop rotation of three to four years involving potato, French beans, peas and peas give nematode reduction and increased the yield of potato. Three to four year rotation with crops like radish, cabbage, cauliflower, turnip, garlic, carrot, green manure crop like lupin etc. brings down the cyst population by more than 50%.

Intercropping

Intercropping of potato with French Beans (3:1), mustard (1:1), radish (2:1) is effective in decreasing the population of PCNs.

Trap cropping

Trap cropping with susceptible potato cutivar, Kufri Jyoti attracted more juveniles than the resistant potato, Kufri Swarna and recorded 53% reduction in nematode population but the trap crops should be destroyed before the completion of PCN life cycle (35-40 days after planting).

Host plant resistance

First cyst nematode resistant cultivar Kufri Swarna was released in year 1985, subsequently "Kufri Neelima" during 2012 and the recent one was Kufri Shayadri during 2019 for Nilgiri hills from ICAR-CPRS, Udhagamandalam.

Chemical control

Application of Furadon 3G at 2 kg a.i./ha at the time of planting is being recommended as a part of package of practices for potato in the Nilgiris to bring down the PCN population Recently, new fumigant molecule Dazomet (Basamid 90G) @ 40-50 g/m^2 also found to be effective in bringing down the PCN population but after application the soil needs to be covered with polythene sheet which may not be possible in larger areas. However, repeated use of nematicides is not only expensive but also hazardous to environment. After harvesting and curing, seed potato tubers can be treated with Sodium hypochlorite (NaOCl) @2.0% for 30 minutes for disintegration of cyst wall. The solution once prepared can be used for soaking the seed tubers twelve times for a period of 30 minutes per soak without affecting the efficacy on cyst degradation. Even after twelve times if the farmer wishes to use the same solution further, the soaking time is to be increased from 30 to 40 minutes. In addition this treatment had no adverse effect on sprouting of seed tubers.

Bio-control agents and organic amendments

Application of bio-control agents *viz., Pseudomonas fluorescens* and *Paecilomyces lilacinus* and organic amendments like neem cake (5 t/ha) blended with *Trichoderma viride* (5 kg/ha) show promise in suppressing PCN population. Under organic management, incorporation of radish leaves @ 1 kg/m^2 and covering with polyethylene sheet also recorded maximum growth parameters, yield and minimum PCN population.

Integrated management

Inter-cropping of potato with mustard in 1:1 plant ratios combined with carbofuran 3G (1kg *a.i.* /ha) application reduced PCN infestation and enhanced potato yield. Application of *P. fluorescens* (2.5 kg/ha) + neem cake (1 t/ha) + mustard intercrop (between potato rows) + carbofuran 3G (1 kg a.i./ha) increased the tuber yield and decreased the PCN population. For eradication of PCN by soil solarisation (4 weeks) followed by application of neem cake (5 t/ha) in combination with *Trichoderma viride* (5 kg/ha) recorded decrease in PCN population.

Chapter -15

USE OF INFORMATION TECHNOLOGY FOR POTATO RESEARCH AND DEVELOPMENT

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Information Technology (IT) is the mantra of modern world. Today IT has pervaded each and every field of human endeavor 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 institute has so far developed many decision support systems, some are Indo-Blightcast, The Potato Pest Manager (PPM), Potato Growing Season Descriptor, Potato growing period and yield calculator, Computer Aided Advisory System for Potato Crop Scheduling (CAASPS), Potato Weed Manager, VarTRAC, etc. An EBook on potato and a potato photographic database are also developed at ICAR-Central Potato Research Institute Shimla.

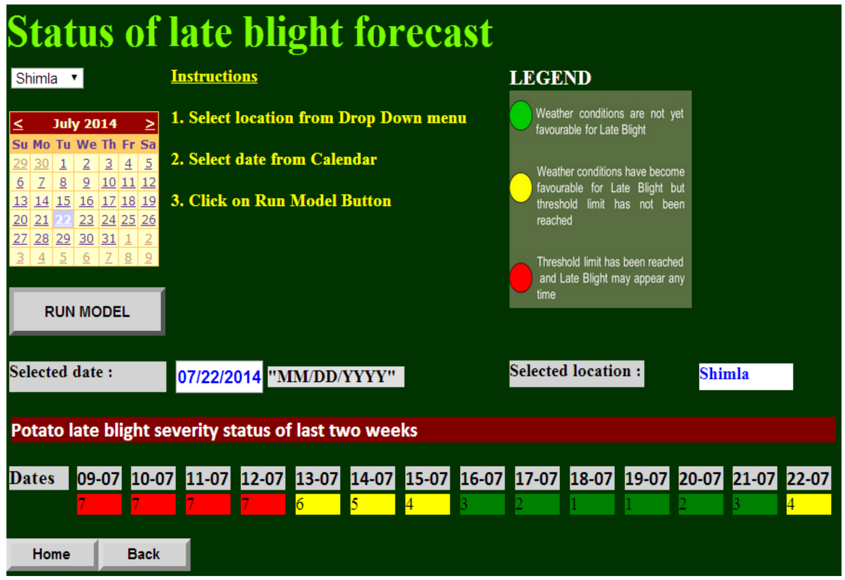
Decision support systems:

1. INDO-BLIGHTCAST- A web based Pan India Model for forecasting potato late blight

Late blight is the most dreaded disease of potato causing annual crop loss of about 12 billion € globally. Its appearance and spread is highly dependent on environmental factors. Under favourable conditions its spread is so fast that it can wipe out the crop within a weeks' time. In India it is very serious in the hills where it occurs regularly but in the plains it may or may not appear and even if it appears its time of occurrence would vary. The time of its occurrence and severity determines the yield loss which may exceed 40% country wide in some years. Prevention through prophylactic sprays of recommended chemicals is the best option since once it appears it is very difficult to control. This, however, requires information on the likely time of appearance of the disease and hence the importance of disease forecasting.

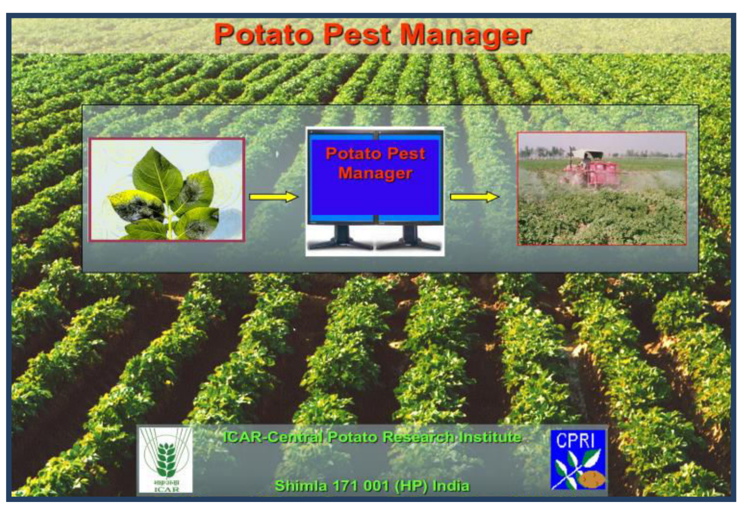
INDO-BLIGHTCAST- is a web based forecasting model (http://cpri.icar.gov.in) developed to predict the first appearance of late blight disease using daily weather data of meteorological stations. This is an improvement over the JHULSACAST model, which requires hourly data of temperature, relative humidity and daily rainfall. The intensive data requirement as well as location specific calibration of JHULSACAST was a serious impediment to its wide spread use. The INDO-BLIGHTCAST, however, is applicable pan India, since, it is web based, it requires only daily weather and does not need local calibration for different regions. Hence it is more robust and its predictions are broader based.
INDO-BLIGHTCAST has two modules one for data entry and the other for the general users to see the status of late blight forecast.

Data entry: The data entry module is user and password protected. The registered users can "Load data"(for viewing already entered data), "Add data" (to save entered data), "Edit data" (to change entered data values) and "Delete data" (to remove data) if required, in addition to running the model. Check late blight appearance status: Through this button, any user (requires no registration) can select any location which would lead to another window with a calendar and map showing the location with default state map. The user can select a date in the calendar and click on the "Run model" button which would then display the status of late blight in a circle through colour. Green colour indicates that late blight is not likely to appear soon; yellow colour indicates that late blight would appear very soon; and red colour indicates that the weather conditions have become suitable for late blight and it can appear any time within fifteen days. Thus depending upon the time required for taking control measures, the user may start preventive measures at yellow or red colour indication. The model has been developed and tested using the data on late blight appearance monitored at ICAR-CPRI regional stations and AICRP centres over the past several years.



2. Potato Pest Manager (PPM)

For the management of diseases and pests two aspects are involved. The first is to establish the identity of the disease/pest and second is to recommend appropriate preventive and management practices to control them. These objectives are achieved in a sequence of steps as discussed below



Step 1: The photographs showing the symptoms of the diseases/pests are arranged in a photo gallery and displayed in sequence. The user is asked to match the symptoms in the photographs with those he has seen in the field and select the most closely matching one.

Step 2: The appropriateness of the selected photograph needs to be confirmed, because the user may not be fully conversant with the symptoms of different diseases or damage by pests. Information about the biotic/a biotic factors prevailing, together with the symptoms, are necessary for a correct diagnosis. This is done through a set of confirmatory questions.

These are questions about the symptoms of the disease/damage by the pest, or conditions which need to be satisfied for the disease/pest occurrence. This information is arranged in a linear fashion. This arrangement allows insertion/deletion of questions/an option to a question at any level without disturbing the overall structure. Furthermore, this information is presented in a format of questions/statements to the user, while answers are given as options to these questions/statements.

Step 3: Once all the confirmatory questions are answered, the name of the disease/pest corresponding to the photograph selected is displayed along with confidence percentage. The confidence percentage is calculated based on answers given to the confirmatory questions relevant to disease symptoms/pest damage. Each confirmatory question/statement is assigned a certain value such that for all the questions if the option corroborating the disease/pest whose photograph is selected is chosen as the answer, the value adds up to 100.

However, the value allotted to each question may vary depending upon its significance.

Step 4: Many potato diseases/pests can only be controlled through preventive measures taken over a period of time before planting the crop and control is not possible once the disease/pest appears. This is especially the case with diseases/pests where symptoms are seen at/after harvest. Therefore, the preventive measure applicable to the disease/pest identified is displayed in this step. The preventive measures are the set of practices, which would have prevented/mitigated the disease/pest occurrence.

Step 5: In this step information required for suggesting control measures on the standing crop is obtained through a further series of questions. For example, information regarding severity of disease/pest damage, age of the crop, *etc*. is invariably required for deciding the chemicals to be used, their dosage, number of sprays *etc*. This information is again obtained from the user by presenting the questions or statements with various options. The questions or statements are arranged in tree structure and depending upon the answers given to each question a path is followed leading to a recommendation which is attached at the end node.

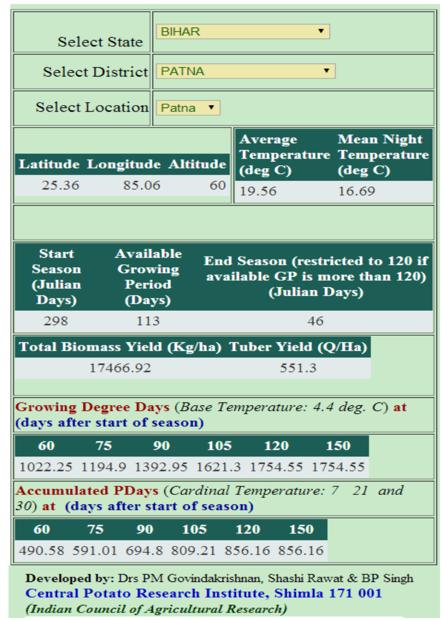
Step 6: This step displays the recommendation based on the options chosen.

This tool/DSS is web based and is developed in ASP.NET and the database is developed in Microsoft SQL. It can be accessed from ICAR-CPRI website (http://cpri.icar.gov.in).

3. Potato Growing Season Descriptor (PGSD)

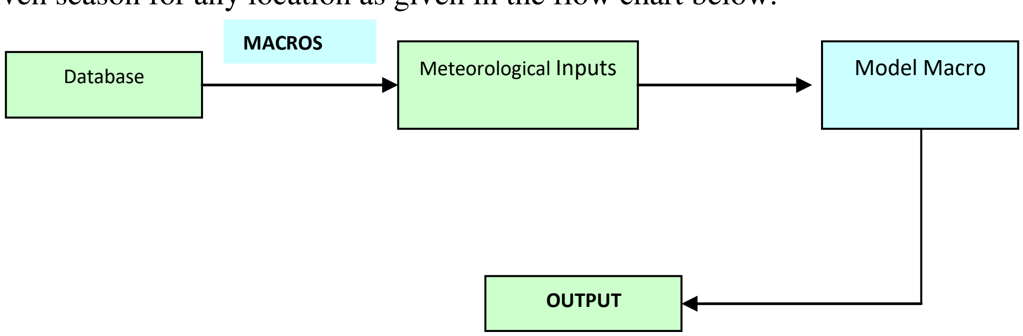
Potato is one of the most sensitive crops to the environment. It has specific temperature and photoperiod requirements for growth and development. Apart from the phenology and growth and yield, the weather conditions during the growing season also affect the size of the tubers as well as its quality. There is also a wide variation in the pest and disease scenario affecting potato primarily due to differences in the in growing season environmental factors in different locations/seasons in which potato is grown in India. Moreover, potato has been adapted to be grown under subtropical conditions in India. This has been possible by the development of resource intensive production technologies. Therefore there is need for careful planning of the production strategy by analyzing the growing season.

The PGSD consists of a database of daily meteorological data generated by MARKSIM weather generator for many locations. The daily meteorological data is analyzed using algorithms to determine the length of the plausible growing season, mean daily temperature, mean night temperature, accumulated growing degree days and accumulated P days during the autumn growing season. The tool also gives the expected yield calculated using a summary model of the autumn crop under constraint free situation. It is expected that these information would be useful for production managers, extension workers and farmers in planning their production strategy.It can be accessed from ICAR-CPRI website (http://cpri.icar.gov.in).



4. Potato Growing Period & Yield Calculator

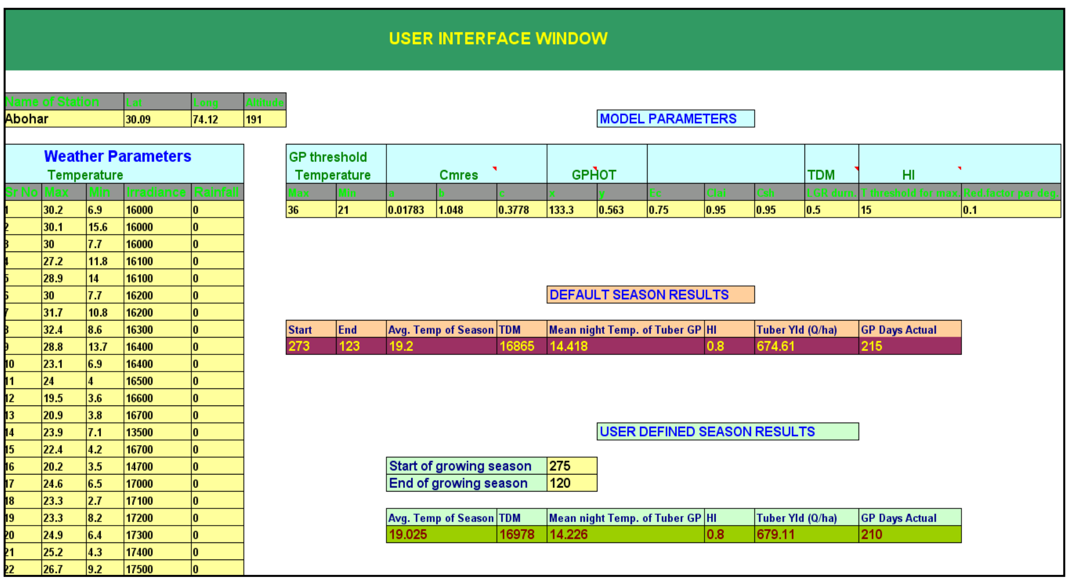
Potato is a short duration crop grown under diverse growing conditions. It is highly flexible in terms of time of planting as it can be planted early, at optimum time or late in the season. Similarly, as regards harvest time it can be harvested at any time after about 3 quarters of the growing season by which time economic yields are realized. Such flexibility makes it an ideal choice to fit in multiple cropping systems. To exploit this flexibility at any given location there is need to identify the growing season/s and the length of each growing season/s. Temperature is the primary determinant for potato under sub-tropical conditions of India. The temperature suitability criteria are that the maximum temperature should be less than 35 ºC, minimum temperature should be less than 21 ºC at least 3 weeks after the maximum temperature suitability criteria is met and it should also be more than 2 ºC to ensure frost free season. Identifying the suitable growing period based on these criteria is difficult and there is also a need to know the expected yield in the different season. A PC based tool was developed for delineating the potato growing seasons and the expected yield of any given season for any location as given in the flow chart below.



A spreadsheet with macros was created to process the raw data and extract the information required by the model. Four fields each with 365 records were created in spreadsheet and macros for screening the day as suitable or unsuitable for potato based on threshold limits for maximum and minimum temperature was written. The starting day number, ending day number and the total number of suitable days of the longest period, where more than two growing seasons were obtained, were derived as outputs. Further the meteorological variables required by the model *viz.* mean temperature and mean irradiance of the growing season were derived from the data of the thermally suitable days for potato.

Macros for estimation of gross photosynthesis (GPHOT), maintenance respiration, linear growth rate *etc.* (Versteeg&vanKeulen, 1986) utilizing the outputs of the database screening macros were written to derive the expected potential yield.

A Graphical User Interface (GUI) was designed in MS Access/Visual Basic. Fields were created for display of location and its spatial features and also for display of the various outputs as shown below.



5. Computer Aided Advisory System for Potato Crop Scheduling (CAASPS)

The optimum time of planting, the most suitable variety and the expected yield at different dates of harvest are vital information required by farmers for scheduling their planting and harvesting times as well as for choosing the variety to be grown. Obtaining such information through field experimentation in the diverse agro-climatic conditions in which potato is grown in India is an uphill task, but this information can be derived from crop models which can simulate crop growth, development and yield with reasonable accuracy under diverse situations.

However, use of crop models requires extensive data inputs as well as technical expertise to handle the model. Therefore, world over, models are handled by researchers and off take of models by field level workers is not very satisfactory. Decision Support Systems (DSS) on the other hand provide a method for delivery of information in a user friendly and simple way. Therefore, this

DSS "Computer Aided Advisory System for Potato Crop Scheduling (CAASPS)" has been developed with the following purposes:

a) To provide information on the expected yields of different varieties planted at different times to enable farmers to decide on the most suitable one for their respective locations.

b) To help decide the time of harvest based on yield accrued at 60, 70, 80 and 90 days after planting.

c) To indicate the varietal performance under different dates of planting and crop durations and thus help choose the appropriate variety.

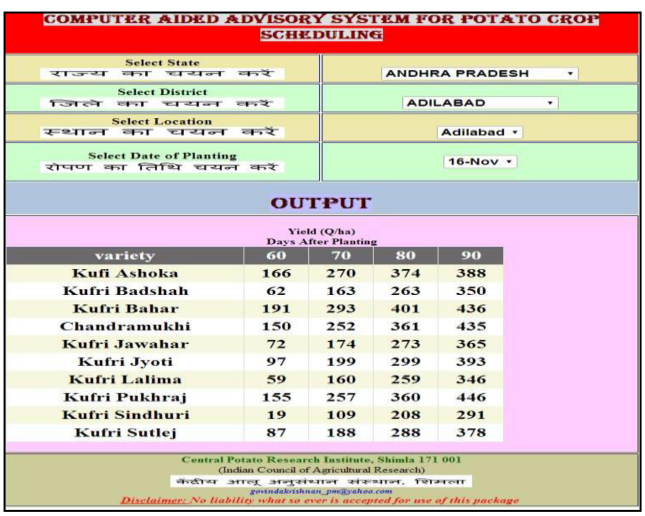
This DSS consists of a database and a user interface. The database consists of state, district and location names along with Infocrop-potato model derived yield outputs.

The model outputs were derived as follows:

1) Weather database were created for important locations in India using MARKSIM weather generator.
2) Suitable thermal window were delineated for each location by defining screening rules for maximum temperature (< 35^{0}C) and minimum temperature (< 21^{0}C).
3) Infocrop-potato model was run for 5 planting situations starting from ten days earlier to the beginning of the suitable thermal window identified by the screening rules and staggered at 10 days interval.
4) For each date of planting, the model was run for 10 varieties under potential situations and 80% of the potential yield was taken as attainable yield.
5) Yield output of each variety at 60,70,80 and 90 days after planting were linked to corresponding spatial attributes *viz.* state, district and location names in MS Access.

User interface: A simple query system was designed for querying the database.

The user first selects the State, and then the Districts of the state. The locations within the district for which information is available are then displayed for selection of one of them.

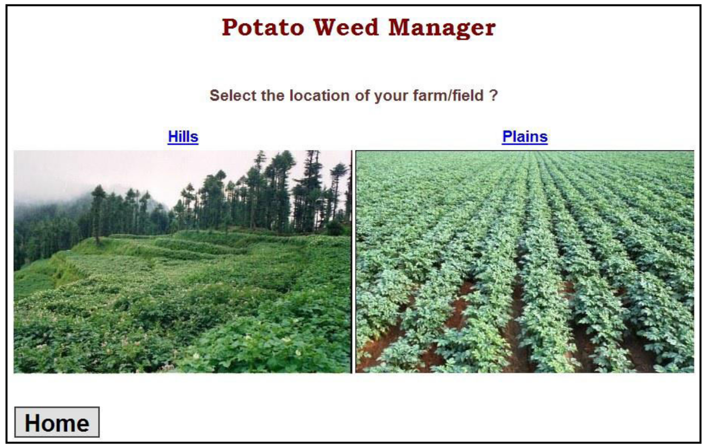


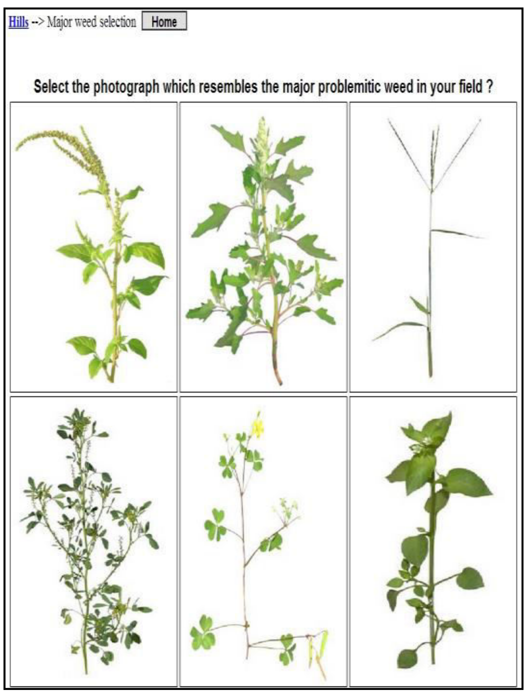
Once the location is selected, the five dates of planting for which model has been run for the selected location is displayed and the user is required to select one of them.

When any of the dates is selected, the attainable yield data for all the ten varieties at five durations, corresponding to 60, 70, 80 and 90 days after start is displayed in tabular format.

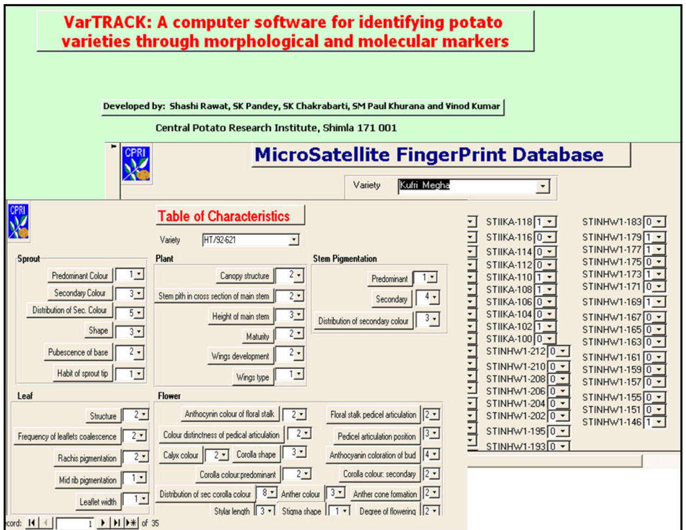
This tool/DSS is web based and is developed in ASP.NET and the database is developed in Microsoft SQL. It can be accessed from ICAR-CPRI website (http://cpri.icar.gov.in).

6. Potato Weed Manager (PWM): Weeds cause enormous loss in potato production. Weeds in potato not only compete for moisture, nutrients, space and light but also harbour several pests and diseases as alternate hosts. Up to 80% reduction in the productivity of potatoes due to weeds is reported. A number of cultural, mechanical as well as chemicals methods are available for controlling weeds in potato crop. Herbicides are available for control of different types of weeds at different stages. The selection of proper herbicide depends upon the type of weed flora and the stage of crop growth. However, weeds prevalent in potato crop vary from region to region and season to season and in the absence of knowledge about weed flora, it is difficult to give precise recommendation for their control. The knowledge of farmer about the weeds is limited only up to its local name and the extent of damage it may cause. Moreover, availability of proper guidance about weed control in the absence of technical advice may lead to improper control method leading to inefficient weed control. To alleviate this problem, a decision support tool "Potato Weed Manager" has been developed. The software is developed in DOT NET technology and the database used is SQL. This software is hosted on CPRI application server and is connected to CPRI website. This software incorporates the photographs of the weeds for identification by the user. This software gives the recommendation for weed control on the basis of situation of potato field, type of weed flora (major and secondary/associated weeds) and the stage of the potato crop. Thus the software provides proper guidance to the farmer about the weed control method to be adopted and dispense with the need of technical knowledge. It can be accessed from ICAR-CPRI website (http://cpri.icar.gov.in).





7. VarTRAC: BIOINFORMATICS-TOOL FOR IDENTIFYING POTATO VARIETIES



A combined view of different windows of the "VarTRAC"

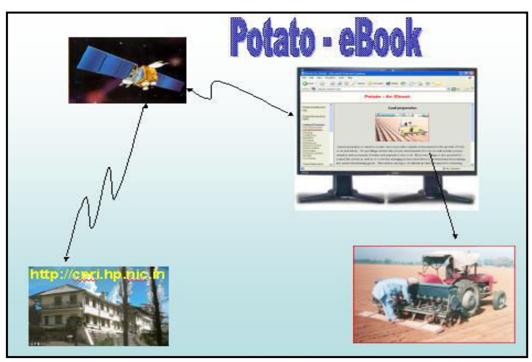
Authentic identification of potato cultivars is important for plant breeders, the variety registration and certification agencies, seed producers, merchants, farmers, growers, processors, and other end-users. Currently morphological descriptors are being used internationally for variety identification. 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" was developed at CPRI for speedy identification of a variety based on the morphological and DNA fingerprint data.

The database was created in MS Access with each morphological character 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 the 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 while 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 variety are known, the software can identify the group of varieties having similarity in respect of those 5 attributes.

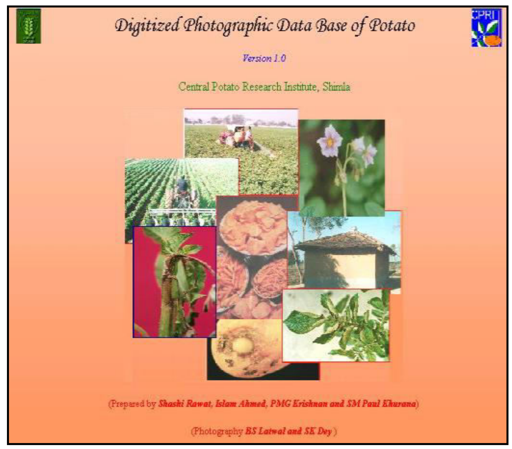
8. E-BOOK ON POTATO



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. It can be accessed from ICAR-CPRI website (http://cpri.icar.gov.in).

9. 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.



Chapter -16

IMPACT OF CLIMATE CHANGE ON INSECT PESTS OF POTATO

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Climate change could exert effects in food supply; therefore, one of the main challenges for modern agriculture is to develop strategies to cope with potential negative impacts of future climate change to ensure food security by 2050 or beyond. Potato belongs to the crop that grows even in unfavorable conditions like high altitudes to warmer pockets of India. More over a few other crops produce comparatively high yields of nutrients per unit area where land is scare. High production levels and highly perishable sale practices enable farmers to be competitive despite the fact of high input cost, labor problem and forced gluts, still potato is an important cash crop and cultivated mainly as an irrigated winter cash crop. Among the various factors related to insect pest and diseases, potato farmers are increasingly forced to face water stress change, changes in rainfall patterns and intensity, frost and fog etc. These conditions are generally interpreted to climate changes. Potato production is highly dependent on climatic factors. All climate change projections are based on simulations and therefore involve uncertainties. However, it is clear that climate change will not only affect the cultivation system but also change the distribution, intensity of insect pest and diseases on potato crop.

Effect of temperature on potato insects:

Climate change resulting in increasing temperature could impact crop insect pests in several ways. One way temperature effect recent trend to decline insect populations especially in tropical regions, while in temperate regions, warmer temperature will result in more types and higher populations of insects. Temperature can potentially effect insect survival; population size and life cycle beside that also affect insect physiology and development directly or indirectly through the physiology or existence of hosts. Some soil insects which take several days to complete one life cycle-like white grub, cut worm, potato tuber moth will tend to moderate temperature or variability over the course of their life history. Some potato crop pests like aphids, white fly, leaf hopers, mite and thrips are developed more rapidly during periods of time with suitable temperature. Increased temperatures will accelerate the development of these insects on potato crop –possibly resulting in more members and generation per year.

Migratory insects such as aphids which are an important insect vector of potato may arrive in Northern plains earlier or the area in which they are able to over winter may be expanded. Natural enemy of insects may be responds differently to insect host due to change in temperature. Parasitism could be reduced if host populations emerge and pass through vulnerable life stages before emergence of parasitoids. Host may pass through vulnerable life stages more quickly at higher temperature, reducing the chance of parasitism. Insects that spend important parts of their life histories in the soil may be more gradually affected by the temperature change than those that are above ground simply because soil provides insulation medium that will tend to buffer temperature changes more than air. Temperature increases that cause farmer's not grow host crop any longer would decrease the population of insect pests specific to potato. The some environmental factors that can impact insect pests and their natural enemies that infect the pests, resulting in increasing attack on insect populations. At higher temperatures, aphids have been shown to be less responsive to the aphid alarm pheromone they release when under attack by natural enemies, resulting more predation.

Affect of precipitation on insect pest populations:

Many insect are sensitive to precipitation and are killed or removed from host plants by heavy rains, this consideration are important when choosing management options for thirps. Some insects like white grub, termite that over winter in soil, flooding the soil has been used as a effective measure. One would expect the predicted more frequent and intense precipitation, forecasted with climate change to negativity impact on these insects. Fungal pathogines of insects are favored by high humidity and their incidence would be increased by climate changes that lengthen periods of high humidity and reduce by those that result in drier conditions.

Affect of CO_2 on insect population:

In general, CO_2 impact on insects is thought to be indirect impact on insect damage results from changes in the host crop. Some workers have found that rising CO_2 can potentially have important effect on insect pest problems. Recently free air gas concentration enrichment technology (FACE) was used to create an atmosphere with CO_2 and O_2 concentrations similar to what climate change models predict for the middle of the 21st century. FACE allows for field testing of crop situations with fewer limitations than those conducted in enclosed spaces. In few cases, like Soybeans grown elevated CO2 atmosphere had 57 % more damage from insect then those grown in present atmosphere and required plant protection treatment in order to continue the experiment. It is assumed that increase in the level of simple sugar in the soybean levels may have stimulated the additional insects feeding. The aphid abundance was enhanced by the CO_2 and temperature. Parasitism rates remained unchanged in elevated CO_2 but showed an increasing trend in conditions of elevated temperature. Research further revealed that clones of *Myzus percicae* have emerged that are resistant to three major groups of insecticides. It is feared that global warming could remove the break that winter now places on the number of insecticide-resistant aphids.

Affect on Indian farmers:

It is likely that farmers will experience extensive impacts on insect management strategies with change in climate. It is assumed that insect will expand their geographic ranges and increase reproduction rates. This means that it is likely that farmers will have more types and higher number of insects to manage. Insecticides and their applications have significant economic costs for growers and environmental cost for society. Additionally, some classes of pesticides like pyrethroids and spinosad have been shown to be less effective in controlling insects at higher temperatures. It is predicted that additional generations of important insect pests specifically in temperate climate as a result of increased temperatures required more insecticide application to maintain population bellow economic threshold levels. In order to avoid insecticide resistance is to apply insecticide with a particular mode of action less frequently, with more insecticide applications required the probability of applying a given mode of action insecticide more times in a season will increase, thus increasing the probability of more and more members of insects developing resistance to insecticides specially sucking insects of potato. A number of cultural practices that can be used by Indian farmers could be affected by change in climate. Although it is not clear whether these practices would be helped, hindered or not affected by the anticipated changes. Using crop rotation as an insect management strategy could be less effective with earlier insect arrival or increased over wintering of insects. However, this can be balanced by change in the earliness of crop planting time, development and harvest. Row covers used for insect exclusion might have to be removed earlier to prevent crop damage by excessive temperatures under the covers would the targeted early insects is also complete their damaging periods earlier or be ready to attack when the row covers were removed.

What Indian farmers can do to adopt?

Climate change is a slow and gradual process that will give enough opportunity to Indian farmers to adopt them. It is not very well under stood, how these changes will affect potato crop, insect, disease, natural enemies and their complex relationship among them. If climate is warmer will increases in yield offset losses to pests or losses to pests outweigh yield advantage from warmer temperatures? It is likely that new insect pests of potato will become stabilized in narrower areas and to be able attack on plants in new regions. It is likely that plants in some regions will be attacked more frequently by certain pests. A few pests may be less likely to attack on crop as changes occur. It is likely that we will not know the actual impact of the climate change on pests until they occur. Clearly, it will be important for farmers to be aware of crop pest trends in their regions and flexible in choosing both their management methods and in the crop they grow. It is important that the potato farmers closely monitor the occurrence of insect pests in their fields and keep records of their incidence frequency and cost of managing pests over time will be a better position to make decisions about whether it remains economical to continue to grow potato crop with appropriate pest management techniques. It is important that farmers may use integrated pest management practices more precisely such as monitoring of insect vectors, forecasting, keeping records of insect pest incidence and choosing economically and environmentally sound control measures will be most likely to be successful in dealing with the effects of climate change.

In India, *B. tabaci* was a minor pest till recently. Data on population buildup during the last 20 years revealed that average population of *B. tabaci* was 11 whitefly /100 leaves during 1984 which rose to 24.24 in 2004. During this period, average ambient temperature increased by 0.07°C. This indicates that climate warming may lead to whitefly infestation in Indo-Gangetic plains. Increase in *B. tabaci* population led to outbreak of a new viral disease known as apical leaf curl in potato which has since been identified as a gemini virus. Gemini Viruses are not reported to infect potato crop world over. Therefore, a new dimension has been added to potato seed production in sub-tropics. The infestation of this virus in some of the varieties *viz.* Kufri Pukhraj, Kufri Anand, Kufri Sutlej reached almost 100% in seed stocks. Consequently, an altogether new approach was adopted to manage this virus which included discarding of the old stocks and their replacement with disease-free stocks from tissue culture and integrated management of whitefly which included delayed planting, seed treatment and weekly application of insecticides including summer oil. This disease has since been contained but the danger persists. *Empoasca fabae* (leaf hopper) is another pest which has assumed significance in early planted crop in sub-tropical plains of India. Its population during 1984 was 16.6 which rose to 23.8 in 2004. The hopper burn damage also increased from 45 to 68% during this intervening period. Sudden warming up of temperature may also lead to flaring up of the pest. This has happened during 2006-07 in Gujarat state. Temperature profile of the region revealed that during crop period right from December to first week of January, ambient temperature was higher and relative humidity was lower than previous years. The increase in temperature was up to 5.8°C during fourth week of December, 2006. This increase in temperature led to faster multiplication of the pest and consequently very heavy (up to 100%) hopper burn damage (Singh *et al., 2008).* Similar to hopper damage, mite infestation has also increased in early planted crop. During 1984-85 its damage was 86% which increased to 100% in 2004. Results tend to suggest that in sub-tropical plains of India, *Myzus persicae* population is on the rise. During 1984-85 mean aphids population/l00 compound leaves were 567 which increased to 653 in 2003-04. On the other hand population of *Aphis gossypii* has increased three fold during the last 20 years. Although *A. gossypii* has low vector efficiency but its appearance right from the emergence of the crop and further maintaining its population throughout the crop season may pose serious problems to seed production in sub-tropical plains.

Suggested References

Bhatnagar A, Dua VK and Chakrawarti SK 2018. Scenario, implications and prospects of climate change on potato (*Solanum tuberosum*) insect pests: A review. *Indian J. of Agricultural Sciences*, **88** (09): 1331-39

Bhatnagar A, Shrama V and Singh BP 2016. Climate change and population buildup of whitefly on potato cultivars in North-western India. *Int. J. of Agricultural Stat. Sciences*, **12** (01): 199-203.

Singh, B.P., Malik Kamlesh, Patel N.H., Patel P. J., Singh, S.V. and Sukhvinder Singh. 2007. First report of "hoper burn" damage in Gujarat state. CPRI, News Letter, 37: 3-4.

Singh, B.P and Narayana Bhat M. 2008. Impact assessment of climate change on potato diseases and pests. In: Impact assessment of climate change for research priority planning in Horticultural crops, CPRI, Shimla. Pp. 197-2005.

Chapter -17

PRODUCTION OF DISEASE FREE PLANTING MATERIAL THROUGH HI-TECH SEED PRODUCTION SYSTEM

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Availability of disease free planting material is a critical input in augmenting potato production. The seed production system in India is based on tuber indexing for detection and elimination of all the prevalent potato viruses followed by clonal multiplication in four successive generations. Although this system is quite effective, its 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.

Micropropagation: Tissue culture has immense potential for application in rapid clonal propagation of vegetatively propagated crop like potato. Under present system of potato seed production, indexed tubers are multiplied in various stages for production of breeder's seed. Indexing is based on testing of a single scooped eye from a tuber. There are reports of inconsistent distribution of potato viruses within a tuber. Therefore, indexing does not assure complete virus freedom in indexed tubers and detection of some viruses is common during field testing in Stage-I. Moreover, the initial healthy material is exposed to virus vectors during field multiplication resulting in progressive viral degeneration. Meristem-tip culture and micropropagation are known to circumvent these problems in initial stages of seed potato production. Meristem-tip culture is based on the observation that the concentration of virus particles is much less in the rapidly growing shoot tips than in other parts of the plant. The plants raised from shoot/sprout meristems (0.2 to 0.5 mm long) on nutrient culture medium, therefore are generally free from viruses. The technique coupled with chemotherapy (B-Azaguanine, 2- Thiouracil, Ribavirin etc.) and lortheromotherapy (37°C for 3-4 weeks) of the plants prior to meristem -tip culture or of the explants during culture, has been successful in eradicating a number of viruses which are difficult to eliminate by meristem-tip culture alone. The in vitro shoots derived from meristem-tip culture can further be multiplied using various propagation methods for obtaining huge quantities of pre-basic seed. Though several in vitro propagation methods are in hand, the methods using nodal cuttings and microtubers are more reliable for maintaining genetic integrity of the multiplied clones since accompanying genetic changes during dedifferentiation and subsequent organogenesis are not reported in them.

The major advantages of such propagation are;

i) Large number of disease-free propagules can be obtained from a single *in vitro* plant in a short period,

ii) A constant flow of virus free plants is possible from original in vitro stock developed through meristem- tip culture and

iii) Propagation can be carried out under disease free conditions throughout the year.

Meristem culture: Meristems are tiny extreme parts of all organs in a growing plant, which are responsible for growth and differentiation. Since the viruses are unable to infect the meristems, it is possible to isolate and culture the meristem, and thereby to regenerate a virus-free plant. In potato, apical and axillary shoot meristems are used to obtain virus free plants. Although meristem cultures can be initiated from ex vitro-grown potato plants, *in vitro*microplants are usually preferred for initiation of meristem culture.

- Excise 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 0.1-0.2mm.
- Incubate the cultures under a 16-h photoperiod (approx.50-60mmol m^2/sec. light intensity) at 24˚C.
- The meristem medium is based on MS basal nutrients supplemented with 8.39 µM D-calcium pantothenate, 1.44 µM GA_3, 0.054µM NAA and 30 g/l sucrose, and solidified with agar6.0 g.
- Test meristem-derived plantlets for viruses by ELISA and/or ISEM.
- Multiply and maintain virus-negative meristem-derived clones by shoot cultures *in vitro* as described above.

Sub culturing of microplants: Micropropagation allows large-scale asexual multiplication of pathogen-tested potato cultivars. At the interval of every 21 days of subculturing, minimum 3 nodal cuttings are obtained from a single micoroplant. Therefore, theoretically, 3^{15} (43 million) microplants can be obtained from a single virus-free mericlone in a year. Various techniques have been developed for producing large number of microplants on nutrient medium under aspetic conditions. The method involves culturing of nodal explants of disease-free microplants on semisolid (agarified) or liquid culture medium. MS medium is most widely used for potato microplant propagation. In vitro-derived microplants are used as (i) explant source for production of microtubers in vitro, (ii) direct transplants in the greenhouse for the production of minitubers, (iii) mother plants for further in vitro multiplication through single node cuttings (SNC's).

Microtuber 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 micropropagated plantlets, they do not require time-consuming hardening period in the greenhouses, and may be adapted easily to large scale planting in the field. For the production of microtubers large number of microplants are produced in initial multiplication. 10-12 segments (each having 3-4 nodes) from six 21 day old plantlets are propagated in liquid media (20 ml) in 250ml In Erlenmeyer flask. In about 3 weeks all the axillary buds grow into full plants and fill the container. At this stage the liquid propagation media is decanted from the Erlenmeyer flask and tuber induction media is added. Microtuber induction media is based on MS basal nutrients supplemented with 10mg/l N^6-benzyladenine (BA), 500 mg/l Chlorocholine chloride (CCC) and 80 g/l sucrose. Incubate these induction cultures under complete darkness at 18-20˚C. Microtubers start developing within 8-10 days and are ready for harvesting after 60-90 days. About 15-20 microtubers with an average weight of 100-150 mg are produced in each flask. Green the microtubers by putting them under white fluorescent light at 24˚C for 10-15 days. Greening can be done both, before or after harvesting. Microtubers are washed in clean water and treated with 0.2% Bavistin for 10 minutes and allowed to dry in dark before being cold stored at 4-5˚C. After about 3-4 months of storage, the sprouted microtubers are ready for field planting.

Aeroponics: Aeroponics refers to the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. The word "aeroponic" is derived from the Greek meanings of aero (air) and ponos (labour). Aeroponic culture differs from both conventional hydroponics and in-vitro (plant tissue culture) growing. Unlike hydroponics, which uses water as growing medium and essential minerals to sustain plant growth, aeroponics is conducted without a growing medium.

In aeroponics, plants growth is facilitated by suspending them in air, in an enclosed environment, and providing them with necessary nutrients by spraying their roots with nutrient-rich water solution. The nutrient solution is continuously re-circulated through the system and monitored and amended whenever necessary. The solution is sprayed in such a way that it creates a mist in the environment, and being an enclosed environment there is no wind flow to move the mist away, and hence the plants grow quickly.

Aeroponic systems mainly consist of an electrical unit, light proof growth chambers, nutrient solution chamber, high pressure pump, filters and spray nozzles. Interiors of growth chambers are covered with black lining to avoid any admittance of light to the root zone of plants. Aeroponic unit can be placed in insect proof net house under natural conditions or controlled environment conditions. For aeroponics, in vitro grown in 15-21 days old microplants are required to be hardened before shifting to this system. For hardening, microplants are transplanted in peat moss, vermiculite or sand and hardened for 15 days at about 27°C in hardening chamber. These hardened plantlets of 10-15 cm height are planted in the 20 mm diameter holes made in the roof of the growth chamber of the aeroponic unit. Cuttings should be dipped in rooting hormone solution for five minutes before planting in the aeroponics to facilitate rooting. Very old and yellowish plants are not suitable for aeroponics and should be avoided. All the essential nutrient elements required for plant growth are dissolved in the water in the solution chamber, and solution pH is maintained at the desired level throughout the crop period. The nutrient solution is compressed through nozzles by the high-pressure pump, forming a fine mist in the growth chambers. With the help of an automatically operated pump, the nutrient solution is sprayed inside the chamber for desired durations at desired intervals. In this way growth chambers are maintained at 100% relative humidity by misting nutrient solution round the clock. Nutrient solution is replenished from time to time and desired pH of the solution is maintained. The pH of the nutrient solution should be maintained at 5.6-6.0 throughout the crop duration. Roots, stolons and tubers develop inside the chamber and leaves are exposed to light. After a week, root systems start developing inside the growth chambers. As in the soil system, stolon and tuber formations are initiated at different intervals depending upon the variety. After a month or so, lower leaves need to be removed with a dissecting blade following strict aseptic measures and the plant should be lowered. The process of lowering the stems is important and is equivalent to earthing up in the field. If stolons start to form in the upper part of the root system, lowering of plants lead to better stolon formation. Picking of the tubers starts after 60-65 days when some of the tubes attain 15-17 mm diameter. Once the first flush is harvested, it triggers formation of more minitubers/plant. In this system, harvesting is done at regular interval when the tubers attain the desired size. On an average 30-35 minitubers can be harvested from a single plant as against 8-10 minitubers under nethouse. Tubers are harvested sequentially as they attain the desired size. Minitubers should be allowed to cure in a dry and clean environment for two to three weeks before placing them into cold storage.These mini tubers are then stored at 2-4°C and used for planting in the next generation.

Chapter -18

MAJOR SOIL & TUBER BORNE DISEASES IN POTATO AND THEIR MANAGEMENT

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Potato diseases are important aspects in cultivation of potato crop. It causes economic loss of the crop and also affects the crop yield for next generation. If diagnosis of the diseases has been not taken timely along with proper plant protection measures, then yield losses will be more. Major diseases under the category of fungal disease are late blight of potato, black scurf, dry rot and bacterial diseases are bacterial wilt, common scab and soft rot etc. Although some diseases such as Sclerotinia rot may become major disease due to climatic changes. Major and some minor diseases are discussed in following points:

Fungal diseases

Late blight

The late blight, fungus like organism co-evolved with potato in Central and South America and subsequently spread to other parts of the world mainly through infected seed tubers. The late blight disease caused by oomycete has a great importance in the history of plant pathology. Initially its causal organism was reported *Botrytis infestans* in 1845 by C. Montagne, a retired French army doctor who had devoted much of his life to the study of fungi. About 30 years' later German scientist Anton de Bary renamed as *Phytophthora infestans* (Mont.) de Bary. During 1844-45, entire crop across Europe, especially in Ireland, was killed prematurely leading to worst ever famine the 'Irish Potato Famine'. One million people died of starvation and another million migrated to USA and other parts of the world.

Late blight was recorded in India for the first time between 1870 and 1880 in the Nilgiri hills. Under subtropical plains, it was first observed in 1898-1900 in Hooghly district of West Bengal. Subsequently, it was reported other parts of the country. Afterwards, appearance of late blight disease is regular feature with high disease severity in hill areas while in plains disease severity is moderate to high level depending upon climatic conditions. As far as Indian scenario is concerned, reduction in potato production due to late blight ranged between 5-90% depending upon climatic conditions, with an average of 15% across the country. Recently, it was observed that yield losses were ranged 10-20% due to late blight during 2013-14 in major potato growing states of the India. Potato late blight had become more severe in recent years due to influx of a new population containing the A_2 mating type especially in USA. In India, most complex races, A_1 & A_2 mating with metalaxyl resistance and new population of *P.infestans* were observed.

Symptoms

Late blight affects all plant parts especially leave, stem and tubers.

Leaves: Pale green water soaked spots (2-10 mm) appear mostly on the margin and tips. In moist weather, spots may appear anywhere on the leaves, enlarge rapidly and turn necrotic and black killing the entire leaf instantly. On the corresponding lower side, whitish cottony growth containing millions of sporangia forms around the dead area in a ring pattern.

Stem and petiole: Light brown lesions develop which elongates and encircles the stem and petioles breaking them and killing the plant /leaves instantly. Stem infection is more severe under high temperature and relative humidity conditions. Symptoms of stem blight are observed more in last ten years.

Tubers: Rusty brown discolouration of the flesh is the typical symptom of late blights. On outside tuber surface, hard depressions with purplish tinge on the sides are a common feature. Normally, late blight infected tubers are hard but associated secondary pathogens may set in soft rot symptoms.

Field Infection: Generally, late blight appears on lower most leaves of the plant which goes unnoticed from a distance. Slowly, the disease spreads to the middle and then upper leaves. Subsequently it spreads whole plants and near of the plants. The disease spreads faster and the entire crop gets killed as if burnt by fire. The heavily infected field gives fetid odor which can be felt from a distance.

Epidemiology and disease cycle

Sporangia are formed wide range of temperature (3 to 26°C) and optimum is 18-22°C. The sporangia are geminate by two way process i.e. indirect and direct germination. It depends mainly on temperature. Indirect germination generally occurs at temperature range of 6 to 15°C (optimum 12°C) by means of sporangia produces zoospores. Direct germination takes place under warm temperature and a range of 4 to 30°C (optimum 25 °C). High relative humidity (> 90%) is required for spore formation, germination and infection; where as >80% is essential for lesions expansion. Extreme light is harmful for *P. infestans* and sometimes sporangia may be killed due to extreme light. Cloudy weather is favourable for late blight. The cool (12-15°C) and high humidity (>90%) weather with heavy dews or rains alternating with warm (18-20°C) moist period favour for rapid development of disease. Infection and disease development is observed a range of 7.2-26.6°C. The infected seed tubers carrying late blight infection serves as a primary sources for disease initiation.

Management

Forecasting of the late blight is an important aspect for management of late blight of potato. In India, the dates of appearance of late blight in Darjeeling hills reported by Chaudhary and Pal (1959). Later, Bhattacharyya et al. (1982) predicted the actual appearance of late blight for Shimla, Shillong and Ootacamund utilizing daily weather data. Singh et al. (2000) developed computerized forecasting model 'JHULSACAST' for western UP for both the rainy and non rainy conditions and it is being utilities for forecasting of first appearance of late blight in the regions and large scale of the farmers are benefited by timely adopting control measures as forecasting given by this model. JHULSACAST model, template was calibrated for development of forecasting model for Punjab, tarai region of Uttarakhand and plains of West Bengal. A decision Support system also developed for assisting in management of late blight by CPRI, which includes three modules i.e. i) decision rules for forecasting first appearance of late blight in plains during rainy and non-rainy years based on temperature, RH, and rainfall data, ii) decision rules for need based application of fungicides, and iii) regression models for yield loss assessment. All these modules have been combined and a web based decision support system developed for western Uttar Pradesh. Recently, Indo-Blightcast a web based Pan-India model for forecasting potato late blight which is an improvement over JHULSACAST has been developed. It predicts late blight appearance using daily mean temperature and RH data available with meteorological stations and does not require hourly weather data, not region/location specific and can be used across the country without any calibration. It is being used for forecasting of late appearance in different AICRPs centres.

Resistant cultivars

CPRI has released varieties having moderate to high degree of resistance to late blight for cultivation both for plains and hills. Some of them are Kufri Girdhari, K. Shailja, K. Himalini and K. Himsona (for hills) K. Swarna and K. Neelima (specially for southern hills) and K. Pukhraj, K.

Anand, K. Sutlej, K. Badshah, K. Arun, K. Jawahar, K. Garima, K. Mohan, K. Chipsona-1, K. Chipsona-2 and K. Chipsona-3 and K. Frysona (for plains).

Cultural methods

- Use disease free seeds only. Avoid seed from the field which has been infected in previous year with late blight.
- High ridge making will reduce the tuber infection.
- Scouting of the field for identification of primary infection foci and their destruction by removal of infected plants after drenching them with recommended fungicides.
- When weather condition is very congenial for late blight, irrigation should be stopped wherever applicable and give the light irrigation if required.
- Destroy and removes the haulms from the field when disease severity reaches more than 80% to reduce tuber infection.

Chemical management

Different spry schedules were tested and found that Chlorothalonil (0.2%) before appearance followed by cymoxanil+mancozeb (0.3%) then metalaxyl+mancozeb (0.25%) and Mancozeb (0.2%) before appearance followed by cymoxanil+mancozeb (0.3%) then fenomidone+macozeb (0.2%) were effective for managing late blight of potato. Howe ever, Proper dose and proper time of spraying is very important. A spray schedule of minimum of four fungicides sprays is recommended, it can be increase or decrease depending upon disease pressure. As first spry of contact fungicides (mancozeb 75%WP/chlorothalonil 75%WP/propineb 70%WP) @ 0.2% should be spray as soon as weather conditions become congenial for late blight or any information received from forecasting models for appearance of late blight/ about a week of advance of canopy closure. As soon as the disease is noticed in the field, second spray with systemic or translaminar fungicide @ 0.3% [(cymoxanil8+mancozeb64%WP /fenomidon10+mancozeb50%WG/dimethmorph50%WP (1g//L) +mancozeb 75%WP (2.0g/L)]. The remaining third and fourth sprays should be at 8-10 days interval (it may be increased or decreased depending upon disease pressure) used using systemic/translaminar for better results. However, contact fungicides could be used only at low disease pressure. Precautions should be taken that proper dose of fungicides with proper coverage of the foliage (top to bottom) with fungicides. Whenever, rains are heavy use sticker @ 0.1% with fungicides to reduce washing of the fungicides.

Early blight of potato

Early blight of potato caused by *Alternaria solani* (*Ell.&Mart*) *Jones & Grout.* The name of early blight was given by Jones, 1892 as this disease observed to develop earlier than Phytophthora blight in the USA. In India the disease was first reported by Butler (1903) on potato leaves at Farrukhabad in Uttar Pradesh. It cause up to 20% loss, some time it may be more. The initial symptoms occurs on the lower leaves and latter develop on the upper leaves. The spots are mostly (1-2mm) circular to oval and brown to black lesions with concentric rings, which produce a 'target spot' effect. Some time the spot may or may not have concentric rings. Infected leaves are affected by disease induced senescence, become necrotic but remaining attached to the plant. The spot may be found on stem at late stage of crop growth and tuber also. Alternaria tuber rot occurs in potatoes harvested during cool humid weather. The infection opens the way for secondary infections by species of *Fusarium* and other organisms. The tuber symptoms comprise brown, circular to irregular and depressed with underneath flesh turning dry brown and corky. Generally disease is more common on mature tissues or on tissues weekend by other diseases or environment and nutritional stress. Early blight is principally a disease of ageing plant tissues. *A. solani* is a polycyclic pathogen as many cycles of infection are possible during a season.

Leaf spots

Leaf spot diseases of potato caused by various fungi *viz., Alternaria alternata* (Fr.) Keissler, *Phoma exigua* Desm., *Phoma sorghina* Doerema,Doren and van Kest., *Cercospora solani-tuberosi* Thirumalachar.

Alternaria leaf spot

The alternaria leaf spot is caused by *Alternaria alternata.* The symptoms of this disease are large as well as small angular spot resembling to early blight. The severally affected leaves dry up and drop off prematurely. The symptoms are variable and non specific. Some country, it named as brown spot and black pit disease.

Cercospora leaf spot

The cercospora leaf spot is caused by *Cecospora solani-tuberosi***.** This disease first observed at Patna in Bihar in the third week of December, 1951. It infects both foliage (leaves) and stems but latter suffers the most. On the lower leaves brown spot (2-5mm) and each spot has whitish center. Spots later coalesce to cover large areas. Stem infection shows brown spot, later turning black and looking like cankers. The another species of cercospora that is *Cercospora concors* caused leaf blotch and some time it is also called as yellow leaf spot.

Phoma leaf spot

Phoma leaf spot is caused by two species i.e. *Phoma exigua and Phoma sorghina*. Leaf spot due to *P. exigua* are larger (1-2cm in diameter) with broad alternate light and dark concentric zones. Affected leaves tissues are not depressed into leaves tissues as in the case of early blight. Affected tubers have grey to greenish black depressed lesion on the surface up to 3.0 cm wide. *Phoma sorghina* caused pinhead size spot, which may be oval, circular or irregular, not exceeding 4.0 mm in diameter. This is more common in western UP. Infected tubers show dark grey large lesions (up to 1.7cm).

Disease cycle and epidemiology

Alternaria solani, A. alternata, *Phoma exigua and P. sorghina* can infect tubers hence capable of surviving during storage and form the primary source of inocululm. These pathogens can survive in soil and plant debris particularly in temperate climate. These disease favoured by moderate temperature (17-25°C) and high humidity (>75%). Early blight development in the field is very severe at day temperature of 25-30°C. Intermittent dry and wet weather is more conducive for early blight. *A. alternata* is a successful saprophyte and certainly survives in the soils and plant debris.

Management

- The disease free seeds should be used for planting.
- Cultivation of solanaceous crops being collateral hosts, nearby potato fields must be avoided.
- Apply recommended dose of fertilizer especially nitrogen.
- Spraying of Mancozeb 75% WP or Chlorothalonil 75%WP or Propineb 70%WP @ 0.2% for managing the early blight and leaf spot diseases.

Black scurf and stem canker

Black scurf and stem canker caused by *Rhizoctonia solani* Kuhn is an important disease of potato in the category of soil and tuber borne diseases. It affects roots, stolen, stems, leaves and tubers. The disease has mainly two phases viz. stem canker and black scurf. Stem canker phase is the girdling on the stem with brown colour and some time upward rolling of the leaves also observed. Black scurf phase is formation layer of black sclerotia on the surface of the tubers. The black scurf is described as "the soil that will not wash off". This phase is more common in the field particularly at the stage of plant senescent. Moreover, late harvested crop shows more black scurf incidence because maximum development of sclerotia takes place in the period between dehaulming and harvest of the crop in general. The pathogen grows in the culture at range of 8-35°C and optimum is 25°C. The survival structure i.e. sclerotia of the pathogen which germinate between 8 to 30 °C and optimum is 23°C.The pathogen causes the greatest damage at 15-21°C and 18°C is optimum for development of stem lesions. The fungus survives both in tuber and soil. Infected seeds are the main sources of infection.

Management

- Healthy seed should be used for planting. Treatment of the tubers with 3% of Boric acid for 30 min in dip treatment/spray before the cold storage or with Pencycuron @ 0.25% at the time of planting has been identified effective for management of black scurf.
- Seed tubers should be planted shallow. So that less opportunity for the fungus to attack the sprouts.
- Crop rotation with cereals and legumes should be followed to decline population levels of the *R. solani.*
- Various fungicides such as Thiophanate methyl+Pyraclstrobin, Carboxin+Thirarm, Penflufen, Carbedazim+mancozeb and Thifluzamide are also reported effective against this disease.
- *Trichoderma viride* and *Bacillus subtilis* are reported for control of *R. solani.*

Fusarium wilt and Dry rot

This disease caused by *Fusarium* spp and it causes wilt under field condition and dry rot mainly at post harvest stages. The losses caused by dry rot in plains and hills range between 5-23%. In India, it is common in hills and plains. At wilting stage, plant showed lower leaves turn yellow and affected plant dries off rapidly. Both stems and tubers at stolon end show vascular browning. Moreover, Internal flecking of stem extended to upper leaves also. Sometimes, damping off seedling type symptoms also observed when temperature is high in early planting. In dry rot symptom, the skin of the dry rot infected tubers first becomes brown, then turns darker and develops wrinkles. These wrinkles are often irregular concentric circles. In later stage of infection, a hole may be observed in the center of ring with whitish or pinkish growth of fungal mycelium. When cut the affected tubers, whitish or brownish tissues are seen with one or more cavities. Under high relative humidity the secondary organisms such as *Erwinia* spp. can invade the infected tubers and cause soft rot. Infected tubers and soils are the primary sources of inoculums. The fungus remains viable in soil for 9 to 12 months. *Fusarium* spp. has good saprophytic ability to survive in soil. The fungus grows well between 15 to 28 °C and high humidity favoures for infection of tubers.

Management

- Use only clean and healthy seed tubers for planting and storage.
- The tuber damage and injury must be avoided during harvest, grading, transport and storage etc.
- To avoid the adhering of contaminated soil on the tubers.
- Washing of tubers to remove contaminated soil which adhere to the tubers and drying in shade, can reduce the risk of infection.
- Dip treatment with 3.0 % Boric Acid for 30 minute before the cold storage is effective.
- Avoid seed cutting, if possible otherwise seed pieces may be treated with mancozeb @ 0.2% for 10 minutes and shade dry for 24-48 hrs before planting.
- The crop rotation must be adopted for managing wilt disease.

Potato Wart

This disease caused by *Synchytrium endobioticum* (Schilb) Perc. In India wart disease of potato was first reported by Ganguly and Paul (1952) from Darjeeling hills and it continues to be endemic to that area. It is a quarantine disease. The disease shows cauliflower like warty growths on tubers, stolons and stem bases but not roots. Under wet conditions, it may be seen in the form of greenish-yellow excrescences on the stem and leaves at or near the soil level. It is not necessary that all tubers from a diseased plant show wart like symptoms. Diseased tubers may show either one or more tumors but sometimes are completely transformed into warty mass.

The wart disease is seed and soil borne in nature. The pathogen spreads from one locality to another through infected seed tubers, infested soil adhering tubers, machinery and other carriers of contaminated soil. The wart is favoured by periodic flooding followed by drainage and aeration since free water is required for germination of sporangia and dispersal of zoospores of the pathogen. The resting sporangia are thick walled and may remain viable in soil for almost three to four decades. The resting sporangia may germinate over a wide range of temperature, the optimum being between 14 to 24 $^{\circ}$C. The optimum temperature for wart development is found to be from 16.7 $^{\circ}$C to 17.8°C.

Management

- Wart immune varieties viz., Kufri Jyoti, K Bahar, K Sherpa and K Kanchan, Pimpernel etc should be grown.
- Introduction of the disease in a field or locality can be effectively checked by domestic quarantine activity.
- Practices long term crop rotation (5 years or more) with non-solanaceous crops preferably maize, radish, cabbage and peas.
- Diseased potato should not be used for planting.
- Rogue out plant of susceptible varieties.
- Warted lupms and potato peelings should not be thrown in the field or in the manure pit but destroyed by burning.

Powdery Scab

Powdery scab caused by a fungus *Spongospora subterranea.* It is found mainly in cool and wet climates. This disease attacks only the underground parts of the potato plants and does not show any effect on the growth of the plant. It appears as pimple like spots on the surface of young tubers. These spots are circular, smooth and light brown which gradually increase in size and later turn to scab like lesions. However, unlike common scab the lesions of powdery scab are round, raised, filled with powdery mass of spores and surrounded by ruptured remains of epidermis. Under certain conditions wart like protuberances may develop. The spore balls of pathogen on the tubers as well as in the soil serve as a source of infection. It can also survive in soil up to 5 years. The temperature below 18°C and wet soil favors the development of the disease.

Management

- Use of healthy seed for planting.
- The disease can be managed by proper drainage facility.
- To follow the practice of crop rotation with non-solanaceous hosts.

Charcoal Rot

Charcoal rot caused by *Macrophomina phaseolina* (Tassi) Goidanich. The perfect stage of the fungus is considered to be *Botryodiplodia solani tuberosi* Thirum. This disease causes three types symptoms i.e. stem blight, charcoal tuber rot and dry rot tuber. The stem blight phase pathogen attacks the stem at or below the ground level and a lesion appears on the basal part of the stem. Subsequently, affected foliage show wilting and turn yellow. The charcoal rot affected tubers show black areas around eyes and proliferated lenticels. To begin with a black spot about 2-3 mm in diameter developed around a lenticels which appears as a whitish speck at the center. On the cutting the affected tuber, internal tissues show black patches beneath the spot on the surface of the tuber. The dry rot affected tubers show black sunken areas on the surface, underneath which a cavity is formed on account of destruction of tissues. The soil and infected tubers serve as source of inoculum. Temperature around 30 °C or above are very favorable for infection, the rot is slow at 20 to 25°C and stops at 10 °C or below. Fungal growth stops in tubers placed in cold stores but it resumes the growth after cold storage.

Management

- Planting early maturing cultivars, frequent irrigations to keep down the soil temperature and harvesting before the soil temperature exceeds 28°C can reduce the disease incidence.
- Rotation with non-host crops and use of seed from disease free area, avoiding cuts and bruises at harvest can also be followed to reduce disease incidence.

Sclerotinia rot

Sclerotinia rot caused by *Sclerotinia sclerotiorum,* produce almost white lesions with a distinct edge on the stems. The stem lesions frequently encircle the stem, leading to a wilting of the leaflets, which turn papery white around the edges. On splitting of infected stems, white sclerotia can be seen which later changed to black in colour. More number of sclerotia is observed when plants are at maturity. The affected tubers develop a heel-end rot. Internally, the rot is pale-brown with fluffy white mycelia and black sclerotia developing in cavities. The disease is growing well under prolonged high humidity in well-developed foliar canopies with wet leaves at low to moderate temperature (15-25°C). Follow the cereal crops as rotation and using potato varieties with an open canopy helps in the disease management.

Silver scurf

Silver scurf caused by *Helminthosporium solani.* This disease dose not affects any other part of the potato plants except the tubers. On tuber skin blemishes appear which starts as small, round, silvery patches on the skin. When these tubers lesions moistened often appear very clear silvery patches. These patches expand and merge during storage. Both tubers and soil may serve as primary sources of inoculum. Symptoms are not normally present at harvest but the disease can develop rapidly in store under humid, warm (>3°C) conditions. Treatment of tubers with a fungicide prior to planting or at harvest (into store) may reduce infection and limit disease development but cannot control existing infections.

Sclerotium rot

Sclerotium rot caused by *Sclerotium rolfsii* Sacc. The disease symptom on the potato plant is seen in the form of dark brown lesion on the stem just below the soil surface. Subsequently, plants are wilted and show a white weft of course fungal threads which girdle the basal part of the stem. The sclerotia resembling mustard seeds develop on the hyphae growing on the infected stem, roots, all the underground parts of the plants and surrounding soils. The affected tubers show at first small spots which have a brownish margin, are slightly sunken and are yellow to tan in colour. The disease causes sever damage at 25 to 30°C. The mycelia and sclerotia are survive in the soil and are responsible for infection of the crop. The seed treatment with Carboxin @ 0.2% dip for five minutes and shaded dry followed by one percent *Trichoderma harzianum* dip treatment for 5-10 minutes also reported effective. Flooding of the soil kills this pathogen and thereby reduces the infection.

Bacterial Diseases

Bacterial wilt of potato

It is one of the most important bacterial diseases and 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, losses up to 80 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 affects the crop at two stages; (a) killing the standing plants by causing wilt and (b) causing rot of infected tubers in field, storage and transit. 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 zero tolerance to this disease in most international seed certification systems.

Symptoms: The earliest symptom of the disease is the slight wilting in leaves of top branches during hot sunny days followed by total unrecoverable wilt**.** The cross-sections of stems may reveal brown discoloration of infected tissues. In advanced stages of wilt, cut end of base of the stem may show dull white ooze on squeezing. Bacterial wilt in field can be distinguished from fungal wilts by placing the stem cut sections in clear water. Within a few minutes, a whitish thread like streaming (bacterial ooze) can be observed coming out from cut end in to water. The same test can also be carried out to see infection in tuber. In tubers, two types of symptoms are produced; they are vascular rot and pitted lesions 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. These 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. The pathogen survives through infected seed tubers, many weed hosts and in plant debris in soil. Mean soil temperature below 15^{o}C and above 35^{o}C do not favour the disease development.

Management: The control of bacterial wilt has proved to be very difficult because of the seed and soil borne nature of the pathogen. However, economic losses can be minimised using following practices:

- **Healthy seed:** Use of healthy planting material can take care of almost 80% of bacterial wilt problem.
- **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 with non-host crops like cereals, garlic, onion, cabbage and *sanai* (Indian Senna). Paddy, sugarcane and soybean, though are not hosts of *Ralstonia solanacearum*, still they carry the 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 the 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 furrows along with fertiliser reduces pathogen population from field and gives effective control.

Common Scab of Potato

Common scab of potato caused by *Streptomyces spp*.This disease was first recorded in Patna during 1958. Since then, it has become endemic in various potato growing states. At least 13 different *Streptomyces* spp. have been found to cause common scab on potato worldwide.

Symptoms

Generally, developing underground parts of stems as well as stolons and tubers are susceptible to common scab. Roots and above ground plant parts are not susceptible nor are tubers with fully mature skin. Scab begins as small reddish or brownish spot on the surface of the potato tubers and its initial infection takes place during initial stage of tuber. The various kinds of symptoms have been recorded viz., (a) A mere brownish roughening or abrasion of tuber skin (b) Proliferated lenticels with hard corky deposition, might lead to star shaped lesion (c) Raised rough and corky pustules (d) 3-4 mm deep pits surrounded by hard corky tissue (e) Concentric series of wrinkled layers of cork around central black core. The pathogen is both seed and soil borne. It can survive in soil for several years in plant debris and infested soil. A favorable condition for disease is pH between 5.2 to 8.0 or more, temperature in the range of 20 to 30°C and low soil moisture.

Management

- Use only disease free seed tubers.
- Give tuber treatment with boric acid (3% for 30 min.) before the cold storage and shad dry before the storage.
- Irrigate the crop repeatedly to keep the moisture near to field capacity right from tuber initiation until the tubers measure 1 cm in diameter.
- 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.
- Summer ploughing the potato fields and leave the soil exposed to high temperatures during summer.

Soft Rot and Black Leg

Pectobacterium atrosepticum (syn. *Erwinia carotovora* sub sp. *atroseptica*), *P. carotovorum* sub sp. *carotovorum* (Jones) (syn. *E. carotovora* subsp. *carotovora*), *Dickeya* spp. (including *D.dianthicola*, *D. dadantii, D. zeae*) (syn. *E. chrysanthemi*) are main bacteria causing agent to this disease although many other bacteria also reported to cause the disease. This disease causes losses up to 100 per cent when poor handling of the produce, poorly ventilated storage or in transit.

Symptoms

This disease causes two types of symptoms. First type is soft rot and second one is black leg. Soft rot mainly found on tubers while black leg on the haulms system. A small area of tuber tissue around lenticels or stolon attachment point becomes water soaked and soft in initial. 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. The black leg stage develops from soft rot infected seed tubers. 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. 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. Sometimes stem rot and petiole rot also observed. The infections take place at 94 to100% relative humidity and temperature of 21°C to 29°C.

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. Decaying tubers in soil could serve as source of contamination for healthy tubers. Tubers harvested in wet soil, poor ventilation in transit and storage promotes the rot. Soft rot bacteria may survive in soil, on tuber surface, lenticels, periderm, cortex, ground tissue and vascular tissue.

Management

- To avoid excess irrigation, provide proper drainage and restrict nitrogen dose to minimum 150kg/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 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.

Suggested References

Alexopoulos, C J. Mims C W and Blackwell,M. 1996. *Introductory Mycology*.Fouth ed. John Wiely & Sons. Inc USA.

Arora RK, Shrama S and Singh BP. 2014. Late blight disease of potato and its management. *Potato Journal,* 41:16-40.

Collins, WW. 2000. The global initiative on late blight- alliance for the future. In, Potato Global Research and Development, Vol I, Khurana SMP, Shekhawat GS, Singh BP and Pandey SK (eds.), Indian Potato Association, CPRI, Shimla, India: 513-524.

Derevnina, Lida., Petre, Benjamin., Kellner, Ronny., Dagdas, Yasin F., Sarowar, M N., Giannakopoulou, A., la Concepcion,Juan Carlos De., Chaparro-Garcia, A., Pennington, H.G., van West,P. and Kamoun, S. 2016. Emerging oomycete threats to plants and animals. *Philosophical Transaction of the Royal Society. B* 371:20150459.

Dutt, BL. 1979. *Bacterial and Fungal Diseases of potato*. (Ed.) ICAR, New Delhi.

Kamoun, S., Furzer, O., Jones, J. D. G., Judelson, H. S., Ali, G. S., Dalio, R. J. D., Roy, S. G., Leonardo, C., Antonios Zambounis, Franck Panabières, David Cahill, Michelina Ruocco, Andreia Figueiredo, Xiao-Ren Chen, Jon Hulvey, Remco Stam, Kurt Lamour, Mark Gijzen, Brett M. Tyler, Niklaus J. Grünwald, M. Shahid Mukhtar, Daniel F A, Me Mahmut Tör, Guido van den Ackerveken, John Mcdowell, Fouad Daayf, William E Fry, Hannele Lindqvist-kreuze, Harold J G, Meijer Benjamin Petre, Jean Ristaino, Kentaro Yoshida, Paul Birch R J. 2015. The top 10 oomycete pathogens in molecular plant pathology, *Molecular Plant Pathology*, 16, 413–434.

Kromann P,Taipe A, PerezWG and Forbes,GA. 2009. Rainfall thresholds as support for timing fungicides applications in the control of late blight in Ecuador and Peru. *Plant Disease*, 93:142-148.

Lal M, Arora R K, Maheshwari Uma, Rawal S and Yadav S. 2016. Impact of late blight occurrence on potato productivity during 2013-14. *International Journal of Agricultural & Statistical Sciences*.;12 (1):187-192.

Lal, M, Saurabh Yadav, Subhash Chand, SK Kaushik, BP Singh and Sanjeev Sharma. 2015. Evaluation of fungicides against late blight (*Phytophthora infestans*) on susceptible and moderately resistant potato cultivars. *Indian Phytopathology* 68:345-347.

Lal, M Saurabh Yadav and B. P. Singh (2017). Efficacy of new fungicides against late blight of potato in subtropical plains of India. *Journal of Pure and Applied Microbiology.* 11 (1): 599-603.

Lal, M, Sanjeev Sharma, S K Chakrabarti and Manoj Kumar (2017). Thifluzamide 24% SC: A New Molecule for Potato Tubers Treatment against Black Scurf Disease of Potato Caused by *Rhizoctonia solani. Int.J.Curr.Microbiol.App.Sci*.6 (6), 370-375.

Sharma S, Sundresha, S and Singh, BP. 2015 Late blight of potato. In *A manual on diseases and pest of potato*-Technical Bulletin No. 101 (Ed. BP singh, M Nagesh, Sanjeev Sharma, Vinay Sagar, A Jeevvlatha and J Sridhar) ICAR-central potato research institute, Shimla, HP, India. p. 1-6.

Shekhawat GS, Chakarabarti SK and Gadevar AV.2000. Potato Bacterial Wilt in India. ICAR-Central Potato Research Institute, Shimla, Technical Bulletin No. 38.

Sagar, V. 2015 Bacterial wilt and Brown rot. In *A manual on diseases and pest of potato*-Technical Bulletin No. 101 (Ed. BP Singh, M Nagesh, Sanjeev Sharma, Vinay Sagar, A Jeevvlatha and J Sridhar) ICAR-Central Potato Research Institute, Shimla, HP, India. p. 20-23.

Singh BP, Ahmed I, Sharma VC and Shekhawat GS. 2000. JHULSACAST: A computerized forecast of potato late blight in western Uttar Pradesh. *Potato Journal* 27: 25-34

Singh BP, Govindakrishnan PM, Ahmad I, Rawat Shashi, Sharma S and Sreekumar J. 2016. INDO-BLIGHTCAST – a model for forecasting late blight across agroecologies, *International Journal of Pest Management*, 62:4, 360-367.

Singh BP, Arora R K and Khurana SMP.2002. *Soil and Tuber Borne Diseases of Potato*. Technical Bulletin No.41 (Revised). ICAR-central potato research institute, Shimla, HP, India.

Somani AK, Khurana SMP, 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 & MicrobialBiotechnology* (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 ColorHandbook.* Manson Publishing Ltd, London.

Chapter -19

NUTRITIONAL REQUIREMENTS OF POTATO CROP

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Nutrient management is second most important component in potato crop cultivation following water for realising yield potential of a variety. However, it needs to be done in such a way that productivity remains sustainable and environment friendly. Gap of nutrients required by the crop and expected availability in soil has to be supplied through external nutrient application. This may be done through organic and inorganic sources. Potato is one of the most sensitive crops to low nutrients supply from soils and being a shallow rooted crop its fertilizer use efficiency for N is approximately 40-50% and for K it ranges between 50-60% while it is only 10-15% for P. Thus a constant balanced supply of macro-nutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) and micro-nutrients (zinc, iron, copper, manganese, boron, molybdenum and chlorine) is essential for normal plant growth, development and ultimately tuber yield. Basic philosophy of nutrient management should be to apply fertilizers at rates that ensure high nutrient use efficiency so that cost of cultivation of potato is reduced unutilized quantity of fertilizers is also reduced to environmentally acceptable levels.

Different approaches are available for assessing nutrient requirement. These are visual deficiency symptoms, plant testing for critical limits and soil test based mainly estimating availability. Technological development and socio-economic situation of potato growers suggest that soil test based nutrient application is more feasible at grass root level. Potato crop requires 115-160 kg N, 15-21 kg P and 100-150 kg K for producing 30-40 t tubers per ha depending upon variety and crop duration. Micronutrients are required in small quantity and their uptake is about 210-240 g Zn, 700-900 g Mn, 1200-1400 g Fe and 40-50 g Cu. Soil analysis has revealed that soils of potato growers are generally deficient in organic matter and nitrogen, medium to high in case of phosphorous and potassium. Micro-nutrients are also generally not deficient in such soils. In some regions deficiency of zinc and iron has been observed. However, decision for nutrient application should be taken based upon soil analysis and as intensive cultivation is followed in this state than external supply of nutrient through organic and inorganic sources for adequacy is required.

Nitrogen (N) is the most yield limiting nutrient in majority of potato growing soils. It is required in large amounts to maintain optimum shoot and tuber growth. Nitrogen has a great influence on crop growth, tuber yield and its quality. Potato plants having sufficient N have vigorous growth, increased leaf area index produce large tuber size as well as numbers. 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. Ammonium sulphate containing 20% nitrogen in ammonical form and 24% sulphur is generally recommended in neutral soils as well as for production of processing potatoes. Neem coated urea (46.4% N) is generally advocated to apply at top dressing to avoid both leaching and sprout injury in early growth stage. In Potato, phosphorous application increases number of tubers, produces tubers of uniform size, boosts bulking and increases yield of tubers and hastens maturity. Application of P at optimum rates increases tuber starch and vitamin C content. Most common P fertilizers used in potato cultivation are single super phosphate (SSP) with 16% P_2O_5, Di-ammonium phosphate

(DAP) with 46% P_2O_5 and complex fertilizers (N: P: K). Proper placement of fertilizer has a great influence on phosphorous use efficiency and its application in furrows at planting time is better than broadcasting. Potassium is the third yield limiting nutrient element in potato production. It imparts resistance against drought, frost and diseases. Its application activates number of enzymes involved in photosynthesis, carbohydrate metabolism and proteins and assists in translocation of carbohydrates from leaves to tubers. It also increases yield by increasing number and yield of large sized tubers, therefore, its management has special significance in processing potato production. Potassium chloride (60%) popularly known as Muriate of potash (MOP) and potassium sulphate (approx. 50%) are main source of potassium.

Calcium plays an important role in maintaining tuber quality in storage and reducing internal tuber disorders. Calcium sulphate and calcium nitrate can be used as Calcium sources. Gypsum can be applied at or before planting and calcium nitrate is applied at planting. Magnesium plays a central role in photosynthesis, as it is present in the centre of each chlorophyll molecule. It is also involved in various key steps of sugar and protein. Magnesium deficiency can be a problem in soils where high rates of potassium fertilizer have been used. Magnesium sulphate (20%) is the most common source for Magnesium. Sulphur is recognized as fourth major nutrient after N, P and K and in view of its role in improving crop quality. It is required in many metabolic activities and its deficiency is similar to N in many ways. Elemental sulphur (80%), Single Super Phosphate (12%), Potassium Sulphate (18%) and gypsum (13- 15%) are common source of Sulphur.

Although micronutrient elements are needed only in traces but many soils may not supply them in sufficient quantity for healthy growth and optimum yield of potato. Zinc, Boron, Iron, Molybdenum, Copper, Manganese are the examples of micronutrients. Use of inorganic fertilizers and high yielding potato varieties has resulted in higher demand for these elements. This has resulted in micronutrient deficiencies particularly B and Zn in many soils. Micronutrients play an important role in suppressing plant diseases and improving the resistance of potato plant. Sulphate salts of different micro-nutrients are common source of micro-nutrients at planting. Foliar spray is another option after planting of crop for correcting their deficiencies in standing crop.

Recommendation in potato crop is to apply half quantity of N at planting time and rest half should be given 20-25 days after planting at inter-cultivation or earthing up. If earthing is not done than rest of N quantity should be divided into two parts and applied at 25 and 45 days after planting. Unlike N, phosphorous is immobile in soil, so its full dose is given as basal. Potassium is mobile in soil and crop tends to uptake this element more than the requirement. Studies have revealed that splitting of K has not given advantage in yield and its basal application is sufficient for higher tuber yield. In case of deficiency, secondary nutrients like sulphur and micro-nutrients like zinc and iron can be applied at planting, while rest of the trace elements can be sprayed two to three times on foliage during active growth phase.

Integrated nutrient management is highly recommended in recent situation for recycling or organic residues, lowering the cost of cultivation and sustainable tuber yields. Use of organic sources (FYM, compost, crop residue incorporation, green manures and bio-fertiliser *etc.*) would not only complete requirements of crop for secondary and micro-nutrients, but also reduce demand for macro-nutrients considerably. This would further reduce cost of cultivation and import bills particularly for phosphate fertilizers which are costliest. Works of scientists has concluded that FYM (15 t ha^{-1}) takes care of half of P and K requirement of potato crop. Green manuring (sesbania, cowpea etc.) supplement nutrition by way of bringing nutrients from deeper soil layers and symbiotic N fixation. Further, these crops improve soil physical condition and usually reduce N requirement of potato crop by 15-20%. Crop residue incorporation of rice, wheat and leguminous crops also improves soil organic carbon and ultimately nutrient supply to the crops in long run. Microbial inoculants like *azotobacter* and phosphorous solubilizing bacteria have also been tried in potato crop. Their use can also result in saving on inorganic N and P up to 20% depending upon agro-ecologies.

References

ICAR- Central Potato Research Institute, Shimla: www.cpri.icar.gov.in

Rawal S, Dua VK, Mankar P, Kumar D, Malik K, Lal Mehi, Singh S, Lekshmanan DK, Das B .2019. Indian good agricultural practices for the production of potato crop, ICAR-Central Potato Research Institute, Shimla. (Under publication)

Sud KC and Sharma RC (2003) Major and secondary nutrients. In: The Potato: production and utilisation in sub-tropics (Eds. Khurana SMP, Minhas JS &Pandey SK), Mehta Publishers, New Delhi, India, pp 136-147. ISBN 81-88039-18-7

Sud KC, Upadhayay NC, Trehan SP, Jatav MK, Kumar M and Lal SS (2008) Soil and plant tests for judicious use of fertilisers in potato. Technical Bulletin No. 91, ICAR-Central Potato Research Institute, Shimla,80p.

Trehan SP (2003) Micro-nutrient requirements of potato. In: The Potato: production and utilisation in sub-tropics (Eds. Khurana SMP, Minhas JS &Pandey SK), Mehta Publishers, New Delhi, India, pp 148-153. ISBN 81-88039-18-7

Trehan SP, Upadhayay NC, Sud KC, Kumar M, Jatav MK and Lal SS (2008) Nutrient management in potato. Technical Bulletin No. 90, ICAR-Central Potato Research Institute, Shimla, 64p.

Table 1: Macro- nutrient recommendations for potato crop

Crop	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
Early	150-180	80	100
Seed	150-175	80	100
Main (ware)	180	80	100
Main (processing)	270	80	150

Table 2: Micro- nutrient recommendations for potato crop

Micro-nutrient*	Soil application (kg/ha)	Spray application (g/100 l)
Zinc sulphate	25	200
Ferrous sulphate	50	300
Manganese sulphate	25	200
Copper sulphate	25	200
Ammonium molybdate	2	100
Sodium borate	2	100

*Soil test based

Chapter -20

MODERN METHODS OF IRRIGATION AND ITS EFFECT ON POTATO

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Potato (Solanum tuberosum L.) has a sparse and shallow root system and nearly 70% of total water is used by the crop from upper 30 cm soil layer. It requires 4000-600 mm water depending upon climatic conditions, soil type, length of growing season, duration of variety, purpose of crop and irrigation methods etc. Water requirement of potato is quite high and frequent irrigations are necessary to maintain optimum moisture in the soil throughout its growth. Excess or limited availability of water, light textured soils having low water retention capacity and shallow rooting system of plants are some of major factors adversely affecting the crop productivity. The yield and quality of potato depends upon a proper balance between soil air and soil moisture, which can be achieved by adopting a sound water management program. Efficiency of water could be increased if water losses are minimized. Evaporation can be checked by use of mulches whereas percolation losses of water by resorting to drip and sprinkler irrigation. Besides, the crop should be raised with optimum levels of other production inputs as they improve water use efficiency.

Water needs of the 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.

Techniques used to find out water requirement of potato

One pre-planting irrigation is usually given for land preparation and one pre-emergence light irrigation given to ensure quick and uniform plant emergence in the field. The various approaches have been used for working out water requirement of the crop -

1. Time interval approach: In this approach different depths of water were applied at different intervals for scheduling of irrigation. The studies 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.

2. Soil moisture/tension approach: According to this concept, irrigations were scheduled whenever soil moisture tension increased to the 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 the irrigation interval of 7-12 days.

3. 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 were 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.

4. Leaf water potential (ψ1) approach: Plant is the integrating component of soil water status 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 (ψ1) 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.

5. 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 of crop growth 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.

6. 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 others. However, most of the reports, have indicated stolonization followed by tuberization as most critical stages for potato.

7. Irrigation under specific situations: In North-Western parts of India , where frost is a problem, crop 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 10-12 days before the haulms die down or are killed deliberately. Early crop is harvested green and 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 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. Whereas, in plains and plateau areas, the potato grown in winter and rainfall is insufficient to meet the crop water requirement. Hence, light and frequent irrigations are necessary to obtain the sustainable crop yield.

Water management in plains

About 80% of potato cultivation in India is concentrated in the north-western plains where it is grown under assured irrigation in rabi season (October-February). Irrigation method used in potato crop must ensure adequate and uniform application of water with minimum losses as deep percolation and runoff. 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. The different irrigation methods used for applying irrigation to the crop are given below -

1. Furrow irrigation: Among various irrigation methods viz. surface, sub-surface, drip & sprinkler irrigation methods, the furrow irrigation is most common and popular method for irrigating the crop. The field is laid out in alternate ridges and furrows and water should applied in furrows seeps into ridges which are moistened to top by the capillary action of soil.

Under mechanized cultivation, the crop is irrigated in long furrows spaced widely at a distance of about 60 cm, where mechanization is not followed, irrigations can be given in short furrows spaced at 45-50 cm apart. Whatever the form of furrow irrigation, water should never overflow the ridges as this seals the surface soil pores, thereby raises the bulk density and leads to anaerobic conditions. Such adverse effects result in seed tuber decay at planting especially in plains when soil temperatures are high. Field channels of about 70–100 cm width serve bilaterally a set of 6-8 furrows in each bed. The ridges may be wetted only up to about two-third of height leaving the rest to be moistened gradually by capillary movement of water. Generally, 4-5 cm of irrigation water should be applied at each irrigation. However, the irrigation efficiency under furrow irrigation method is low and seldom exceeds 50%.

2. Micro-irrigation methods: Modern methods improve the efficiency of water and nutrients by increasing availability of these inputs to the crop, they also improve hydro-thermal regimes and physical conditions of soil by maintaining the proper balance between soil air and soil water in the plants root zone for better growth and development which results in to higher yield and numbers as well as tuber quality. With the increasing water scarcity and recurring droughts in many parts of the country, the use of drip and sprinkler irrigation have become extremely important.

i). Drip or trickle irrigation: Drip method involves slow application of water in the plant root zone which provides scope to utilize water and nutrients efficiently. The moisture availability is always equal to the field capacity in surface soil throughout growth period. About 40-50% less water is required for growing potato under drip irrigation, it also enhances the potato production and keeps productivity at high level (20-30%) in comparison to furrow irrigation. Raised bed two or triple rows planting methods are beneficial. The increase in yield is contributed by an increase both in tuber size and numbers. Besides, drip irrigation also provides several advantages to potato growers, including no water runoff from field, precise application of water, ability to apply nutrients through fertigation, minimum leaching losses of water & nutrients with reduced canopy moisture and risk of foliar diseases. The earthing-up practice could also be dispensed.

ii). Sprinkler irrigation: The sprinkler system gives uniform distribution of water without compacting soil surface, reducing water losses in terms of deep percolation and surface run off. It could be used in special situations viz. in undulating topography, extremely sandy soils with very high water intake rate or fine-textured soils with very low intake rate and costly and scare water supply. It is also beneficial in frosty nights as a preventive measure against freezing injury to the plants. The uniformity of water is assured only by overlapping pattern of sprays from different size nozzles. Nitrogen applied directly to the crop as foliar spray, helps in better growth and tuber development. The system is expected to economize on water by about 30-40% with higher crop yield than surface irrigation method. If sprinkler irrigation is practiced, the closer spacing opted advantageously. Raised bed two /triple rows planting methods are beneficial. However, the initial cost of system consisting of pipes, risers and sprinkler heads, pressure pump is high and technical know-how is required to install and run the system efficiently.

Scheduling of micro-irrigation

The proper irrigation scheduling is most important aspect for efficient utilization of available water resources at farm. Irrigation scheduling depends on moisture retention capacity of soil, crop growth stages, atmospheric factors and rooting patterns of potato cultivars. One pre-planting irrigation is usually applied for land preparation and one pre-emergence light irrigation can be given to ensure quick emergence and crop establishment. Thereafter, irrigation depth and time for drip and sprinkler methods can be worked out by using following formula -

$$\text{Application rate (mm/hour)} = \frac{\text{Discharge of water (lph)}}{\text{Spacing between two drippers/sprinklers (m)} \times \text{Spacing between two rows of system (m)}}$$

Under drip method, the irrigation should be applied at alternate day based on CPE (cumulative pan evaporation). Experimental results advocated that integral laterals with inline/inbuilt/flat dippers (16 mm OD/30 cm/2 lph) placed on each ridge at 60 cm distance corresponds to operate for 35-45 minutes at 125% of CPE for each irrigation in single row planting. Whereas, for paired/triple row raised bed planting, the system should run for 1¼ -1½ hours at each irrigation depending upon the prevailing soil moisture conditions in the field (Sood & Singh, 2008 and 2014).

For sprinkler irrigation method, weekly two irrigations at 150% of CPE are needed for sustainable crop yield. For example, sprinkler system (e.g. 560 lph discharge/10 m x 10 m, distance between two sprinklers and two lateral lines) corresponds to operate for 2.0-2½ hours at each irrigation depending upon the prevailing soil moisture conditions in the field. However, the application rate & time for each irrigation may vary with the specifications of system.

Fertigation through micro-irrigation

The potato crop raised with drip irrigation/fertigation, the one third dose of fertilizers (60:27:33 kg NPK/ha) through CAN or AS, SSP or DAP & MOP, respectively should be applied as basal at planting. The remaining two third dose of fertilizers i.e.120:53:67 kg NPK/ha) should be given through fertigation in eight equal splits, twice in a week starting from plant emergence to six weeks of planting (@ 15, 6.63 & 8.37 kg N, P2O5 and K2O/ha through urea, di-ammonium phosphate and muriate of potash, resp.). When fertilizers are used for fertigation fill the fertilizer tank with 35 liters of water and add 15 kg fertilizer and close the lid of tank tightly and then run the system for at least half an hour. After fertigation, the system needs to be run for 5 minutes.

Under sprinkler irrigation/fertigation, the one third dose of nitrogen i.e. 60 kg N/ha with full dose of phosphorus (80 kg P_2O_5/ha) and potash (100 kg K_2O/ha) through CAN or AS, SSP or DAP & MOP, respectively should be applied as basal at planting. The remaining two third nitrogen i.e.120 kg N/ha should be given through fertigation in eight splits, twice in a week starting from plant emergence to six weeks of planting (@ 15 kg N/ha through urea). When fertilizer is used for fertigation, fill the tank with 35 liters of water and add 15 kg urea and close the lid of tank tightly and then run the system for at least 35-45 minutes (Sood and Singh, 2008 & 2014).

Water management in hills

Potato is grown as a rain fed crop during summer from March/April to Sept/October in hilly areas. The total rainfall is generally in excess of evapo-transpiration, but, the crop usually suffers from drought before or on set of monsoon and from the excess moisture during later stages of growth. The studies have shown that there is surplus of 84 cm water per annum. This much quantity of water if conserved or stored and recycled during crop growth period by using modern irrigation techniques would greatly help in mitigating the drought problem for its effective use- i) increasing soil water storage capacity; ii) conservation of soil moisture; iii) in situ water harvesting ; iv) water harvesting in farm reservoirs/ ponds, and v) proper drainage system etc.

Efficient and economic use of water

Potato is an efficient user of water, but its needs are also inflated by unproductive water losses. A number of techniques have been developed to reduce water losses and to improve water use efficiency, as described below:

1. Use of mulches: The potato fields have to be irrigated frequently as mentioned earlier, and are therefore, subject to high rates of evaporation especially before full vegetative growth covering the soil surface. Reduction in evaporation during early stages of growth either through tillage or mulching results in increased yield and thereby increases water use efficiency. Use of paddy straw mulch should be encouraged as it is reported to increase WUE by 15% under Punjab conditions.

2. Use of anti-transpirants: Studies on use of anti-transpirant, viz. abscisic acid, have shown that it has only a transitory effect in reducing transpiration. As such this approach may not hold good in field, at least in potato.

3. Cultural factors: It appears quite workable to improve WUE by stimulating growth through improved practices viz. i) manuring and fertilizer use, ii) weed control, and iii) adoption of optimal cultural practices. Positive interaction of irrigation and nitrogen increased water use efficiency. This is because the N fertilizer stimulated growth and increased yield without increasing the required quantity of irrigation water. Moreover, the crop growth with manures or fertilizers, particularly those which stimulate growth covers the ground quickly and thus reduces evaporation. The increase in evapo-transpiration or consumptive water use by the crop due to manuring and fertilizer use, may therefore, be small when compared with a large response in yield. Consequently manures and especially nitrogen improve water use efficiency. Compared to nitrogen, water use efficiency was not affected by phosphate and potassic fertilizers. Weeds compete with crop not only for water but also for nutrient and space and therefore, they reduce the growth and crop yield, even if the water loss through weeds is replenished. The weed control by cultural or chemical methods not only improves water use efficiency but also leads to water economy.

4. Inter-cropping: Even with the best management practices, some water is likely to go below the root zone of the potato. Part of this water could be recovered by wheat inter-sown in furrows, soon after potato are earthed up. This amounts to in-situ recirculation of water that might have percolated down unavoidably.

5. Alternate furrow irrigation: Under conditions of water scarcity, 38% saving in irrigation water was achieved by applying water to alternate furrows in turns at the expense of 11% decrease in yield. This practice seems promising where water is a major limiting factor in potato production.

6. Stages of water stress: Knowledge of critical stages of water stress is essential for a judicious use of irrigation water. In potato, stolonization and early tuberization stages are the most critical. An inadequate supply of water during these stages affects the yield more than the water stress at other stages. Therefore, plants should be irrigated at 0.3 bar tension or at 15-20 mm CPE during critical stages of growth. However, the plant could experience mild water stress (0.5 bar tension) during early and late crop stages and this approach can be used to save about 30% irrigation water.

7. Improved methods of irrigation: As discussed earlier, drip and sprinkler methods of irrigation can economize irrigation water by 30-50%. These modern methods could be advocated to the progressive potato growers because the initial cost of installation is high.

Suggested References:

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

Name Singh and MC Sood. 2013. Architecturing of planting geometry and drip layout systems for potato production under drip irrigation. Progressive Agriculture 13 (2): 207-11

Name Singh and MC Sood. 2013. Raised bed planting techniques for potato production under furrow and sprinkler irrigation methods. Annals of Horticulture. 6 (1): 45-48.

Name Singh, MC Sood and S S Lal. 2014. Potato production under Drip and Sprinkler Irrigation. Technical Bulletin No. 97, CPRI, Shimla 28. pp 1-32.

Chapter -21

BREEDING FOR POTATO VARIETIES FOR PROCESSING

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Potato (*Solanum tuberosum* L.) is 3rd most important food crop in the world after rice and wheat in terms of human consumption and popularly known as the 'king of vegetables'. India is the second biggest potato producer and almost a third of all potato is harvested in China and India. Availability of indigenous varieties, good quality seeds and right package of agronomic practices triggered a revolution in potato production causing very fast growth in area, production and productivity. Potato production increased more than 33 times since 1950, due to both increased area and yield. The per capita potato consumption in India has risen from 12 kg/year in the early nineties to about 24 kg/year during 2017-18. Increased production, however, brought in a peculiar problem of glut situation when supply exceeded demand resulting in price collapse. In India till 1989, all the varieties were bred for consumption as fresh potato. Therefore, despite large quantities of potato available in the market, the availability of potatoes for processing was poor. Long day adapted European processing varieties were not successful in India, as they were not suited to short winter days. Some of the varieties like Kufri Chandramukhi, Kufri Jyoti and Kufri Lauvkar were used by the chipping industry from the produce of crop grown in warmer areas where night temperatures are relatively high (around 10^0 C).

Efforts to introduce European and north American processing and table varieties has not been successful in the country mainly because these varieties were bred for long day conditions whereas, the crop in India is grown under short winter days. Keeping in view the demand of quality raw material for processing, ICAR-Central Potato Research Institute launched a breeding programme in 1990 for developing indigenous processing varieties.

Indian Breeding programme for processing potatoes

Under this programme, crossing were made at ICAR-Central Potato Research Station, Kufri (HP) in hills (31° N 77° E; 2402 m above msl) and raising and evaluating of segregating progenies and selection of suitable genotypes was done at ICAR-Central Potato Research Institute, Campus, Modipuram (U.P.) in the plains (29° N 76° E; 222 m above msl). Assessment of segregating populations for as many characters as possible in the initial stages was done to eliminate undesirable genotypes facilitating better assessment of the selected genotypes in subsequent generations (easily identifiable characters were considered for this purpose). Extensive evaluation of genotypes was done in subsequent generations for tuber dry matter, reducing sugars, chip colour and yield. Finally the selected hybrids are tested under industrial processing conditions.

Generally, any plant breeding program is based on two fundamental steps, (1) production of genetic variability through either conventional or innovative methods, and (2) efficient selection within the variability created. There are two methods to create variability, sexual hybridization and genetic engineering. Similarly, breeding varieties for value addition comprises of following major steps:

- Identification and evaluation of parental lines with desirable attributes

- Combining the desired attributes with high yielding base variety through hybridization or genetic manipulations
- Evaluation of segregating population/clones and selection for stability of yield and desired processing traits

Inheritance of processing especially related to quality traits is poorly defined and genetically least researched. The available information on various quality traits of interest is presented below.

Morphological attributes

Tuber shape: Tuber shape is a varietal character but it is also influenced by environmental conditions and cultural practices. Inheritance of the tuber shape is yet not finally concluded due to contradictory results of the researchers. Some researchers considered long tubers as being dominant to round tubers, but others suggested that round shape was dominant to either oval or long oval.

Growth cracks: The causes of growth cracks are not well understood. It is attributed to fluctuating water stress or changes in tuber growth rates. In addition to the abiotic stresses, there is also a heritable component, which does not result in clearly delineated groups, suggesting that a number of minor genes may be involved. Therefore, for selection of this character one has to rely on observations in various environments over a number of years, as is presently practiced.

Hollow heart: Hollow heart is a physiological defect resulting from an internal cavity of varying dimensions. It is found more frequently in the larger tubers. Development of hollow heart is often associated with periods of rapid tuber growth, which may have been preceded by a period of moisture or nutritional stress. The expression of this trait is affected by various environmental and genetical factors.

Greening: Potato tubers exposed to light in the field, during or after the harvest develop a green pigmentation, initially at the surface and subsequently throughout the whole tuber. This condition is caused by the formation of chlorophyll. Greening of potatoes is often associated with an increased level of glycoalkaloids, which impart a bitter taste to the tubers and are poisonous. Tuber greening is inherited in a quantitative manner with most of the variation being additive. However, broad sense heritability was sufficiently large to permit effective selection within the potato breeding programmes.

Biochemical attributes

Dry matter: Starch constitutes about 70% of the dry matter (DM) content of potato tubers. There is considerable variation among cultivars for DM content and this trait is also influenced by the environment during the growing season as well as storage. Dry matter has been associated with many other quality parameters such as texture, suitability for processing and susceptibility to mechanical damage. It is polygenically controlled and responds to selection, but the environmental effects are so large that much effort is required to achieve significantly higher dry matter content that are currently available in the known varieties. Too high DM content also badly affects certain culinary properties, such as disintegration on boiling (sloughing), so that selection for high DM content *per se* is seldom a breeding objective. Moreover, high DM has a negative correlation with total tuber yield.

***Reducing sugars**:* Starch is the major carbohydrate source in potato tubers, yet small but varying amounts of sugars, namely sucrose, glucose and fructose are also present. Reducing sugar content of 0.1 % per l00g fresh weight is ideal for processing into chips and higher than 0.33% is unacceptable. Sugar content of tubers varies considerably among seasons, locations and also varieties. The chip colour has high heritability thus allowing fairly reliable prediction of parental values based on progeny means.

Glycoalkaloids: Potato tubers contain small quantities of naturally occurring steroidal glycoalkaloids, a class of potentially toxic compounds, found throughout the family Solanaceae. Cultivars vary with respect to their inherent glycoalkaloid content; at lower levels it is suggested that they may enhance potato flavour, but at higher concentration (above 15 mg 100 g $^{-1}$ fresh wt.) they impart bitterness and levels above 20 mg 100 g^{-1} fresh wt. are considered unsuitable for human consumption resulting in symptoms typically associated with food poisoning. There are conflicting reports available in the literature about the inheritance of this trait. Some reports suggest that it is inherited in a dominant manner with a couple of genes controlling this trait while others indicate its polygenic inheritance. Nevertheless, it is important that initial content of parental material may be assessed before starting a breeding programme particularly with wild species.

Indian processing varieties:

Concerted breeding efforts for development of processing varieties by CPRI has led to develop and release of eight processing varieties namely Kufri Chipsona-1 and Kufri Chipsona-2 (1998), Kufri Chipsona-3 (2006), Kufri Himsona (2007), Kufri Frysona (2009), Kufri Chipsona-4 (2010), Kufri FryoM (2018) and advanced stage hybrid MP/6-39 (recommended for release). These varieties are gradually occupying large areas of various regions for meeting the requirement of quality potatoes for processing. There is however, need to continue to breed better varieties for different purposes, especially early-medium maturing varieties for warmer areas of country where growing period is shrinking and for vast Indo-Gangetic plains. The salient features of the processing varieties are given below-

Kufri Chipsona-1 (MP/90-83): The variety is a selection from the progeny of the cross CP2416 x MS/78-79. The female parent CP2416 is the Mexican genotype MEX 750826, while the male parent is from Indian potato breeding programme which involved KufriJyoti and EM/H-1601 in its parentage. The variety produces white-cream ovoid tuber with shallow eyes and white-cream flesh. The variety produces ~30-35 t/ha yields under north Indian plains. Its dry matter content is 20-23%and reducing sugar content is 10-75 mg/100 g fresh weight. The variety yields processing grade tubers to the tune of 60-75%. The variety has good late blight resistance and is well adapted to Indo-Gangetic plains. The tubers possess excellent keeping quality. The variety is suitable for making chips, French fries and flakes.

Kufri Chipsona-2 (MP/91-G): The variety is a selection from the progeny of the cross CP2346 (F-6) x QB/B 92-4. The female parent F-6 is an accession received from International Potato Centre, Lima, Peru, while the male parent is an indigenous advanced stage hybrid developed from Kufri Red and Navajo (from USA). The variety produces white-cream round tuber with medium eyes and cream flesh. The variety produces nearly 30-32 t/ha yields under north Indian plains. The tubers of this variety have reducing sugars in the tune of 30-100 mg/ 100 g fresh weight and dry matter content is 22-24%.The variety has high degree of late blight resistance. The processing grade yield is 65-75%and is highly suitable for chip making.

Kufri Chipsona-3 (MP/97-583): The variety is a selection from the progeny of the cross MP/91-86 x Kufri Chipsona-2. The female parent MP/91-86 is a promising selection from the processing breeding programme. The variety produces white-cream ovoid tuber with shallow eyes and white flesh. The variety produces ~30-35 t/ha yields under north Indian plains. The tubers of this variety have reducing sugar content of 10-100 mg/100 g fresh weight and dry matter content 20-23%.The variety has moderate resistance to late blight and is suitable for chips and flakes preparation. The variety yields reasonably good process grade tubers to the tune of 70-80 %.

Kufri Himsona (MP/97-644): The variety is a selection from the progeny of the cross MP/92-35 x Kufri Chipsona-2. The female parent MP/92-35 is a selection from processing breeding programme. The variety produces white-cream ovoid tuber with shallow eyes and white flesh. The variety produces ~15-20 t/ha yields under hilly regions of the country. The variety produces nearly 30-35 t tuber yield when grown in north-western/central plains The tubers have dry matter content of 21-24% and reducing sugars 10-80 mg/ 100 g fresh weight. The variety has a high degree of resistance to late blight. The variety is suitable for chips and flakes making

Kufri Chipsona-4 (MP/01-916)**:** The variety is selection from the progeny of cross Atlantic x MP/92-35. It produces high yield with higher proportion of chip grade tubers. It has early maturity with field resistance to late blight, thus helping farmers in saving on costly fungicides. The variety produces white-cream round-ovoid tuber with shallow eyes and white flesh. The variety produces ~18-22 t /ha yields during kharif crop in Karnataka and 30-35 t/ha tuber yield in rabi crop in plains. It is suitable for preparation of chips owing to its round-ovoid shape, high dry matter (>20%) and low reducing sugars (40-80 mg/ 100 g fresh weight). It will fill the void of a suitable chipping variety from Karnataka, West Bengal and Madhya Pradesh where processors are in need of variety combining high tuber yield and high level of late blight resistance. Long dormancy and good keeping quality will help storage of this variety for longer period thus ensuring round the year availability of raw material to chipping industry.

Kufri Frysona (MP/98-71): The variety is selection from the progeny of MP/90-30 x MP/90-94. It produces attractive white-cream long oblong tubers with shallow eyes and white flesh. The variety produces nearly 30-35 t/ha tuber yield in rabi crop in plains of the country. It possesses very good field resistance against late blight disease and has reasonably good frost tolerance. It is a good keeper under country store conditions and possess longer tuber dormancy period of more than 8 weeks. It possesses high tuber dry matter (22%), low reducing sugars (30-80 mg/100 g fresh weight) and very good quality French fries can be prepared. The industrial testing has shown the superiority of this hybrid for French fry making in terms of taste, texture and colour.

Kufri FryoM (MP/04-578): The variety is selection from the progeny of Kufri Chipsona-1 x MP/92-35. It produces attractive white long oblong tubers with shallow eyes and white flesh. The variety produces nearly 30-35 t/ha tuber yield in plains of the country. Tubers do not show deformities like cracking or hollow heart. It has field resistance against late blight disease. It is a good keeper under country store conditions and possess longer tuber dormancy period of more than 10 weeks. It possesses 20% tuber dry matter, low reducing sugars (50-90 mg/100 g fresh weight) and very good quality French fries can be prepared.

MP/06-39: It is main-season dual purpose variety having medium maturity with high tuber yield (35-35t/ha), field resistance to late blight, very good keeping/culinary quality and suitable for growing in central plains (processing and table purpose) and northern plains (table purpose). It produces attractive white-cream ovoid uniform tubers with shallow eyes and white-cream flesh. It possesses field resistance to late blight. The variety has been for recommended for release in 37th group meeting of AICRP (Potato) held during 3-4th September, 2019 at JNKVV, Jabalpur, Madhya Pradesh.

Future Thrusts

To keep the pace with the future needs of growing processing industry in India, suitable cultivars needs to be developed with the desirable traits which are expected are: Varieties with the processing quality demanded by the manufacturers of chips, French fries and flakes. Resistance to low temperature sweetening so that tubers can be stored at 2 to 4°C to control the development of diseases, weight loss and sprouting in store, with reduced reliance on sprout inhibiting chemicals

Suggested References

CPRI. 2013. Vision-2050. Central Potato Research Institute, Shimla, India.

Gaur PC, SK Pandey, SV Singh and Dinesh Kumar. 1999. *Indian Potato Varieties for Processing.* Tech. Bull. 50, Central Potato Research Institute, Shimla, p. 25.

Gupta VK, SK Luthra and BP Singh 2014. Potato processing varieties: Present status and future thrusts. National seminar on post-harvest management and processing of potato for increasing food security in India. 22 Sep, 2014, UAS campus, Dharwad, Karnataka, India

Gupta VK, SK Luthra and BP Singh 2014. Breeding potatoes for value addition: A comprehensive approach for sustainable potato production. National seminar on emerging problems of potato, November 1-2, 2014, Central potato Research Institute, Shimla, HP, India Abstracts: p159

Luthra SK and VK Gupta. 2019. Development of potato varieties for processing industries-An overview. National Seminar on Strategic Management of Production & Post Harvest Technologies of Onion, Garlic & Potato for Uplifting the Livelihood of Farmers at IARI, New Delhi held on March 11-12, 2019. Sovenior page:50-61

Marwaha RS, Dinesh Kumar, SV Singh and SK Pandey. 2006. Emerging technologies in potato processing. *Processed Food Industry,* May 2006: 39-44.

Singh SV, SK Pandey, Dinesh Kumar, P Kumar and SM Paul Khurana. 2002. *Production of Potatoes for Processing,* Extension Bull. 33, Central Potato Research Institute, Shimla, India, 13 p.

Marwaha RS, Dinesh Kumar, SV Singh and SK Pandey. 2008. Nutritional and qualitative changes in potatoes during storage and processing. *Processed Food Industry* 11: 22-30.

Talburt W F, Smith O. 1975. Potato Processing Third edition, pp 305-402. West port: The AVI Publ. Co., Inc.

Chapter -22

CONTRACT FARMING OF POTATO IN INDIA- SUCCESSES, CONSTRAINTS AND WAY FORWARD

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Introduction

Contract farming is not very old concept in rural economy of India. The process of contract farming involves cultivating and harvesting for and on behalf of big business establishments or Government agencies and forwarding the produce at a pre-determined price. In return, the contracted farmers are offered high price against their farm produce. The role of contract farming in Indian agriculture is becoming more and more important, since organized farming practice has become the need of the hour in the process of rapid industrialization.

Contract farming (CF) can be defined as agricultural production carried out according to an agreement between a buyer and farmers, which establishes conditions for the production and marketing of a farm product or products. Typically, the farmer agrees to provide agreed quantities of a specific agricultural product. These should meet the quality standards of the purchaser and be supplied at the time determined by the purchaser. In turn, the buyer commits to purchase the product and, in some cases, to support production through, for example, the supply of farm inputs, land preparation and the provision of technical advice.

Models of Contract farming

Informal model - This model is the most transient and speculative of all contract farming models, with a risk of default by both the promoter and the farmer**.** However, this depends on the situation: interdependence of contract parties or long-term trustful relationships may reduce the risk of opportunistic behaviour. Special features of this CF model are:

- ✓ Small firms conclude simple, informal seasonal production contracts with smallholders.
- ✓ The success often depends on the availability and quality of external extension services.
- ✓ Embedded services, if at all provided, are limited to the delivery of basic inputs, occasionally on credit; advice is usually limited to grading and quality control.
- ✓ Typical products: requiring minimal processing/ packaging, vertical coordination; e.g. fresh fruit/ vegetables for local markets, sometimes also staple crops.

Intermediary model - In this model, the buyer subcontracts an intermediary (collector, aggregator or farmer organisation) who formally or informally contracts farmers (combination of the centralised/ informal models). Special characteristics of this CF model are:

- ✓ The intermediary provides embedded services (usually passing through services provided by buyers against service charges) and purchases the crop.
- ✓ This model can work, if well-designed and if incentive-structures are adequate and control mechanisms are in place.

- ✓ This model can bear disadvantages for vertical coordination and for providing incentives to farmers (buyers may lose control of production processes, quality assurance and regularity of supplies; farmers may not benefit from technology transfer; there is also a risk of price distortion and reduced incomes for farmers).

Multipartite model - This model can develop from the centralised or nucleus estate models, e.g. following the privatisation of parastatals. It involves various organisations such as govern- mental statutory bodies alongside private companies and sometimes financial institutions. Special features:

- ✓ This model may feature as joint ventures of parastatals/ community companies with domestic/ foreign investors for processing.
- ✓ The vertical coordination depends on the discretion of the firm. Due attention has to be paid to possible political interferences.
- ✓ This model may also feature as farm-firm arrangement complemented by agreements with 3rd party service providers (e.g. extension, training, credits, inputs, and logistics).
- ✓ Separate organisations (e.g. cooperatives) may organise farmers and provide embedded services (e.g. credits, extension, marketing, sometimes also processing).
- ✓ This model may involve equity share schemes for producers.

Centralized model - In this model, the buyers' involvement may vary from minimal input provision (e.g. specific varieties) to control of most production aspects (e.g. from land preparation to harvesting). This is the most common CF model, which can be characterised as follows:

- ✓ The buyer sources products from and provides services to large numbers of small, medium or large farmers.
- ✓ The relation/ coordination between farmers and contractor is strictly vertically organised.
- ✓ The quantities (quota), qualities and delivery conditions are determined at the beginning of the season.
- ✓ The production and harvesting processes and qualities are tightly controlled, sometimes directly implemented by the buyer's staff.
- ✓ Typical products: large volumes of uniform quality usually for processing; e.g. sugar cane, tobacco, tea, coffee, cotton, tree crops, vegetables, dairy, poultry.

Nucleus estate model - In this model, the buyer sources both from own farm and from contracted farmers. The estate system involves significant investments by the buyer into land, machines, staff and management. This model can be characterised as follows:

- ✓ The nucleus estate usually guarantees supplies to assure cost-efficient utilisation of installed processing capacities and to satisfy firm sales obligations respectively.
- ✓ In some cases, the nucleus estate is used for research, breeding or piloting and demonstration purposes and/ or as collection point.
- ✓ The farmers are at times called 'satellite farmers' illustrating their link to the nucleus farm. This model was in the past often used for state owned farms that re-allocated land to former workers. It is nowadays also used by the private sector as one type of CF. This model is often referred to as "outgrower model".
- ✓ Typical products: perennials

Advantages of Contract Farming to Producer/farmer

- ✓ Makes small scale farming competitive - small farmers can access technology, credit, marketing channels and information while lowering transaction costs
- ✓ Assured market for their produce at their doorsteps, reducing marketing and transaction costs
- ✓ It reduces the risk of production, price and marketing costs.
- ✓ Contract farming can open up new markets which would otherwise be unavailable to small farmers.
- ✓ It also ensures higher production of better quality, financial support in cash and /or kind and technical guidance to the farmers.

Advantages of Contract Farming to Agri-based firms

- ✓ It ensures consistent supply of quality raw material to processing firms, at right time at lesser cost.
- ✓ Optimally utilize their installed capacity, infrastructure and manpower, and respond to food safety and quality concerns of the consumers.
- ✓ Make direct private investment in agricultural activities.
- ✓ The price fixation is done by the negotiation between the producers and firms.
- ✓ The farmers enter into contract production with an assured price under term and conditions.

Disadvantages of contract farming for the Company

- ✓ No method exists to discourage defaulting farmers. There prevails no legal resort for the company while facing with large scale breach of contracts.
- ✓ Small size land holding of farmer: Difficult to manage large number of farmers.
- ✓ Insufficient insurance scheme for comprehensive crop protection in case of natural calamities.

Disadvantages of contract farming for the farmers

- ✓ Weak bargaining power vis-à-vis a mammoth agro-industry, monopsony market power and exploitative terms.
- ✓ Risk and uncertainty involved in producing new, unfamiliar crops and that too producing for markets that might not always live up to their presumption- or their sponsors' expectations.
- ✓ Remarkable changes in market conditions, debts caused due to production complication, poor technical advice, or a company's failure to honour contracts.
- ✓ Manipulation of quality standards by company in order to turn down purchases.

Contract Farming of Potato: All major potato processors in India have undertaken contract farming operations in India. The models adopted by all of them are similar to the one adopted by the PepsiCo India which is also the one of the oldest in the country. The model of PepsiCo has been emulated by other companies like ITC, Merino Industries and Satnam Agri Ltd. For better understanding of the concept this model has been thoroughly elaborated.

Model of Pepsico India: PepsiCo India (previously known as Pepsi Foods Ltd) started its first potato chips manufacturing plant at Channo district Sangrur in Punjab. Later the company added two more plants to its manufacturing capacities in India at Ranjangaon near Pune in Maharashtra and Sankarail near Howrah in West Bengal. At present, the company requires about 1,40,000 tonnes processing grade potatoes every year. In order to meet its raw material requirements the company has been adopting contract farming in Punjab, Maharashtra, Karnataka, Jharkhand and West Bengal with more than 14,000 farmers at an area over 12,000 acres.

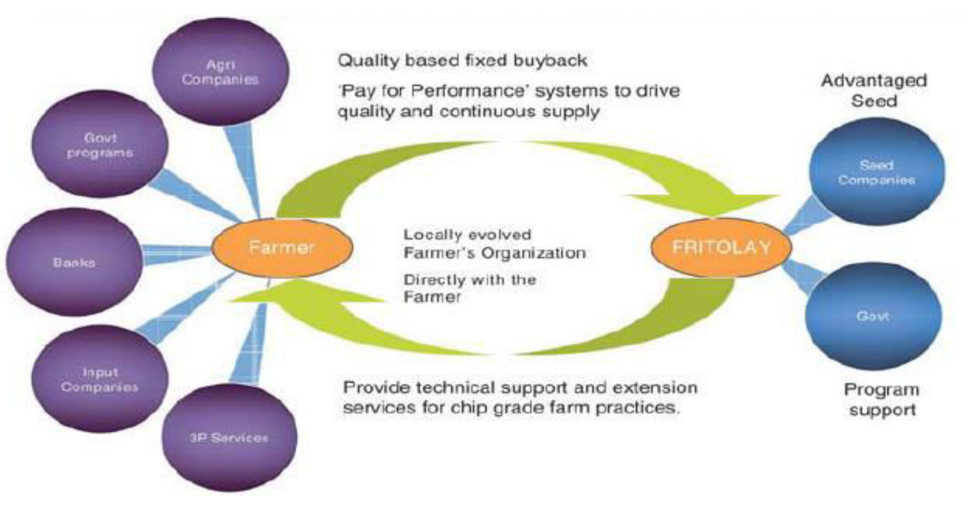
The PepsiCo contract farming model differs slightly from state to state, but the basic model of operation is "Partners in Progress Model" (Fig. 1) where efforts are made to provide a win-win market linked self-sustaining opportunities. In the "Partners in Progress Model", FritoLay establishes cooperatives or locally evolved farmers organizations to be affiliated directly. The farmers who can produce potato of quality as per requirement are identified by these cooperatives or farmers organisations.

The PepsiCo Company procures the production as per the price, quantity and quality which are pre agreed. Farmers also get incentives for meeting high quality standards, by PepsiCo to drive quality and a continuous supply. A 360-degree farmer connect program has been introduced by PepsiCo that Includes:

- Safeguarding farmers from open market price variations, by providing guaranteed buy-back of produce at pre-determined prices.
- High quality planting material provided to the farmers, including its proprietary advanced seed varieties.
- Providing Soft financing by way of national level tie-up with State Bank of India.
- Partnership with insurance companies to provide crop/weather risk insurance to safeguard farm incomes.
- Supplying plant protection scheme and technical know-how formulated in association with agricultural input companies namely Bayer, BASF and DuPont.

"Partners in Progress" contract Farming Model adopted by PepsiCo

The salient features of this model has been the supply of quality seed potato, assured technical support, monitoring of crop health, facilitation of farm credit and crop insurance to the contracted farmers.



Frito Lay's "Partners in Progress" Model

Seed - potato: Company provides good quality seed potato to its contract farmers in all operation areas. For this, it is undertaking contract farming operations for seed-potato multiplication at farmers' fields after getting *in-vitro* material from its state of the art tissue culture facility at Jalandhar. Although price of seed-potato provided by the company is much higher (sometimes more than double) than the one prevalent in the market, yet the quality of the seed justifies higher price.

Agro-chemicals and fertilizers: Company purchases identified inputs from different companies at a lower price and provides such inputs to contract farmers at lower than their open market price. Through this activity company not only ensures lower price to its contract farmers but quality of inputs is also ensured.

Crop health monitoring: Crop health is regularly monitored with the help of agronomists hired by the company and in serious cases the scientists from the CPRI, Shimla. Such vigilance helps farmers to reap higher yield of desirable tubers and realise better net profits as compared to the non – contract farmers in the area.

Buying at farm gate: Small and marginal farmers have the biggest headache of taking their small volumes of the produce to the markets and get remunerative prices.

Generally, farmers have to pay higher transportation cost due to their small volume of produce. In order to save farmers from such hardships company facilitates quality check, grading, bagging and transportation of the produce from farm gate. The account-payee cheques are provided to contract farmers as quality based value of their produce in order to avoid any kind of financial fraud or cheating.

Institutional support: Besides above mentioned support the company talks with other companies and provides other institutional facilities (through other companies) such as credit and insurance facilities to its contract farmers at lower interest/ premium.

Constraints/Challenges in Contract farming: As in any other form of contractual relationship, there are prospective disadvantages, risks and uncertainties involved in contract farming. If the conditions of the contract are not honoured by any of the contracting parties, then the affected party stands to lose. Typical contractual setbacks include farmer sales to a different buyer by way of side selling or extra-contractual marketing, a company's denial to purchase products at the pre-agreed prices, or the downgrading of produced quality by the company. Inequitable nature of the business association between farmers and their buyers is usual criticised in contract farming arrangements. Buying firms, who are inevitably more dominant than farmers, may use their bargaining influence for their short-term financial gains, even though in long run this would be counterproductive and disadvantageous to the buying firms as farmers would cease to supply them there production. Despite of this difficulties, the balance between merits and demerits for both engaging firms and farmers tends to be on the positive side: presently in agriculture contractual arrangements are more and more frequently being used worldwide.

- ✓ Contract farming arrangements are often criticized for being biased in favour of firms or large farmers, while exploiting the poor bargaining power of small farmers.

- ✓ Problems faced by growers like undue quality cut on produce by firms, delayed deliveries at the factory, delayed payments, low price and pest attack on the contract crop which raised the cost of production.
- ✓ Contracting agreements are often verbal or informal in nature, and even written contracts often do not provide the legal protection in India that may be observed in other countries. Lack of enforceability of contractual provisions can result in breach of contracts by either party.
- ✓ Single Buyer – Multiple Sellers (Monopsony)
- ✓ Adverse gender effects - Women have less access to contract farming than men.

Policy Support

Agricultural marketing is regulated by the States' Agricultural Produce Marketing Regulation (APMR) Acts. In order to regulate and develop practice of contract farming, Government has been actively advocating to the States/ Union Territories (UTs) to reform their agricultural marketing laws to provide a system of registration of contract farming sponsors, recording of their agreements and proper dispute settlement mechanism for orderly promotion of contract farming in the country. So far, 21 States (Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Madhya Pradesh, Mizoram, Nagaland, Odisha, Punjab (separate Act), Rajasthan, Sikkim, Telangana, Tripura and Uttarakhand) have amended their Agricultural Produce Marketing Regulation (APMR) Acts to provide for contract farming and of them, only 13 States (Andhra Pradesh, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Rajasthan and Telangana) have notified the rules to implement the provision.

Constraints and Way Forward

- ➢ A legal judicial system for imposition of contracts to be involved at the panchayat level and district administration level for arbitration and prompt redressal of disputes. The contract between the company and the farmers should be irrevocable and enforceable by both the parties. The contracting company should not manipulate with the quality standards to turn down purchases. Neither the farmers should sell off the seeds and other inputs and /or produce to any other company or individual or sell it in open market.
- ➢ Assistance in the promotion of extension education by companies. A productive system can be formed to leverage and support Government's extension infrastructure by companies.
- ➢ Instructional credit and crop insurance system need to strengthen to support small farmers to avail seed and other inputs.
- ➢ Contract farming is unlikely to touch the small and marginal farmers, including many women farmers who need more help in accessing better inputs, technology and credit. Only mid-sized farms of a certain acreage are roped in for contract farming. It will also not benefit millions of tenant farmers who work on daily wages. Their plight of being landless labour with paltry wages continues and the security of their tenancy depends on the implementation of legislative

reforms like Model Agricultural Land Leasing Act 2016 introduced by the central government which needs to be adopted by State governments to make them effective.

- The big corporations have money power which translates to bargaining power vis-à-vis the farmers. In the beginning, they may agree to pay farmers according to their labour and other input costs, but gradually they can start paying them less because the farmers have no other alternative. It often turns out to be a monopsony situation in which one buyer deals with many sellers — an arrangement which favours the buyer.
- Contract farming can also help in reducing the number of people dependent on agriculture. It is possible if small farmers pool their land en masse in a cooperative for contract farming. In any case, there is need for more effective regulation so that farmers' rights are protected and land is not transferred to corporations. If Farm Producers' Organization (FPOs) could be involved in dealing with big corporations, the farmers could operate from a position of strength and leverage
- In case when there is rejection of the crop of contract farmers on the basis of quality of the produce or because it does not match the specific requirements, the farmers face a difficult situation as they do not have other outlets to sell the produce. Often the State government has to rescue them. On the whole, it is an unequal relationship — the small farmer verses the giant corporation. Yet the security and smoothness of contract farming operations are attractive for farmers against the idea of individual farming based on much toil and sweat.
- Many organized players should be encouraged to enter this sector and should make a difference in the next few years so that the sector should see major investments. The Contract Farming expects substantial improvement in quality, productivity and reduced losses in Fresh produce supply chain, perhaps a mix of cooperative and corporate model should work best for this sector. The role of subsidies may have to be studied for effective growth prospects.

Conclusion: This case study of the PepsiCo's Frito Lay contract farming for potatoes is a good example of how international quality requirements are met by small farmers in India. A very strong extension network by PepsiCo co. helps to monitor and maintain quality at every level. Evidently the farmers working as contract grower's benefit on several fronts: there is extensive training and education of farmers for proper timing and method of sowing, harvesting and other field operations; farmers' overall management capabilities are enhanced by meetings and visits by agricultural experts from time to time. Gross margins for contract farmers are higher.

Furthermore, because the company announces prices ahead of the production season, they are sure of covering at least their production costs and can invest in agrochemicals and other inputs, which in turn leads to enhanced productivity. Other risks from insect pest infestation and weather changes are also minimized as the company's extension agents are constantly working with the farmers to give timely input on these issues. Finally, weather insurance is also available for the company contract farmers, which further minimizes risks. The obvious advantage for the company is getting an assured quantity and quality for chips making to enable utilization of the processing plant at optimal capacity. Direct involvement with farmers enables good communication that ensures availability of produce which meets the specific quality requirements for processing and indicators for the company's HACCP and ISO certification.

Suggested References

Tripathi, R.S., Singh, R. and Singh, S. 2005. Contract Farming in Potato Production: An Alternative for Managing Risk and Uncertainty, *Agricultural Economics Research Review,* Vol. 18 (Conference No.) 2005 pp 47-60.

Dutta, A., Dutta, Avijan and Sengupta, S. 2016. A Case Study of PepsiCo Contract Farming for Potatoes, *IOSR Journal of Business and Management (IOSR-JBM).* PP 75-85.

Chaturvedi, R. 2007. Contract farming and FritoLay's Model of Contract Farming for Potato, *Potato J*ournal. 34 (1-2):16-19

Kaur, P. 2014. Contract Farming of Potatoes: A Case Study of PEPSICO Plant, *International Journal of Scientific and Research Publications*, 4(6): 1-5.

Dhaliwal, H.S., kaur, M., Singh, J. 2004. *Evaluation of contract farming scheme in punjab state (for rabi crops),"*, Research Report, Department of Economics, PAU, Luhiana.

Glover D. J.1987. Increasing the benefits to smallholders from contract farming problems for farmers organisation and policy makers, *World Development, 15(4: 441-448.*

Singh, S. 2000. Contract farming for agricultural diversification in the Indian Punjab: A study of performance and problems, *Indian Journal of Agricultural Economics,* 55(3): 283-294.

Eton, C.S. and Andrew W.S. 2001. Contract farming-partnership for growth, *AGS Bulletin No. 145, Rome: Food and Agriculture Organisation.*

Asokan, S.R. and Singh, G.2003. Role and constraints of contract farming in agro-processing industry, *Indian Journal of Agricultural Economics,* 58(3):566-576.

Wagh, R.M.2017. Contract Farming Practice in India: *A Review, Int. Arch. App. Sci. Technology* 8 (4): 10-13.

Kumar, Y.V., Sharma, S., Chaudhari, B.D. 2019. Contract Farming-Prospects and Challenges in India, *Bulletin of Environment, Pharmacology and Life Sciences*, 8(3): 08-16.

Manjunatha A.V., Ramappa, K.B., Lavanya B.T. and Mamatha, N.C.2016. Present Status and Prospects of Contract Farming in India, *International Journal of Agriculture Sciences,* 8(7): 1072-1075.

Singh, B.P., Rana, R.K. and Kumar, M. 2011. Technology infusion through contact farming: success story of potato, *Indian Horticulture, May-June, 2011:49-51*

Chapter -23

POTATO PRICE LINKAGES AMONG THE NORTHERN HILL AND PLAIN MARKETS

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Introduction: Horticultural crops are gaining prominence due to their significant contribution in ensuring nutrition, health and wellness. Potato has been historically the most important vegetable and continues to receive the same status as on date. Indian potatoes are produced in both the plain and hill regions in different seasons. The crop is grown in the winter season in almost all the plain states while hilly states produce potato in rainy and summer seasons. Uttar Pradesh, West Bengal and Bihar are the major supplying states for plain potato. Uttarakhand has advantage in production and supply of hill potato. Despite a very small share in the country's production (around one per cent), potato is considered to be an important crop of Uttarakhand state, helping in diversification towards high value crops besides achieving the objectives of nutritional and livelihood security. Potato occupies more than 9 per cent area of total horticultural crops of the state and contributes around 24 per cent to total horticultural production. Hill potato is preferred by the consumers because of its taste and lower starch content as compared to potato grown in plains and is supplied to the entire northern India.

Potatoes are available throughout the year in the markets either from plain/hill regions or cold storages; first four months of the year are dominated by the supply of plain potato; whereas, hill potato is available in the markets for rest of the eight months. The hill potato is available for a longer duration in the markets. The spatial and temporal variations in potato supply are supposed to be linked to price variations. Such temporal and spatial variations in prices of agricultural commodities have become increasingly evident phenomena in the current regime. Variations in prices of agricultural commodities, especially of horticultural commodities are becoming much more frequent and severe. As the market information and intelligence activities are gaining importance, the markets are assumed to be integrated in a better manner as the possibilities of supply expand from one market to the other markets. Thus, it becomes important to study the variations in prices are linked and transmitted to other markets. Particularly, when the produce is attached to a geography specific tag which creates difference in product taste like hill potato and plain potato.

Different studies have used different frameworks to analyse the market linkages and market performance. Mukhtar and Javed (2007) analyzed the market performance by studying market integration. Market integration can be measured as a strength and speed of price transmission between markets across various regions of the country (Ghafoor et al., 2009). Several other studies have also empirically analysed the market integration of agricultural commodities in India by using the cointegration technique (Kar et al., 2004; Jha et al., 2005; Yogisha, 2005; Jayasuriya et al., 2007; Shenoy, 2008; Sekhar, 2012; Paul et al., 2015). However, despite the importance of potato crop in northern region, no empirical study has been reported to analyse the price movements and linkages among hill and plain potato markets in northern India. The present study is an attempt to systematically analyse the price movements in the major wholesale markets of potato in major hill and plain markets of north India. The findings will be helpful for the producers as well as other players in the potato value-chain along with policy makers to take appropriate decision and action pertaining to potato marketing.

The present study confines to the major hill and plain markets of north India. One of the major potato wholesale markets of Uttarakhand i.e., Haldwani was purposively selected as it receives maximum arrival of hill potato in the state and is the most important assembling and distributing market for hill potato in Uttarakhand. Dehradun is next most strategic market in the hill region as it captures maximum hill potato from Garhwal region of Uttarakhand state. Agra and Lucknow are other major producing and distributing markets in the plain region. Delhi is the major consuming market in northern India. Thus, these markets were selected purposively to study the price cointegration among other major hills and plains markets. Secondary data related to monthly wholesale prices were collected from AGMARKNET, for the period January 2005 to March 2015 for selected markets. The prices were taken in their natural logarithms to avoid the problems of heteroscedasticity.

1. Potato Price Linkages among Different Markets

Unit root test: Before determining the interdependence between different price series of potato, the stationarity in these series was tested by using KPSS unit root test (Kwiatkowski et. al., 1992). The empirical evidence suggests that all the price series (hill markets and plain markets) are non-stationary at level as the null hypothesis is rejected at 5% level of significance. After the first differencing, these series became stationary and were found to be integrated at order 1 or I (1) as the null hypothesis is not rejected at 5% level of significance.

Cointegration analysis using Enger-Granger two step procedures: Two-step Engle-Granger method (Engle et al., 1987) was used to check for cointegration between Haldwani markets and other hill and plain markets. In this method, the cointegration equations were estimated using OLS method and the residuals from the estimation were examined. The variables would be cointegrated if the residuals generated from the equations are found to be stationary. The residuals obtained from the above equations were checked for stationarity using Augmented Dickey–Fuller (ADF) unit root test and were found to be stationary at level. Thus, it can be concluded that potato prices are co-integrated in the hill and plain region of northern India.

Granger-Causality Test: After examining cointegration among different price series, Granger-causality test (Granger, 1969; Granger, 1980) was also applied to examine the direction of price causation. The Granger-causality shows the direction of price formation between the two markets and related spatial arbitrage i.e., physical movement of the commodity to adjust the price difference (Ghafoor et. al., 2009). The result of Granger-causality is presented in Table 1 which shows the F-statistics for the causality test between selected potato markets. Interestingly, in all the tests, the optimum lags found out to be 2.

Results show that there is bidirectional causality between Haldwani and Dehradun markets. In case of markets of plain region of northern India, there is bidirectional causality between the market pairs: Haldwani-Delhi and Haldwani-Lucknow. However, Haldwani market shares unidirectional causal relationship with Agra market wherein causality runs from Agra market towards Haldwani market. This is justified as Haldwani market receives quite low extent of potato arrivals as compared to Agra market.

Table 1. Granger-Causality Test between hill and plain markets

Null Hypothesis:	lag	F-Statistic	Probability
Haldwani does not granger cause Dehradun	2	5.950	0.004
Dehradun does not granger cause Haldwani	2	6.152	0.003
Haldwani does not granger cause Delhi	2	4.499	0.013
Delhi does not granger cause Haldwani	2	9.682	0.000
Haldwani does not granger cause Agra	2	1.748	0.179
Agra does not granger cause Haldwani	2	6.451	0.002
Lucknow does not granger cause Haldwani	2	8.631	0.000
Haldwani does not granger cause Lucknow	2	5.950	0.004

Error Correction between Haldwani and Other Markets

The coefficient of error correction term denotes the speed of adjustment. Higher the speed of adjustment, higher is the chance of correction of any disequilibrium in potato prices due to change. The equations explain the relationship between the selected pairs of potato markets and the coefficients of ECT terms indicate speed of adjustment of market prices towards equilibrium (Box 1).

Box 1. Estimated equations from ECM between the potato prices in selected markets

$$\Delta \ln Haldwani_t = -0.195ECT_{t-1} + 0.261\Delta \ln Dehradun_{t-1} - 0.081\Delta \ln Haldwani_{t-1}$$

$$\Delta \ln Dehradun_t = -0.323ECT_{t-1} + 0.138\Delta \ln Haldwani_{t-1} + 0.046\Delta \ln Dehradun_{t-1}$$

$$\Delta \ln Haldwani_t = -0.179ECT_{t-1} + 0.513\Delta \ln Delhi_{t-1} - 0.166\Delta \ln Haldwani_{t-1}$$

$$\Delta \ln Delhi_t = -0.400ECT_{t-1} - 0.124\Delta \ln Haldwani_{t-1} + 0.633\Delta \ln Delhi_{t-1}$$

$$\Delta \ln Haldwani_t = -0.251ECT_{t-1} + 0.330\Delta \ln Agra_{t-1} - 0.066\Delta \ln Haldwani_{t-1}$$

$$\Delta \ln Agra_t = -0.241ECT_{t-1} - 0.004\Delta \ln Haldwani_{t-1} + 0.451\Delta \ln Agra_{t-1}$$

$$\Delta \ln Haldwani_t = -0.187ECT_{t-1} + 0.387\Delta \ln Lucknow_{t-1} - 0.133\Delta \ln Haldwani_{t-1}$$

$$\Delta \ln Lucknow_t = -0.423ECT_{t-1} - 0.024\Delta \ln Haldwani_{t-1} + 0.429\Delta \ln Lucknow_{t-1}$$

The speed of adjustment in the markets of northern India ranges from 17 per cent to 42 per cent. The highest adjustment speed (42.3%) was noticed when Lucknow prices were assumed to be determined by the prices in Haldwani market, while the lowest adjustment share (17.9%) was observed when the prices in Haldwani market were assumed to be dependent on prices in Delhi market. The error correction terms for potato in all the markets exhibited the desired negative sign which clearly exhibited the price convergence between Haldwani and other markets in the short run with markets mainly Delhi, Lucknow from plain region and Dehradun from hill region of northern India showing greater speed of adjustment as compared to the Agra market.

2. Variance Decomposition in Potato Prices

Table 2 presents the Cholesky variance decomposition of prices of potato for Uttarakhand and North-Indian markets. All the selected markets were standardized with Delhi market prices, because it is considered to be a large consumer market in the country. For decomposing the prices in various markets, all the markets were arranged in a sequence based on their average volume of arrivals of potato for the period from 2010-11 to 2013-14. The Cholesky variance decomposition analysis indicates the amount of information of each variable that contributes to the targeted variables in the auto-regression. Table depicts that in terms of prices, Agra market has mostly been affected by its own shocks and very less affected by Haldwani and Dehradun markets. The statistics reveal that during the long run, the shock to Agra market can cause more than 81 per cent fluctuation in the variance of its own market; it is also called "Own-shock". Although, after its own-shock, Agra market is largely affected by Haldwani market (i.e., 8.51 per cent) followed by Dehradun market (7.88 per cent) and it is important to highlight that the contribution of Haldwani as well as Dehradun market has been increasing remarkably. However, Haldwani market is largely affecting by its own-shock i.e., 80.34 per cent, which has declined from 94.91 per cent, but the contribution of Lucknow market showed a gradually increasing trend i.e., from 2.74 per cent to 14.32 per cent. It is clearly evident that the major contribution of Lucknow market was observed by Agra market which is more than its own-contribution. Similarly, impulse on Dehradun market can cause about more than 88 per cent fluctuation by its own-shock followed by Haldwani market.

Table 2.Variance Decomposition for change in potato prices for selected markets

Variance Decomposition	Markets	Periods 1	2	3	4	5	6	7	8	9	10	11	12
Agra	***S.E.***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***	***0.3***
	Haldwani	0.0	2.3	6.5	7.5	8.6	8.8	8.7	8.6	8.6	8.6	8.5	8.5
	Dehradun	0.0	0.2	1.6	2.6	3.4	4.5	5.8	6.5	7.0	7.4	7.7	7.9
	Agra	100.0	97.5	91.7	89.2	86.4	84.6	83.4	82.7	82.1	81.7	81.4	81.2
	Lucknow	0.0	0.0	0.2	0.6	1.6	2.1	2.1	2.1	2.2	2.3	2.4	2.4
Lucknow	***S.E.***	***0.3***	***0.3***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***
	Haldwani	0.0	0.7	2.4	3.1	3.1	3.2	3.7	4.0	4.2	4.3	4.3	4.3
	Dehradun	0.0	0.1	0.1	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0
	Agra	50.4	49.3	49.5	48.4	48.4	48.1	47.8	47.6	47.6	47.5	47.5	47.5
	Lucknow	49.6	50.0	48.0	47.8	47.8	47.8	47.6	47.3	47.2	47.2	47.2	47.2
Dehradun	***S.E.***	***0.1***	***0.1***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***
	Haldwani	2.1	2.0	4.2	4.3	4.4	4.9	5.2	5.3	5.3	5.4	5.4	5.4
	Dehradun	96.5	92.9	90.5	90.3	90.1	89.1	88.7	88.6	88.6	88.6	88.6	88.6
	Agra	0.9	3.9	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.9	3.9	3.9
	Lucknow	0.6	1.2	1.1	1.3	1.5	1.9	2.1	2.1	2.1	2.1	2.1	2.1
Haldwani	***S.E.***	***0.1***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***
	Haldwani	94.9	92.9	90.4	87.4	84.3	82.2	81.3	80.8	80.6	80.5	80.4	80.3
	Dehradun	0.0	0.0	0.0	0.1	0.3	0.5	0.5	0.5	0.6	0.6	0.6	0.7
	Agra	2.3	3.2	3.6	4.4	4.3	4.4	4.5	4.5	4.5	4.6	4.6	4.6
	Lucknow	2.7	3.9	6.0	8.1	11.1	12.9	13.7	14.2	14.3	14.3	14.3	14.3

Source: estimated by authors; Cholesky Ordering: Agra, Lucknow, Haldwani and Dehradun

3. Conclusions

The present study examined the movement of prices in the major wholesale markets of potato along with the arrival trends, market behaviour, cointegration, causality and price transmission in major hill and plain markets of northern India.Strong and positive association has been noticed among the potato prices in selected markets, which indicates that prices tend to move together across markets. Further, Haldwani market showed a positive and strong correlation with other markets. It was observed that potato prices are co-integrated in the hill and plain region of northern India. A bidirectional relationship is observed among Haldwani and all the markets of northern India except Agra and there exists the phenomenon of price convergence between Haldwani and all the markets in the short run with markets mainly Delhi, Lucknow from plain region and Dehradun from hill region of northern India showing greater speed of adjustment as compared to the Agra market. Fluctuations in Lucknow market were highly affected only due to price movements in Agra market in both short and long term but on other side it is observed that prices in Agra, Dehradun and Haldwani markets were fluctuating majorly by their own shock.

Prices of potato in the major markets of northern India exhibit fluctuations and these variations in prices are interlinked affecting all the selected markets. To protect the producers from these variations in prices of potato, one needs to keep a watch on these price signals that transmit from one market to the other markets. As the selected markets of northern India are spatially integrated, the price triggers need to be identified to control the extreme price situations. As potato crop and its stakeholders have suffered from very high price volatility in the recent past, strong market intelligence network in the region can help disseminate early potato price signals to curtail such extreme shocks with an advance and effective supply, trade and policy management.

Suggested References

Engle, R.F. and Granger, C.W.J. (1987). Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55 251-276.

Ghafoor, A., Mustafa, K., Mushtaq, K. and Abedulla (2009) Cointegration and causality: An application to major mango markets in Pakistan. *Lahore Journal of Economics*, 14(1): 85-113.

Granger, C.W.J. (1969). Investigating causal relation by econometric and cross-sectional method, *Econometrica* 37: 424–438.

Granger, C.W.J. (1980). Testing for causality: A personal viewpoint. *Journal of Economic Dynamics and Control* 2, 329-352.

Jayasuriya, S., Kim, J. H. and Kumar, P. (2007) International and internal market integration in Indian agriculture: A study of the Indian rice market. In: *Proceedings of the European Association for Architectural Education Conference*, held at University of Montpellier, France, 25-27 October.

Jha, R., Murthy, K.V.B. and Sharma, A. (2005) Market Integration in Wholesale Rice Markets in India. Working Paper 3.Australian National University, Canberra.

Kar, A., Atteri, R. B. and Kumar, P. (2004) Marketing infrastructure in Himachal Pradesh and integration of Indian apple markets. *Indian Journal of Agricultural Marketing*, 18(3): 243-261.

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P. and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*. 54 (1–3): 159–178.

Mukhtar, T. and Javed, M.T. (2007) Market integration in wholesale maize markets in Pakistan. *Regional and Sectoral Economic Studies*, 8(2): 85-98.

Paul, R.K., Saxena, R., Chaurasia, S., Zeeshan and Rana, S. (2015) Examining export volatility, structural breaks in price volatility and linkages between domestic & export prices of onion in India. *Agricultural Economics Research Review*, 28(2): 101-116.

Saxena, R., Singh, N.P., Paul, R.K., Pavithra, S., Joshi, D., Kumar, R. and Anwer, E., (2016). How evident are the potato price linkages among the northern hill and plain markets? Evidences and implications. *Indian Journal of Agricultural Marketing*, *30*(3s), pp.157-167.

Sekhar, C.S.C. (2012) Agricultural market integration in India: An analysis of select commodities. *Food Policy*, 37(3): 309-322.

Shenoy, A. (2008) The Integration of the Indian Wheat Sector into the Global Market. Working Paper 353. Stanford Centre for International Development, Stanford University, Stanford.

Yogisha, G. M. (2005) Market Integration for Major Agricultural Commodities in Kolar District, M.B.A. Thesis, submitted to University of Agricultural Sciences, Dharwad.

Chapter -24

ADVANCES IN SAFE HARVESTING METHODS AND POST HARVEST HANDLING OF POTATOES TO REDUCE LOSSES

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About 90% of potatoes grown in India are harvested in February-March. Temperatures begin to rise at harvesting time and therefore, potatoes have to be stored during the hot summer months. The requirement for ware/ processing potatoes for 6-7 months during the year is met with stored potatoes. Besides, the seed potatoes are essentially stored in cold stores. Pre-storage factors, *viz.* tuber maturity, handling during harvest, skin curing, tuber health, variety etc. have significant implications on the ultimate quality of stored potatoes in all the methods of storage and subsequent utilization. For reducing losses during storage, followings are some of the basic operations/ factors which should be kept in mind.

Pre harvest and harvesting

Irrigation should be stopped two weeks before de-haulming and harvesting/ digging is preferred in dry weather to ensure that soil does not interrupt harvesting operation and tubers should be clean. Before starting harvesting operation haulms are removed manually sickles or with chemical methods. Potato digging is a cumbersome process and involves about 600-700 man hours/ ha for manual digging of 30-40 tons of potato from huge soil mass of around 100 tons. In manual harvesting spade or *khurpa* is used which causes up to 10% tuber cut or bruise which is a huge loss to the farmers. In manual harvesting some potatoes are always left behind in the field. Animal drawn plow is another tool for potato digging. This method is faster as compared to manual digging but in case of large fields with this method harvesting is delayed and soil may turn over-dry. Tractor operated diggers are fast, economical and cause least damage to the tubers (Fig. 1). Digger elevator is an efficient machine which exposes 90-95% tubers in optimum field conditions. This machine has to be maintained properly as there are many parts which move in soil and cause more wear and tear. Soil moisture and tractor speed are to be tuned so as to have least bruising/cut on the tubers. Multipurpose passive blade potato digger (Fig.2) is less expensive equipment. It exposes about 80-85% potatoes and is easy to maintain. It can be used in early crop (60 days without cutting haulms) and also can successfully work in semi-dry field conditions.

	
Fig. 1. Tractor operated digger elevator	**Fig. 2. Low cost blade type digger**

A two row potato combine harvesters has been developed at CRPI to perform potato digging and picking operation simultaneously (Fig. 3). Some other firms have also developed single and two row potato combine harvesters in recent years. Functions of the combine harvester machine are to dig the potato tubers from 15-20 cm deep soil, separate the tubers from soil clods, convey the tubers to the sorting platform and collect them in to a hopper. Further it can be unloaded in to a transporting trolley or on a heap. Four workers have to be deployed with these machines to sort the rotten/ bruised tubers or soil clods passing over the sorting table. These machines are usually powered by a 50 to 60 hp tractor. Over heating of the tubers during digging/ harvesting in the field should invariably be avoided, otherwise it enhance black heart symptoms during storage.

	
Fig. 3. Two row Potato combine harvester	**Fig. 4. Potato sorting and grading machine**

Grading and sorting: Graded, sorted and properly packed potatoes always fetch good price in the market. Manual grading is not uniform and it requires a lot of time and energy which bring down the overall returns. Various manual as well as power operated graders have been developed for size grading of the potato tubers. Rubber belts having different size of round or square shaped perforation are generally used in the grading system (Fig. 4). Lot of labour has to be still required in these high capacity graders for feeding sorting and packaging of the potatoes.

Seed treatment: In case the harvested produce is seed then the tubers needs to be treated before storage to protect against diseases. For controlling tuber and soil born diseases viz. common scab, black scurf and powdery scab, 3% boric acid treatment can be given with the help of an electric powered seed treatment machine. In this machine boric acid is sprayed on the potatoes moving and rolling over a conveyor. All the surfaces are coated with the chemical and the used solution is re-circulated. This machine can treat about 30-35 tons of potatoes per day.

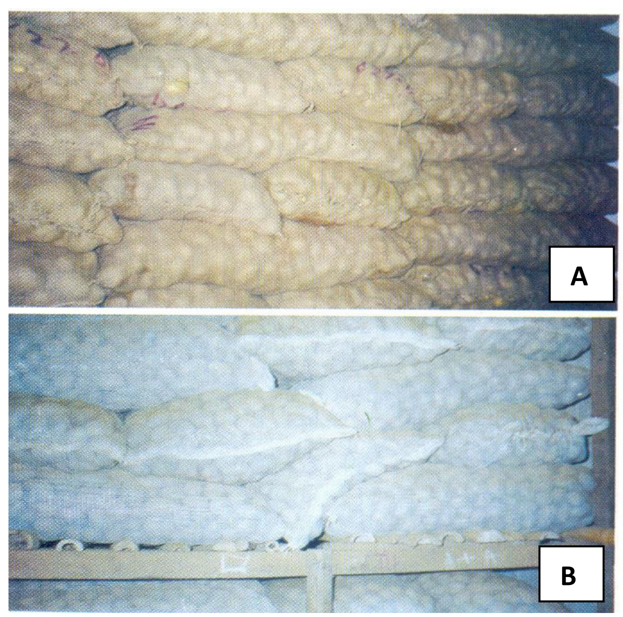

Fig.5. Proper stacking (A) ensure better air circulation than the bas stored in a haphazard manner (B).

Storage factors with special reference to seed potatoes

It is important to remember that even the best storage facilities and practices can simply ensure that the original quality of the seed potatoes is retained – storage can do nothing to improve quality. Therefore, it is desired that tubers of only best quality be stored for seed purpose. Unsuitable conditions during the storage of seed potatoes can affect quality. Does the storage facility meet the requirements? These are some of the basic questions which need to be answered and generate interest for achieving optimum seed quality.

A. *Losses due to high temperature in cold store*
   - The centre-most product in a stack is more frequently subjected to rotting due to high temperature
   - The process of cooling to achieve the desired storage temperature of potatoes sometimes takes long time due to large stack dimension and inadequate circulation of air throughout the cold store
   - The potato bags in the cold storage are sometimes loaded in haphazard manner, leaving very less space for air circulation around the stacks which would increase the cool-down time, thus increasing losses during storage
   - Large stack dimension enhance temperature due to inadequate circulation of air
   - Bags loaded in haphazard manner : poor air circulation and increase the cool-down time (Fig.5)

B. *Losses due to very low temperature in cold store*
   - Tissue injury because of internal ice formation, also called as cold injury (< 2^{o}C)
   - Chilled potatoes become weakened - low metabolism
   - Even slightly frozen tubers exhibit discoloration
   - More prolonged exposure – necrotic (dead) tissues

C. *Some physiological disorder in potato tubers*

S. No	Disorder	Possible cause
1	Black spot	Physical impact causes development of black spot within 24- 72hrs
2	Black heart	-Low O_2 (CO_2 higher than 1%) and over heating in the field itself
3	Greening	(Acceptable in seed), 1-2 weeks exposure to light
4	Dis-colouration of tissues	Exposed to freezing at 1^{O}C or below for some time
5	Enlarged lenticels	Excess irrigation during crop growth

Factors during transportation of seed potatoes

Seed potatoes are often transported over long distances. Due to different planting times, conditions during transportation can vary greatly. Since unfavorable conditions during transportation can affect the quality of seed potatoes, the transportation of seed potatoes is an important step and deserves the same attention as all the other steps in the handling of seed potatoes. The same applies to on-farm transportation. Is the transport currently in use suitable for the transportation of your seed potatoes? There are three basic requirements in the transportation of seed potatoes: The seed potatoes must be kept dry, the temperature must remain moderate, and there must be sufficient ventilation. Other relevant points in this context are as follows-

- Seed potatoes kept in cold storage must be dry when loaded onto the truck.
- Workers should not stand or walk on the seed potatoes, since this causes damage and bruising.
- Where possible, extremely high and extremely low temperatures must be avoided during transportation.
- During the summer, seed potatoes must be protected from rain, hail and direct sunlight.
- If possible, seed potatoes should be transported overnight in order to avoid the worst heat. The truck should be loaded in such a way as to allow for sufficient ventilation.
- The transportation of seed potatoes in open trucks is suitable for short trips, for example when driving to the fields on the farm. Where seed potatoes are transported over long distances on open trucks covered with a tarpaulin, the tarpaulin must not be in direct contact with the seed potatoes, and there must be sufficient space for ventilation.

Purpose specific storage

Potato storage methods being practiced in India can be broadly divided in to two categories *viz.* refrigerated storage and non refrigerated storage.

Refrigerated Storage

Storage at 2-4 ^oC: Cold storage facility was developed primarily for the storage of seed potatoes, but they are also being used for the storage of table potatoes. About 93% of the cold storage capacity in the country is being used exclusively for the storage of potatoes. Seed potatoes are stored in cold stores which maintain temperature 2-4^{o}C and 90-95% RH. At this temperature, sprouting does not take place, weight loss is minimum and seed maintains it proper vigour which is essential for taking subsequent crop. But 2-4^{o}C is not the ideal storage temperature for table potatoes as at this temperature; they become sweet due to sugar accumulation (Table.1) and are not preferred for consumption. Due to increased awareness, consumer preferences have changed and the requirements of potatoes with less sugar development are met through storage at elevated temperatures.

Table 1. Sugar balance (mg/hr/kg) in potato tuber during storage

Biochemical activity	Storage temperature (^{o}C)					
	0	3	6	10	15	20
Starch→ Sugars	32.0	32.6	33.6	35.8	39.3	44.0
Respiration	2.3	2.8	3.5	4.5	6.5	9.5
Sugars → Starch	1.7	20.8	25.8	31.3	32.5	34.5
Sugar Balance	28.0	9.0	4.3	0	0.3	0

Storage at 10-12^{o}C: Potatoes meant for table use and processing are stored at 10-12^{o}C, in most of the countries. When potatoes are stored at this temperature, accumulation of reducing sugars is minimum and therefore they do not become sweet. Besides, the chips produced from these potatoes are light in colour. 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). CIPC is available in liquid formulation and is applied in the form of a fog using a fogging machine. It is applied @ 35 ml (50% a.i.) per tonne of potatoes. CIPC treated potatoes are safe for consumption 30 days after treatment as the CIPC residue is within the acceptable limit of 25 mg CIPC/kg of potatoes. This storage technology has been tried by several cold stores in the country during the last decade with encouraging results. This technology needs further improvement for successful storage of potatoes meant either for ware purpose or for processing use for 7-8 months.

Potato heap

Non-refrigerated Storage : *On-farm storage:* Though the refrigerated storage is essential for long-term storage but for short-term storage of 3-4 months non-refrigerated methods can be used profitably. Traditionally, farmers in India have been storing potatoes in cool dry rooms, heaps and pits. The pit method is very popular in the Malwa region of Madhya Pradesh. Heaps are made by heaping potatoes in the shade of a tree to a maximum height of 1m and covering them with 1 foot thick wheat /rice straw or sugarcane trash. Pits are also dug under the tree shade and these are of two types, viz. Pukka and Katcha. Generally 5-30 tones of potatoes are stored in heaps and 10-40 tones of potatoes are stored in pits. Traditional storage methods are in use in states of Assam, Bihar, UP, MP, Gujrat Maharashtra and Karnatka and these have several advantages. They are cheap and no investment is needed on storage structure. Furthermore, the materials required are locally available. The temperature in heaps and pits vary from 23-32^{o}C and the RH: 60-96%. The higher temperatures prevailing in heaps and pits prevent accumulation of reducing sugars and therefore these potatoes are preferred for table use as well as for processing. The reducing sugar content normally does not exceed 150mg/100 g tuber fresh weight and the chips are generally acceptable (score <3). The only disadvantage of traditional methods is that storage losses are high due to rotting. Improving the efficiency of these storage methods can reduce storage losses. Experiments carried out by CPRI at three locations viz. Jalandhar, Modipuram and Patna have shown that it is possible to store potatoes on-farm for 3-4 months with acceptable storage losses. Potatoes of Kufri Jyoti can be stored in heaps for 105 days with total loss of 10.9% at Jalandhar, for 90 days with total loss of 7.1% at Modipuram and for 80 days with total loss of 27% at Patna. On-farm storage in heaps is recommended for short term for ware use and also for processing purposes.

	
Katcha Pit	*Pukka* Pit

Evaporative Cooled Store (ECS): The insulated potato store (capacity: 20 tonnes) is equipped with passive evaporative cooling which does not require any other source of energy for cooling. These ECS were evaluated at Jalandhar and Modipuram and it was found that the daily maximum temperatures in the ECPS remains 6-13 °C lower than the ambient during March-June. RH remains high at 70-95 %. Due to moderate temperature and high RH the weight loss in potato tubers is significantly reduced. Ware potatoes can be stored in good condition up to the beginning of June when the price in the market is much higher than the prices at the time of harvest. During storage the reducing sugar decrease and potatoes are not as sweet as the cold stored potatoes. Potatoes stored in ECS fetch premium price as they are suitable for ware consumption as well as for processing. The storage life as well as tuber quality can be further improved by using sprout inhibitor like CIPC. This technology is suitable for 80-90 days in regions where the temperatures are high and humidity is low during the storage period.

 Fig. 21. Potato store run on passive evaporative cooling, at Central Potato Research Station, Modipuram	 Country Store at Modipuram
ECS: ICAR-CPRI Model	*ECS: CIP Model*

Summary: Harvesting methods have been standardized and various machines are available for harvest and post harvest operations for potato in India. Now it is the duty of extension workers to hand hold farmers to identify right machines, of right size for different operations and use it optimally to have safe produce. Adopting safe harvest methods will definitely help in completing field operations timely with lesser cost which will enable them timely sowing of subsequent crops and also to store the surplus and sale in the market at right time. Similarly, by adopting the right type of storage method, as per requirement of the produce and its intended use, the losses are likely to be reduced drastically. All this, will surely help in reducing input costs, better seed quality, acceptable quality after storage and increasing farmers income and better product quality for the end user.

Chapter -25

DNA FINGER-PRINTING AND MARKER ASSISTED SELECTION IN POTATO

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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. It was introduced to India by early 17th century probably through British missionaries or Portuguese traders.

Potato varietal development and release system in India:

Conventional potato breeding broadly involves selection of desirable parents having the trait of interest, hybridization to get a segregating population in F_1 generation (potato is highly heterozygous), elimination of undesirable genotypes in F_1 and in the subsequent clonal generations, preliminary and replicated yield trials against standard varieties over locations and years to select a superior genotype. A genotype performing well under advanced generation trials is introduced to multi-location trials under AICRP (P). Presently, ICAR-CPRI has 25 centres located all across the country. AICRP experiments involve varietal trials, agro techniques and pest and disease management. These trials are conducted for at least 2-3 years and suitable hybrid is recommended for release in AICRP (P) group meetings. Later the recommended hybrid is released and notified by the central sub-committee on crop standards, notification and release of varieties (CVRC) or state sub-committee on crop standards, notification and release of varieties (SVRC) based on its merit so that certified breeder seed of these varieties could be produced.

Molecular markers for potato variety identification:

Distinctness, uniformity and stability test involves significant observations at each crop stage, time-consuming, based on mainly polygenically controlled traits and is influenced by environmental and location factors. This led to search for other robust techniques for variety identification/distinction. DUS descriptors, 51 in number were identified & developed in potato in India through PPV&FRA, Delhi which are now used as morphological markers for varietal distinction. Biochemical markers have the disadvantages of protein interactions during different development stages and causes inaccurate results. Molecular markers have the advantages of reproducibility, less influenced by the environment, non stage or tissue specific, lesser cost etc.

Initially RAPD markers were used to identify polymorphism which is created due to insertions, deletions, translocations and inversions. In potato RAPD markers OPA-03 and OPC-04 led to identification and formation of distinct band pattern and identification of commercial potato varieties. However, with the advancement in the sequencing technologies, sequence based molecular markers like SSR Simple Sequence Repeats (SSR)/ Microsatellites become popular in diversity and fingerprinting analysis. SSR are short tandem repeats flanked by conserved DNA sequences (Fig. 1). SSRs are polymorphic DNA loci that contain a repeated nucleotide sequence.

Each repeat unit can be 2 to 7 nucleotides in length, and alleles differ by the number of repeats. The number of nucleotides per repeat unit is the same for a majority of repeats within a microsatellite locus.

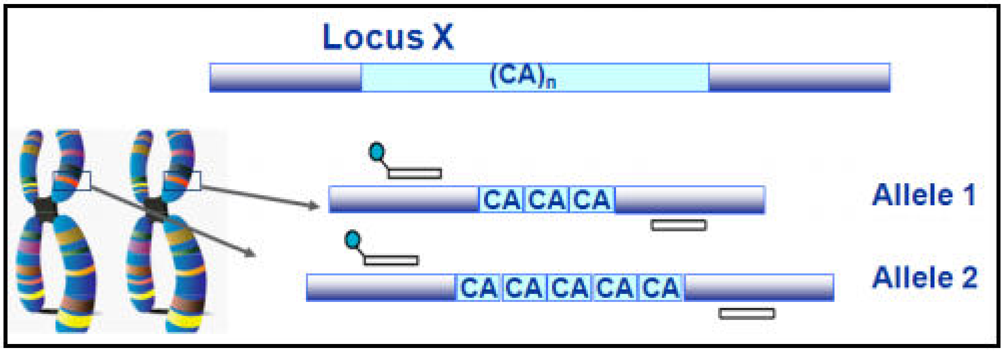

Fig. 1: Allelic differences in the same gene locus

They are ideal fingerprinting markers that detect multiple loci, co-dominant, cheaper, hypervariable, generate better quality amplicons, suitable of multiplexing, low template DNA requirement and higher reproducibility. Ghislain *et al*., 2009 developed potato genetic identity (PGI) kit based on 24 chromosomes specific SSR markers (Table 1) i.e. two markers for each chromosome separated by 10 centiMorgan distance except for markers on chromosome VII at 3 centiMorgan.

Table 1. SSR markers of Potato genetic identity kit and their chromosomal location

Chromosome Number	**Marker**	**Chromosome Number**	**Marker**
Chromosome I	STM5127, STG0016	Chromosome VII	STM0031, STI0033
Chromosome II	STM1064, STM5114	Chromosome VIII	STM1104, STI0003
Chromosome III	STM1053, STG0010	Chromosome IX	STM1052, STI0014
Chromosome IV	STI0001, STI0012	Chromosome X	STG0025, STM1106
Chromosome V	STI0032, STPoAc58	Chromosome XI	STG0001, STM0037
Chromosome VI	STM0019, STI0004	Chromosome XII	STM5121, STI0030

Among all available global SSR markers, ICAR-CPRI, Shimla has identified 2 SSR markers viz., (STIKA and STU6SNRN) in potato to give distinct pattern for varietal identification.

SSR analysis

Microsatellite analysis is the separation of fluorescently labeled fragments using forward and reverse primers and determination of the relative size of the fragments. Typical workflow for fragment (Microsatellite) analysis is given below:

Table 2. Workflow for SSR fragment analysis using capillary sequencer

Phase		Technology	Material and Methods
1	Isolation and Purification of DNA	GenElute™ Plant Genomic DNA Miniprep Kit	Leaf samples and DNA isolation
2	Quantification of DNA	Spectrophotometric measurements	NanoDrop 2000/2000c Spectrophotometer
3	PCR amplification	Dye-labeling and amplification of fragments using a thermal cycler	Thermo-cycler
4	Capillary electrophoresis	Separation of fragments based on size using a genetic analyzer	3500/3500xL Genetic Analyzer (3500 Series instrument)
5	Data analysis	Sizing and optional genotyping	GeneMapper® Software

Marker assisted breeding

Developments in molecular biology during the last thirty years have allowed better understanding of genetic regions associated with resistance and susceptibility to diseases and pests. Most of the genes controlling monogenic (major *R*-genes) and polygenic resistance (QTL’s) to late blight have been mapped and located on the 12 potato chromosomes. Breeding for resistance in potato through pyramiding (incorporation of several different genes) started long time back but exact quantification of the achieved resistance effect was not reported. Pentland Dell and Escorts were some early potato cultivars developed through such breeding strategies (Bradshaw, 2009). Marker assisted selection (MAS) have been successfully employed in disease resistance in potato. The research on resistance to late blight in recent years has been focused on stacking of several *R*-genes in one cultivar/genotype which might increase both durability and level of resistance. Stacking of two *R* genes has been reported to improve durability of late blight resistance, besides delaying the onset of late blight disease. The additive effect of pyramiding *P. infestans* resistance genes *Rpi-mcd1* and *Rpi-ber* was studied by introgression in diploid *S. tuberosum* population. Sarpo Mira with at least five reported *R* genes (*3a, 3b, 4, Smira1, 2*) is one of the few potato cultivars, developed through conventional breeding, which expresses significant levels of durable late blight resistance (Kim *et al.,* 2012).

At CPRI, parental lines selected through genotyping of indigenous and exotic potato germplasm collection of CPRI repository by molecular markers tightly linked to R1, R2 and R3 genes are being utilized for pyramiding these genes in single potato host background for providing enhanced durable late blight resistance (Fig. 2). Major QTLs for late blight resistance have been identified in diploid wild species *Solanum chacoense* using Amplified Fragment Length Polymorphism(AFLP) and Simple sequence repeats(SSR) markers (Chakrabarti et al., 2015). Similarly for all major viruses and potato cyst nematode, MAS is being used. Presently there are four different *R* genes namely Ry_{adg}, Ry_{sto}, Ry_{hou} and Ry_{chc} known to confer extreme resistance (ER) to PVY. Additionally, four *N* genes, viz., Ny_{chc}, Ny_{dms}, Nc_{tbr} and Ny_{adg} also confer high resistance (HR) to PVY. The gene Ny_{adg} conferring HR to PVY is epistatic to Ry_{adg}. As a result, the genotypes carrying both Ry_{adg} and Ny_{adg} exhibited ER to PVY. In India, a triplex (YYYy) potato parental line with Ry_{adg} gene having extreme resistance to PVY has been developed using MAS (Kaushik *et al.,* 2013). The R genes Rx_{adg} (*Rx1*), Rx_{tbr}, Rx_{acl} (*Rx2*), $Rx_{HB}^{scr}/Rx_{CP}^{scr}$ confers extreme resistance to PVX. A single dominant gene *Ns* was reported which confers HR for PVS in *S. tuberosum* ssp *andigenum*. Genotypes with *Ns* gene remain symptomless and no virus (PVS) titters develop in enzyme-linked immunosorbent assay (ELISA). The markers SCG17321, UBC811660 and SC811260 have proved to be highly accurate to select PVS resistant potato genotypes through MAS (Witek *et al.,* 2006). Genes for resistance to PVM were reported in wild and cultivated *Solanum* species. The PVM resistance gene *Rm* originates from *S. megistacrolobum* and is responsible for a hypersensitive response of potato plants to PVM infection. The dominant gene *Gm* was derived from *S. gourlayi* and confers a different type of PVM resistance than the *Rm* gene. The *R* genes which confer ER to PVA were Ry_{sto}, Ra_{sto}, Ra_{adg} and Ry_{ho} whereas *N* genes were Na_{adg}, Na_{sto}, Ny_{chc}, Na_{dms}, Ny_{dms}, Na_{tbr} and $NaKE_{tbr}$ confers HR to PVA (Barker, 1996; Cockerham, 1970; Hamalainen *et al.,* 1998). Molecular markers associated with Ry_{adg} are also used to select genotype having PVA resistance. In 2009, a single gene from *S. etuberosum* (Rlr_{etb}) was mapped to chromosome IV which confers resistance to PLRV, besides some German potato cultivars were derived by introgression of genes from *S. demissum*. Recently, a sequence characterized amplified region (SCAR) marker designated as 'RGASC850' was derived from resistance gene analog (RGA), which is highly predictive of Rl_{adg} based resistance. In addition, a cleaved amplified polymorphic sequence (CAPS) marker based on 'RGASC850' was developed for distinguishing the genotypes carrying Rl_{adg}gene.

For PCN, researchers have proved the complementary effect of the two resistance sources, *S. tuberosum* ssp. *andigena* and *S. vernei* and therefore the joint effect of multiple *R*-genes will result in broad spectrum and high level of resistance. Several mapped loci that harbours resistance to *G. pallida* and *G. rostochiensis* have been mapped from various wild and cultivated potato species. Molecular markers are available for selection genotypes resistant to PCN. So far, 19 genes including major and minor QTLs have been placed on potato chromosome map, conferring resistance against PCN (Dalamu *et al.*, 2012).

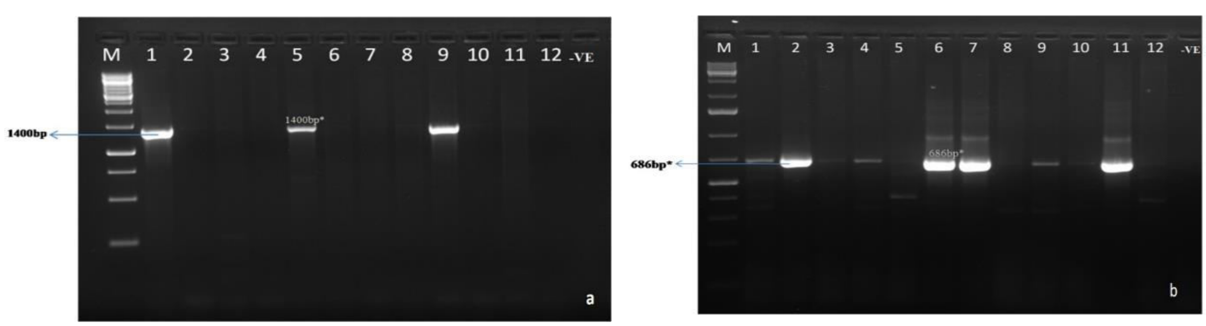

Fig. 2. Screening of parental lines and hybrids for late blight resistance genes (a-R1 and b-R2)

Potato has a tetraploid genome and is commonly propagated vegetatively. It implies that there are large difficulties in obtaining homozygous mutants in which all of the target genes have been altered. Marker-assisted selection is perhaps the most powerful approach that uses DNA markers efficiently for selection of interspecific hybridization by reducing the linkage drag in terms of time and space. The use of DNA markers can be ascribed not only to the use of markers tightly linked to target genes (positive assisted selection), but also in the use of markers specific for the wild donor parent to perform selection against the wild genome (negative assisted selection; Barone, 2004).

A very exciting development in the context of efficient selection has been the generation of a molecular-linkage map based on functional gene markers involved in carbohydrate metabolism and transport (Chen et al. 2001). Using diploid mapping populations for which molecular maps were already available, the authors performed CAPS, SCAR, and RFLP marker assays for 69 functional genes previously studied and identified (among the others *AGPase*, *SssI*, *GbssII*, *Dbe*, *UGPase*, *Ppc*, and *Cis*). This work allowed the identification of 85 genetic loci covering a considerable amount of the potato genome. The availability of this molecular-function map allowed a candidate-gene approach to be used for studying starch and other sugar-related agronomic traits in potato. Chen et al. (2001) compared the QTL map for starch content previously published (Schäfer-Pregl et al., 1998) with the molecular-function map, and various correlations between the map positions of 14 QTLs for tuber starch content and function-related loci were found. MAS for simply inherited traits is gaining increasing importance in breeding programs, allowing an acceleration of the breeding process. Traits related to disease resistance to pathogens and to the quality of some crop products are offering some important examples of a possible routinely application of MAS. For more complex traits, like yield, abiotic stress tolerance, quality traits etc a number of constraints have determined severe limitations on an efficient utilization of MAS in plant breeding, even if there are a few successful applications in improving quantitative traits. Recent advances in genotyping technologies together with comparative and functional genomic approaches are providing useful tools for the selection of genotypes with superior agronomical performances.

Chapter -26

MAINSTREAMING CLIMATE ADAPTATION IN INDIAN RURAL DEVELOPMENTAL AGENDA: A MICRO-MACRO CONVERGENCE

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Introduction

The increasing intensity of climatic risks on food and livelihood security emphasizes the transformational pathway towards sustainable development. The growing evidences confirm that agriculture sector is heavily experiencing the effect of changing climatic conditions (Lobell et al., 2011; Affhammer and Schlenker, 2014,Campbell et al., 2016; Khanal and Mishra, 2017), severity of which is expected to increase in the near future; with developing nations being the most affected (IPCC, 2012,2014). Weather aberrations and sudden onset of extremes (dry spells, droughts, and floods) adversely affects crop yields through outbreak of pest and diseases (Easterling et al., 2007;Gornall et al., 2010),changes in soil fertility (Tang et al. 2008; Clair and Lynch, 2010), moisture content, and most importantly water quality and resources (FAO, 2011; Misra, 2014, Malek et al., 2018).Such climate induced production risks not only deters food security and nutrition but also heightens the pressure on socio-economic stability of rural economies, further aggravating poverty, unemployment, migration (Singh et al., 2014; FAO, 2016) and social conflicts in the region. The magnitude of such risks however differs among the households, premised on their existing coping capacity, social acceptability to adaptations, collective coherency, and in-situ economic developments (Adger et al., 2003). Agriculture sector in India contributes14% to Gross Domestic Product (GDP) and remains a major livelihood support to more than 50% of total workforce. The system is heavily dependent on south-west monsoon (June to September), which is critical for more than 50 % of the food production around the year. High reliance on rainfall for irrigation, small and fragmented land holdings and limited technical and financial resource base (Acharya, 2006; Khan et al., 2009; Jain et al., 2015; Patnaik and Das, 2017) makes Indian farm households highly susceptible to weather abnormalities. Over the years prolonged breaks in southwest monsoon have increased the frequency of droughts (Udmale et al., 2015; Zhang et al., 2017; Choudhary and Sindhi, 2017) with consecutive drought periods being witnessed in different part of the subcontinent.How ever , a shifting trend in droughts is being observed towards agriculturally important coastal south-India, central Maharashtra, and Indo-Gangetic plains (Mallya et al., 2016). Empirics carried out over the years, indicates vulnerability of Indian agriculture to the changes in climate parameters. Under different temperature and precipitation scenarios studies have shown a significant fall in the productivity of major crops like rice, wheat, maize and millets in the country (Sanghi and Mendelsohn 2008; Guiteras 2009; Lobell et al. 2012; Auffhammer et al., 2012, Kumar et al., 2014; Gupta et al., 2014). Fluctuations in crop yield significantly affect farm revenues and farmer's welfare. For India, annual agricultural income losses due to climate change is estimated in the range of 15%-18%, rising to 20%-25% for unirrigated areas (GOI, 2017). Climate induced stresses are particularly more damaging for the farm households in semi-arid tropics, where rainfall is highly variable, soil fertility is low and drought are recurrent phenomena. Fostering the process of adaptation is therefore a plausible option to deal with extremes and minimizing vulnerability of the marginalized communities in short to medium run.

Farmers possess repository of traditional knowledge about the nexus of climate and agriculture that guide their adaptation decisions to limit the losses against the uncertainties induced by season-to-season variation (Jodha et al., 2012). In such a system, farm decisions or choices to risk management are channeled through mutually reinforcing preconceived notions, beliefs and social obligations, which could be sub-optimal. Capacities to cope or adapt to weather abnormalities and livelihood risks are influenced by wide range of socio-economic factors, prevalence of infrastructure facilities, access to assets and the ability to harness and share knowledge (Patnaik and Das, 2017; Singh et al., 2018b). The willingness and participation of state and institutions in agriculture dependent economies is therefore, essential in bringing the desired behavioral change among the rural households in the way they perceive and act to climatic changes. Moreover, strengthening farmers' capabilities and making their livelihoods more resilient to the unpredictable weather perils, necessitates the need to mainstream climate adaptation into the rural development and poverty alleviation programmes (Dessai, S., and Wilby, R., 2011; Agrawala and Lemos, 2015). Mainstreaming climate adaptation, ostensibly a multidimensional approach postulates convergence between micro and macro level to address the various layers of constraints faced by the rural households.[1]Planning at macro level largely focuses on aggregate data with less factoring for local requirements and needs. Inclusion of ground realties and engagement of village/local communities is central in devising appropriate locally tailored interventions and enhancing need-based adaptive capacity of the farmers (Singh et al., 2014, 2018a).

The growing body of literature recognizes adaptation to climate change as set of strategies that are closely intertwined with the developmental activities (TERI, 2005; Smit and Pilifosova, 2003; Agrawala and Lemos, 2015). In the context of agriculture, programmes and strategies catering to the rural development and advancement are the major drivers for enhancing the resiliency of agriculture ecosystem (FAO, 2016; Singh et al., 2017, 2018a). Building upon these considerations, we reviewed climate induced coping mechanisms adopted by the farmers and several barriers to adaptation, categorized into relevant thematic groups. We also analyzed the adaptation-development continuum in an attempt to link the identified constraints faced by the rural/ farm households to adaptation with the appropriate policy options in the Indian rural developmental framework. This calls for a micro and macro convergence along with significant role of government policy interventions in addressing the dual challenge of development and climate adaptation in agriculture in the developing countries especially in India.

1. **Micro-Level Coping Mechanisms:** There are several risk management strategies adopted by the rural households, largely spontaneous and reactive against climate induced stresses. These responses can be both social and technical in nature based on households' resource endowment, knowledge (Malik et al., 2012; Dinar and Jammalamadaka, 2013; Wood et al., 2014) and myriad

[1]Here micro level refers to the household and village level information pertaining to climate impacts, perceptions and beliefs, behavioral pattern of the farmers', their actions and interactions to develop responses and barriers that restrict the possible coping and diversification options. Macro level on the other hand is multilayered policy chain from national to state to local/ district level.

contextual factors. From policy perspective, it is crucial to understand, what sort of measures are being adopted at the micro-level and their relevance in terms of future sustainability. Following review on adaptation strategies at micro level includes natural resource management, Non-farm activities and sociological perspective.

2.1 Crop-level and Natural Resource Management Adaptations: In response to the perceived variations in temperature and irregular/delayed monsoon, farmers are making shifts in planting schedules and harvesting dates/ timings (Salau et al., 2012; Udmale et al., 2014; Varadan and Kumar, 2014) and adopting improved crop varieties which are less water consuming, high yielding, and drought resistant (Roy et al., 2007; Udmale et al., 2014, Singh et al., 2018a). Crop diversification/ intercropping/ mixed cropping (Jain et al., 2015; Singh et al., 2014; Reddy et al., 2015) are the most identified agronomic practices among the Indian farmers to climatic variations. As opposed to mono-cultivation, intercropping and mixed cropping results in greater productivity and profitability especially in the rainfed/dry land regions (Chandra et al., 2010, Singh et al., 2015; Khannal and Mishra, 2017). In addition, such systems are now seen as environmentally more sustainable adaptation measures that can efficiently utilize the available resources. Shah and Ameta (2008) in Dhala located in the state of Rajasthan and Hegde et al (2017) in Gulbarga district, Bangalore and Kolar district, Karnataka shows that farmers are opting for the package of organic practices such as green manuring, mulching, composting, and zero budget net farming as measures conserving soil properties, utilizing less water and yielding more output than conventional strategies. In the semi-arid regions of India, farmers were found to have a greater preference for less risky crops (Khannal and Mishra, 2017). Planting trees on farmlands are also being practiced among several villages as significant livelihood backup to crop failure (Kattumuri et al., 2015). In Sangrur district of Punjab state, farmers were adopting improved farm machinery such as zero tillage drills, rotavators, laser land levelers, and happy seeders that can potentially enhance input efficiency, conserve soil and water resources, as well as address issue of crop stubble burning (Ojha et al., 2014). Against irregularities in monsoon, in some of the villages of Maharashtra and Andhra Pradesh, there were creation of water saving structures such as farm ponds, furrow channels and check-dams (Banerjee, 2014; Vedeld et al., 2014; Rao et al., 2017). Application of drip irrigation however, remains low in the country with less than 5% of the net sown area (Dev, 2016) owing to high transaction costs and technical complexities. There is also an increasing exploitation of groundwater due to under-provision of irrigation infrastructure, incentives in the form of electricity subsidy and lack of regulations (Rajagopaland Jayakumar, 2006; Jodha et al., 2012; Bantilan et al., 2013).

2 Off-farm/ Non-farm activities: For minimizing the impact of environmental risks and ensuring consistency in domestic consumption pattern, rural households often engage in diverse livelihood-generating activities (Davis et al., 2010; Patnaik and Das 2017). Apart from crop cultivation, dairy livestock, poultry and cattle rearing are often observed as common subsidiary activities among agriculture households (Kumar et al., 2007; Kattumuri et al., 2015). However, given the climatic variations and consequent increase in heat stress on livestock, can put sustenance of such earnings in danger. Farmers also engage themselves in casual/ part-time work or self-employed ventures to face any risky situation. Between 1999-2000 and 2011-2012 it is found that, rural non-farm employment in India increased by 12 percentage points (Saha and Verick, 2016). Bhatta et al., 2015 stated that in Bihar, a large proportion of the farm households were engaged as wage labourers either on other farm lands or in non-farm sectors. In some villages occupational diversification include opening up of small shops like provision store, repair shops, etc. (Tripathi and Mishra, 2017). Participation in employment generating interventions of the government, most notably MGNREGS[2] (Udmale et al., 2015; Banerjee et al., 2013; Singh et al., 2018b) has emerged as a prominent diversification option among the rural households.

Transitory or seasonal migration to urban agglomerations in search of work is seen as an important response strategy by the poor households to deprivations caused by weather shocks (McLeman and hunter 2010; Bhatta and Aggarwal, 2016, Singh et al., 2018b; Rao et al, 2018). Some recent researches have tried to establish the linkage between weather variations leading to changes in crop yields and out-migration in India. For instance, using district level data Viswanathan and Kumar (2015) showed that a 1 per cent decline in rice and wheat yield leads to a nearly 2 and 1 per cent respectively, increase in the rate of out-migration from a state. Another study by Dallmann and Millock (2017) indicated that increased frequency of droughts especially in agricultural states increased the rate of inter-state migration. Remittances sent by people working in town and cities, back to village can be an important source for building requisite assets to deal with extremes.

2.3 Social Networks and other Measures: To compensate for erosion in income and meeting consumption requirements farmers resort to higher borrowing majorly from informal sources (Bantilan and Anupama, 2006; Singh et al., 2018b). Other mechanism to cope up with distress includes sale or mortgage of livestock, land and other farm assets during drought conditions (Selvaraju et al., 2006, Jodha et al., 2012; Varadan and Kumar, 2014, Singh et al., 2016).Despite, an effective risk mitigation instrument, very small segment of the agricultural households insure their crops (GOI, 2013). Such low rate of crop insurance has been largely attributed to poor awareness, delayed compensations and inadequate crop failure assessments. In the villages of Andhra Pradesh, high dependence on Self Help Groups (SHGs) among women was observed for financial needs and access to better inputs and technology than in the villages of Maharashtra (Singh et al., 2015). Adherence to social traditions and festivities form a significant aspect of village economics in India and a huge amount of money is spent on these due strong beliefs and social obligations. However, there seems to be a reduction on such practices owing to growing weather uncertainty (Singh et al., 2018a).

2. Micro-Level Barriers to Adaptation Decision-Making

Grass-root responses to weather variability and extremes are often rendered ineffective due to several constraints that restrict/ impede their effective implementation (Bryan et al. 2009; Deressa et al. 2009). For devising plausible adaptation and livelihood strategies, it is crucial to systematically assess and understand the dynamics of obstacles that translates into weak coping

[2]Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), a flagship programme of the Government of India mandates at least 100 days of guaranteed wage employment in a financial year to every rural household whose adult members volunteer to do unskilled manual work.

capacity and prevents adoption of improved practices. After exploring the literature, a large number of factors ranging from social/ cultural, institutional, informational, technological, financial and infrastructural (Smit and Pilifosova, 2003; Ekstrom and Moser, 2014) were identified that hinders adaptation among rural farm household in India and other developing countries (Table 1).

Table 1: Typology of barriers to climate adaptation

Major constraints	Issues to climate adaptation
Technological	▪ Limited availability of drought tolerant varieties and location specific technologies *(Niranjan et al., 2013;Suddhiyam et al., 2013)* ▪ Limited research on climate change and adaptation in agriculture and its various socio-economic dimensions ▪ Inadequate funds for agriculture R&D activities*(Muller and Shackleton, 2014; Menike and Arachchi, 2016)* ▪ Under-development of irrigation and water efficient infrastructure in rainfed areas *(Elliott et al., 2014; Panda, 2016; Rao et al., 2018)* ▪ High initial cost of investment in water saving technologies like micro irrigation, farm ponds *(Palanisami et al., 2011; Rao et al., 2017)*
Economic	▪ Small and fragmented land holding *(Planning Commission 2007; Kumar et al., 2013; Ojha et al., 2014)* ▪ Affordability and timely availability of farm inputs (seeds, fertilizers) (*Eakin 2000; Mertz et al., 2008; Varadan and Kumar, 2014; Bhogal 2016)* ▪ Inadequate provision of formal financial facilities (credit and insurance) to the rural poor and small and marginal farmers *(Deressa et al., 2009; Jantarasami et al., 2010; Satishkumar et al., 2013; Moser and Ekstrom, 2010;Vedeld et al., 2014;Ndjeunga et al., 2015; Bhave et al., 2016)* ▪ Inefficiencies in agriculture marketing and lack of market access to the farmers *(Bryan et al., 2009;Vedeld et al., 2014; Elum et al., 2017),* lack of post–harvest and storage facilities (*Banerjee et al., 2013, Bhogal, 2016*) ▪ Power shortage (*Ojha et al., 2014*)
Institutional	▪ Policy implementation gaps and poor coordination inter-institutional coordination to implement adaptation actions *(Spires et al., 2014; Azhoni et al., 2017)* ▪ Insecure and poorly defined property rights *(GIZ, 2013)* ▪ Weak institutions for collating and synthesizing data *(GOI, 2010)* ▪ Limited competency of policy makers and other stakeholders in understanding climate change and its integration with the agriculture R&D and developmental programmes(*Revi et al., 2015)* ▪ Weak collective actions, limited participation of SHGs and other state agencies in coping towards climate affects (*Jodha et al., 2012; Bantilan et al., 2013*)

Informational	▪ Lack of information on credit/ insurance facilities and various financial reliefs to the rural farm households *(Nhemachena and Hassan, 2007; Deressa et al., 2009,2011; Bantilan et al., 2013;Rao et al., 2018)* ▪ Insufficient farm household/State level data base to analyse/understand climate impact, vulnerability and coping capacity (*Niranjan et al., 2013; Patra, 2014).* ▪ Poor reliability of grass-root level information and lack of computational capacity *(Meybeck et al., 2012)* ▪ Lack of information on climate changes, adaptation techniques and weather forecast at the farm level (*Deressa et al., 2009;Ozor et al., 2010; Francisco et al. 2011, Taraz, 2017)* ▪ Poor dissemination/ extension of technology *(Satishkumar et al., 2013)* ▪ Unawareness on government welfare and relief programmes *(Singh et al., 2012, 2018a)*
Social/Cultural	▪ Under developed human capital (education) which restricts farmers ability to adopt appropriate measures and adaptation strategies *(Nelson et al. 2009;Wright et al., 2014)* ▪ Societal norms and obligations preventing adoption of new techniques, superiority of traditional practices, low self-efficacy and perception of inability to effectuate change, political and social marginalisation and discrimination. (*Adger et al., 2009; Jones and Boyd 2011; Satishkumar et al., 2013;Le Dang et al., 2014)*

3. Mainstreaming Climate Change Adaptation

Capacity to adapt is multifaceted and dynamic in nature. It is now widely acknowledged that it is the state of development that can reduce exposure and sensitivity of rural households to climate impacts and regulate their capacity to manage risks (Ayers. and Huq, 2009). Broad spectrum of activities ranging from social, economic, technological, infrastructural and institutional arena that promotes sustainable development also encourages adoption of better agricultural practices and livelihood diversification. The close linkage between climate adaptation and development necessitates addressing the two in an integrated manner (Ayers and Dodman, 2010; Fankhauser and Schmidt-Traub, 2011) to achieve climate resilient pathways. One such way of integration is through the concept of mainstreaming climatic perceptions and adaptation strategies into the development policies different scales of national, sub-national and local level. Viewing development planning through climate lens ensures sustainability against climate adaptation and poverty eradication in the long run. In the context of agriculture planning, this requires reshaping the existing programmatic interventions to realign climate change, food, nutrition and livelihood dimensions (FAO, 2016). In addition, convergence between macro and micro level decision-making culture is a must for successfully feeding the cross-scale and cross-sectoral issues and opportunities into the policy realm.

India's decentralized planning process provides an institutional platform for such convergence, with information percolating right from the village/ panchayat/ district to the state and national level (Figure 1). Coordination within and between multiple institutions and stakeholders is central to the mainstreaming agenda. This proves to be more challenging in the Indian democratic context, with large number of ministries and departments having overlapping domains and objectives.

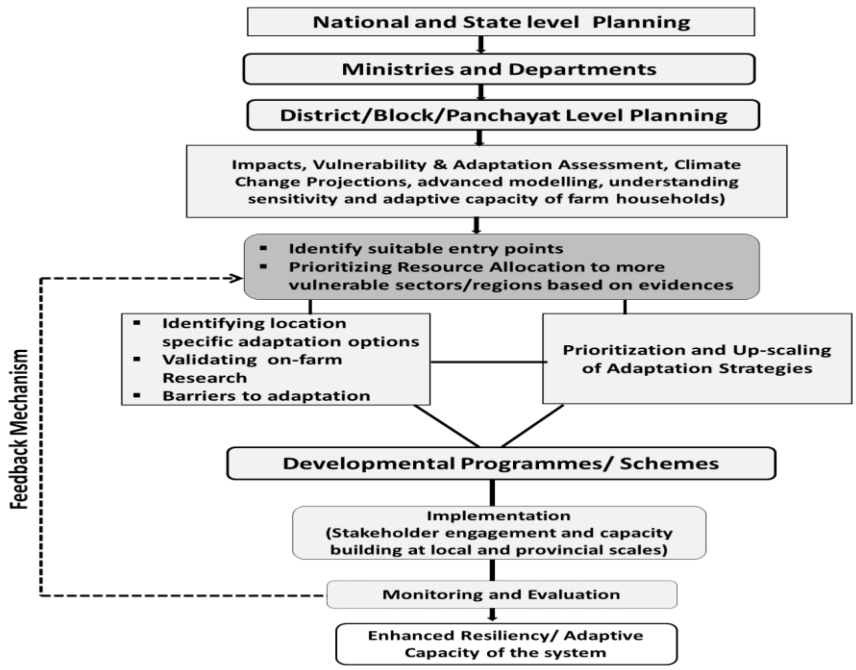

Figure: 1 Framework for mainstreaming climate adaptation into developmental framework

Therefore, each ministry/ department needs to carry an independent climate risk/ vulnerability assessments based on repository of collated grass-root information. It is argued that the participation of local communities and institutions is crucial element in analyzing vulnerability, visible impacts and addressing region specific constraints. For suitable adaptation options, various strategies must be evaluated, before piloting into the field. This phase necessitates a two-way communication across institutions and stakeholders for ensuring complementarity between actions and avoiding possible maladaptation. Suitable entry points in the form of developmental programs need to be identified for infusing both the climatic considerations, barriers and prioritized adaptations strategies. One major aspect of mainstreaming process is allocation of budget for climate change adaptation actions and implementation. There remains a considerable uncertainty over funding mechanism owing to the close relationship between adaptation and development. It is pertinent that allocations should be provisioned more towards climate-oriented interventions and to most vulnerable sections, than on strategies completely coinciding with developmental actions as adaptation and development are *sine qua non*. Moreover, strong local monitoring and evaluation is crucial for regular assessment of strategies, for successfully addressing vulnerability and adaptation constraints.

4. Micro-Macro level Convergence

Based on the barriers identified in the earlier section, following are some of the policy options in the current developmental framework of the Government of India that can help enhance resiliency of the farm households to climate induced vulnerability and risks, directly or indirectly.

5.1 Technologies for Climate Smart Agriculture

Generation and dissemination of real time scientific information, and weather forecast is the most significant component to the development of climate smart agriculture. Programmes having multi-pronged strategy such as, National Mission on Strategic Knowledge for Climate Change, National Mission for Sustainable Agriculture, ICAR-National Innovations in Climatic Resilient Agriculture (NICRA) and National Adaptation fund are creating much needed knowledge networks and climate information system *via*, multi-level capacity building, data gathering, and extensive research and development activities, facilitating climate adaptation at the farm level. Strengthening of agricultural advisory services allow enhanced adoption of improved farm practices and promote informed agriculture operations. Awareness building and communication strategy for climate change and adaptation strategies needs to be integrated into the ongoing extension units such as National Mission on Agriculture Extension, *Krishi Vigyan Kendra* (KVKs) and *Krishi Call Center* at the local or regional level. Further, local crop contingency plans can be put in place using modern tools of remote sensing and Geographical Information Systems(GIS), analyzing changes in land use and land cover.

Table 2: Technological and informational Issues to adaptation and related Schemes

Barrier	Issue for adaptation	How	Who	Schemes
Technological/informational Constraints	Poor dissemination of technology and incompetency of extension agents	▪ Short-term & long-term training of extension agents ▪ Collaboration with private/commercial companies ▪ Information and Communication Technologies ▪ Promote the role of NGOs and other providers/agencies to operate in the entire country, ensuring they	Ministry of Agriculture and Farmers Welfare (*Department of Agriculture, Cooperation & Farmers Welfare*, *Department of Agricultural Research and Education*), Department of Science and	✓ National Mission on Strategic Knowledge for Climate Change ✓ National Mission on Sustainable Agriculture ✓ National Innovations on Climate Resilient Agriculture ✓ National Mission on Agricultural Extension and Technology- Sub-Mission on Agricultural Extension ✓ Kisan Call Centers ✓ Krishi Vigyan

	provide complementary services	Technology, NABARD	Kendras ✓ National Adaptation Fund
Lack of information on climate changes, adaptation techniques Insufficient funds for agriculture R&D activities	▪ Conduct agricultural research to develop practices & invest in extension to promote the practices ▪ Conduct research to determine new precipitation & temperature patterns and forecasts	Ministry of Agriculture and Farmers Welfare (*Department of Agriculture, Cooperation & Farmers Welfare*, *Department of Agricultural Research and Education*), Ministry of Science and Technology (*Department of Science and Technology)*, NABARD	✓ National Mission on Sustainable Agriculture ✓ National Innovations on Climate Resilient Agriculture ✓ National Adaptation Fund
Delayed weather and seasonal climate forecasts	▪ Installation of weather station at village level ▪ Generation of data at grass-root/ panchayat level ▪ Agro-advisory providing real time data at Public and Private and NGO level ▪ Institutional support for agro-	Ministry of Agriculture and Farmers Welfare(*Department of Agriculture, Cooperation & Farmers Welfare*, *Department of Agricultural Research and Education*),	✓ National Mission on Sustainable Agriculture ✓ National Innovations on Climate Resilient Agriculture ✓ Flood Forecasting ✓ Numerical Modelling of Weather & Climate ✓ Agro-Meteorological Services Programme

	advisory services	Ministry of Water Resources, River Development and Ganga Rejuvenation, Indian Meteorological Department	
Affordability and access to farm inputs	• Improved access to subsidized seeds (stress tolerant varieties), planting material, machinery (conservation agriculture), plant protection chemicals etc.	Ministry of Agriculture and Farmer's Welfare (*Department of Agriculture, Cooperation & Farmers Welfare*)	✓ Sub-Mission on Seed and Planting Material ✓ Sub-Mission on Agricultural Mechanization ✓ Sub-Mission on Plant Protection and Plant Quarantine

Note: Adopted and modified from Singh et al., (2017), (2018a)
NABARD *stands for National Bank for Agriculture and Rural Development*

5.2 Natural Resource Management

Encouraging adoption of *in situ* water harvesting technologies, promotion of micro-irrigation (drip and sprinkler), combined with maintenance and creation of drought proofing infrastructure in Public Private Partnership (PPP) mode can reduce water related risks. Schemes like *Pradhan Mantri Krishi Sinchayee Yojana*, National Water Mission, National Mission on Sustainable Agriculture and MGNREGS are progressing under this context. Alongside achieving 'per drop more crop' agenda can significantly address region specific deficits in rainfall distribution. Besides, there is need to strengthen participatory irrigation management (PIM) and water user associations (WUAs) for establishing collective responsibility among the users and ensuring economy and equity in water use. Soil Health Card, National Project on Management of Soil Health and Fertility and *Paramparagat Krishi Vikas Yojana* of Ministry of Agriculture and Farmers Welfare promoting increased application of integrated nutrient management techniques are steps in right direction in mitigating the effect of climate change on soil. New technique of Zero Budget Natural Farming (ZBN) and organic practices should be further encouraged across varied agro-climatic zones.

Table 3: Natural Resources issues to adaptation and related Schemes

Barrier	Issue for adaptation	How	Who	Schemes
Resource Barriers	Insufficient irrigation and water efficient infrastructure in rainfed areas	• Better irrigation management and innovative irrigation practices • Managed aquifer storage • Shift to improved irrigation methods (sprinkler, mini-sprinkler, trickle) • Reduce soil evaporation losses • Promoting sub surface irrigation (SDI) & restricted deficit irrigation (RDI) • Creation of stakeholders consortium	Ministry of Agriculture and Farmer's Welfare(*Department of Agriculture, Cooperation & Farmers Welfare*, *Department of Agricultural Research and Education*) Ministry of Water Resources, River Development and Ganga, Ministry of Rural Development (*Department of Rural Development*), Ministry of Environment, Forest and Climate Change, NABARD	✓ *Pradhan MantriKrishiSinchai Yojana* ✓ National Water Mission ✓ National Innovations on Climate Resilient Agriculture ✓ National River Conservation Plan ✓ Mahatma Gandhi National Rural Employment Guarantee Scheme ✓ Long term Irrigation fund and Micro-Irrigation Fund
	Soil degradation, soil erosion, waterlogging, salinization	• Managing soil erosion, strip/contour farming, crop rotation • Combating desertification& soil erosion • Organic sources to improve soil fertility, mulching • Judicious use of chemical pesticides for reducing pesticides residues • Biological control and IPM • Regular surveillance and monitoring	Ministry of Agriculture and Farmers Welfare (*Department of Agriculture, Cooperation & Farmers Welfare*)	✓ National Project on Management of Soil Health and Fertility ✓ Soil Health Card ✓ Mission on Plant Protection and Plant Quarantine ✓ *RashtriyaKrishiVikasYojana*

Note: Adopted and modified from Singh et al., (2017), (2018a)

5.3 Risk Management, Market Access and Diversification

Formulating viable weather-based crop insurance products requires extensive research and development for developing effective models of risk assessment and management. Recently launched, *Pradhan Mantri Fasal Bima Yojana* by the government contains uniform premium rates for different crop seasons and broader risk coverage in the form of yield loss, post-harvest loss and localized calamities to protect farmers against non-preventable risks. There is also mandatory use of advanced technologies (remote sensing, GIS, etc.) for faster detection of crop losses and claim settlements. However, timely conduct of crop cutting experiments to estimate crop losses and collation of farm level data is crucial for the success of the program. Lack of access to formal financial facilities to the marginalized communities has been the most cited barrier in the field based studies to the process of adaptation. Subsidized interest rate and easy access to formal credit promotes adoption of progressive farm practices, high value inputs and farm mechanization. Further schemes like e-National Agricultural Market and other agri-marketing programmes addressing markets fragmentation, price anomalies, multiple functionaries' chain and information asymmetry can significantly promote regional crop planning and help farmers diversify their income sources to high value crops. Farm systems where either farmers diversify into agriculture practices, livelihood activities or both are less vulnerable to external shocks.[3]Rural population often lack adequate skills and education to serve other off-farm sectors. To fill this skill gaps, mega programmes such National Rural Livelihood Mission, *Pradhan Mantri Kaushal Vikas Yojana, Skill India* can empower rural population in finding suitable non-farm work. The role of educational institutes and Non-Governmental Organizations(NGOs) holds significance in breaking socio-cultural barriers focusing on enhancing behavioural communication strategy at the grass-root level.

Table 4: Economic Barriers to adaptation and related schemes

Constraints	**Issue for adaptation**	**How**	**Who**	**Schemes**
Credit and insurance constraints	▪ Inadequate provision and reach of formal financial credit and insurance facilities ▪ Financial illiteracy among poor farmers	• Credit and Insurance linkage • Access to banking facilities • Financial inclusion • Risk insurance; direct risk transfer • Premium subsidy • Coverage of post-harvest losses • Timely conduct of crop cutting experiments • Increasing participation of farmer groups • Satellite enabled risk	Ministry of Agriculture and Farmers' Welfare (*Department of Agriculture, Cooperation &Farmers Welfare*) Ministry of Finance, NABARD	✓Interest Subvention Scheme for Short Term Crop Loans ✓Kisan Credit Card Scheme ✓*Pradhan Mantri Jan Dhan Yojana* ✓*Pradhan Mantri Fasal Bima Yojana*

[3]There are two major forms of diversifications; agricultural diversification and livelihood diversification (FAO, 2016). Agricultural diversification involves shifting cropping pattern or promoting farm diversification via, animal husbandry, poultry and fisheries. Livelihood diversification on the other hand, blends off-farm activities with farm activities to manage risk from external factors. This includes opening small grocery shops, hotels, participation in employment schemes, or migrating to urban centers for seasonal employment.

		assessment		
Market access and infrastructural Constraints	▪ Inefficiencies in the conduct of agriculture market and its access to farmers ▪ Lack of post–harvest and storage facilities ▪ Limited public procurement centers, and located at far off places ▪ Slow progress on all-weather road, electricity and internet connectivity in rural areas	• Market support measures • Improving Investment agricultural infrastructure • Convergence of govt. programs into umbrella schemes • Setting up of warehouses, cold storage and cold chains • Increased extension services • Setting up of commodity and region wise clusters for farmers groups (FPOs) for marketing & storage • Participation in commodity futures market	Ministry of Agriculture and Farmers' Welfare (*Department of Agriculture, Cooperation & Farmers Welfare*), Ministry of Rural Development (*Department of Rural Development*), Ministry of Food Processing, Ministry of Food and Public Distribution	✓Integrated Scheme for Agriculture Marketing ✓E- National Agriculture Market Scheme ✓Price Stabilization Scheme ✓Agri-Tech Infrastructure Fund ✓Mission for Integrated Development of Horticulture ✓Mega Food Parks ✓*Pradhan Mantri Gram Sadak Yojana* ✓ *Indira Awas Yojana* ✓*Deen Dayal Upadhyaya Gram Jyoti Yojana*
Lesser off - farm livelihood options	▪ Insufficient off farm employment opportunities ▪ Under developed human capital (education) to absorb in other non-farm enterprises	• Linkage between farm and non-farm activities (Upstream & downstream) • Incentivising rural non-farm activities • Diversification-both vertical and horizontal • Promotion of equipment, training and market facilities • Enhancing gender and youth participation • Skill development • Promotion of livestock, dairy and fisheries sector	Ministry of Rural Development (*Department of Rural Development*), Ministry of MSME, Ministry of Skill Development, Ministry of Agriculture and Farmer's Welfare (*Department of Animal Husbandry, Dairying & Fisheries*)	✓Mahatma Gandhi National Rural Employment Guarantee Scheme ✓National Rural Livelihood Mission ✓*Pradhan Mantri Kaushal VikasYojana* ✓Prime Minister's Employment Generation Programme ✓Dairy Entrepreneurship Development Scheme ✓National Dairy Plan

Note: Adopted and modified from Singh et al., (2017), (2018a)

Social safety nets in the form of cash and kind transfer is increasingly found to be proven as possible actions that can help foster resilience to weather variability (World Bank, 2010; Castells-Quintana et al., 2018). In addition to protection, such measures promote livelihood and mechanisms to scale up and out against weather perils (Hansen et al., 2018).

Conclusion

Recognizing the vulnerability of Indian agriculture to climatic variability, there is an urgent need to mainstream climate adaptation into the rural policy landscape for inclusive and climate resilient sustainable development. This paper reviewed various coping mechanisms adopted by the farmers and the barriers preventing households from autonomous adaptations. The review necessitates the need for integrating adaptation and micro-level assessment to understand factors across different agro-climatic regions in order to develop suitable solutions that fit the local geographical framework. Several programmatic interventions exist in the current rural development framework of the government that can help achieve the twin objective of adaptation and development, provided it effectively captures climatic considerations. Building capacity of community-based group, NGOs, cooperatives and farmers associations can create awareness on climate adaptation and technologies for sustainable livelihoods. Moreover, there is a need to strengthen private sector participation in development of post-harvest management, infrastructure building and climate research and development in the country. For further enhancement of climate specific programmes at the grass-root level, convergence with the mega programs pertaining to poverty alleviation, irrigation, extension builds the platform.. Strong institutional mechanisms need to be enforced to monitor, evaluate and address climate related technical and knowledge gaps for successful implementation of region specific climate change action plans. Moreover, participation and concerted efforts are needed to strengthen synergy between vertical and horizontal policy chain to effectively mainstream climatic consideration within the planning framework. The current scenario makes a urgent call for the policy maker and other stakeholders to review programmes and schemes for enhancing the adaptive capacity of vulnerable section and making Indian agriculture climate resilient. Similar initiatives can be replicated in other developing countries of the world having preponderance of agrarian economy and climate change threats.

Chapter -27

VULNERABILITY OF POTATO CULTIVATION UNDER CHANGING CLIMATE

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Climate change and global warming is now an recognized fact and reality and its effect at local level is increasing day by day with lot of variability in daily, seasonal pattern and occurrence of extreme weather events. Climate change will mean adapting to a new reality. It is a transversal topic. Climate change could cost India 2.8 per cent of GDP, and lower living standards of nearly half of its population by 2050, as average annual temperatures are expected to rise by 1-2 per cent over three decades, warns this new report released by the World Bank South Asia is highly vulnerable to climate change (Mani et al., 2018). The climate change and global warming will have a profound effect on potato growth in India affecting not only production and profitability, but seed multiplication, storage, marketing and processing of this perishable vegetatively propagated crop (Singh et al., 2009). Worldwide, potato is the fourth largest source of food and India is the second largest producer of potato in the world. Its production is greatly affected by uncertainty of rainfall and temperature. Potato, a tuber, is widely consumed in India. It was found that, without adaptation, the total potato production in India, under the impact of climate change, might decline by 2.61% and 15.32% in the years 2020 and 2050, respectively. The impacts on productivity and production varied among different agro-ecological zones.

Climatic requirement of Potato: The vegetative growth of the plant is best at a temperature of 24°C while tuber development is favoured at 20°C. Hence, potato is grown as a summer crop in the hills and as a winter crop in the tropical and subtropical regions. The crop can be raised up to an altitude of 3000 m above the sea level. In the central plains of India such as Madhya Pradesh, Gujarat and Orissa, potato is a winter or rabi crop. Therefore, the time of planting here is during the months of October and November. Potato can be both kharif and rabi crop in the Deccan plateau, i.e., in states like Andhra Pradesh, Karnataka and Maharashtra. Potato is grown almost in all states of India. However, the major potato rowing states are Himachal Pradesh, Punjab, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, West Bengal, Bihar and Assam.

Potato growth and development is affected at high temperatures. No potato crop growth is possible below 2 ^{0}C and above 30 ^{0}C. The minimum (0-7 ^{0}C), optimum (16-25 ^{0}C) and maximum (40 ^{0}C) temperatures for net photosynthesis are reported. Potato requires cool night temperature to induce tuberization. Although photosynthesis in potato is suppressed by high temperature, it is not as sensitive to temperature as tuberization and partitioning of photosynthates to tuber. The radiation use efficiency (RUE) is suppressed under high temperatures. High temperature reduces tuber number and size (Ewing, 1997).

Adapting potato to tropical growing condition: Among the root and tuber crops potato is perhaps the only crop whose productivity is likely to be negatively impacted due to climate change. The INFOCROP-Potato model suggested severe yield reduction in southern and peninsular India (9-47%) and moderate reduction in Indo-Gangetic plains (3-13%). The potato production may decline by 2.61 and 15.32% in the year 2020 and 2050, respectively. To overcome this situation and to satisfy the projected demand, it is necessary to initiate immediate work plan for developing varieties and production technologies for cultivating potato under tropical condition. Emphasis will be given for developing (i) short duration varieties (ii) varieties with early bulking and maturity, (iii) varieties that can tuberize at ≥25 oC, (iv) management of heat tolerance, (v) management of invasive and range-expanding pests and diseases, and (vi) cold chain management.

Productivity enhancement: Plateauing of yield gain in potato is a roadblock for achieving production target in a sustainable manner. Out-of-box thinking and innovative technologies are immediately required for breaking this barrier. The following approaches will be adapted for harnessing maximum yield potential of different crop plants: (i) broadening genetic base of varieties, (ii) exploiting genes for direct yield enhancement, (iii) improving photosynthetic energy conversion (€c) efficiency, and (v) improving sink strength.

Adaptations to climate change : In potato the optimum date of planting (DOP) is highly location specific even within small states and varies appreciably according to local weather conditions, soil and cropping systems. Therefore, a general recommendation to advance or delay in future climate scenarios is impractical. However, adaptation studies on change in DOP indicate possibility and extent of sustainable potato production in future climate scenarios by modification in DOP. In Punjab and Western UP the delayed planting by 5-10 days generally increased or sustained the tuber yield in warmer 2020 and 2050. In these frost prone areas in the current climate the prime concern was to escape the frosting period in late December and early January by selecting an optimum planting date (OPT) allowing at least 75-90 days of growing period. Even in the current climate during frost free years delayed planting was found beneficial but is not recommended due to enhanced risk of frost damage. In Eastern UP and Bihar the delayed DOP by 5 to 10 days might sustain the potato production with only minor losses (0-10%) in tuber yield in future climate scenarios. In West Bengal (WB) there is no advantage from delayed planting and recommended DOP is the best option with a loss of 4-8% only. In WB, other adaptation measures like heat tolerant varieties, mulching etc. may prove beneficial. Similar was the situation in plateau and South India with yield losses of 4-100% depending upon the location. Results indicate that for states of WB, plateau region and south India development of heat tolerant varieties and other adaptation measures need to be developed as change in DOP might not be very effective (Singh and Lal, 2009).

Table 1. Effect of Adaptation through change of planting date on potato production in few important locations of Potato Growing Areas in India (Adopted from Singh and Lal, 2009) (DOP: Date of planting; OPT: Optimum date of planting)

Indo-Gangetic Plains					Plateau Region and South India				
Location	DOP	Change (%) in yield			Location	DOP	Change (%) in yield		
		Current	2020	2050			Current	2020	2050
Jalandhar (Punjab)	-5	-5.6	6.7	-3.4	Indore (MP)	-5	-2.0	-8.4	-20.9
	OPT	0.0	7.3	3.7		OPT	0.0	-8.4	-17.3
	+5	15.1	18.1	13.8		+5	-0.2	-4.2	-12.0
	+10	19.4	21.7	18.9		+10	1.4	-14.1	-18.3
Agra (UP)	-5	0.6	-15.2	-36.9	Anand (Gujrat)	-5	-2.6	-21.3	-44.3
	OPT	0.0	-5.6	-7.7		OPT	0.0	-15.2	-47.6
	+5	11.2	1.3	-28.8		+5	-1.4	-18.5	-48.8
	+10	22.1	18.2	14.4		+10	1.2	-5.5	-43.8
Varanasi (UP)	-5	1.9	-0.2	-7.8	Hasan (Karnataka)	-5	4.7	-32.5	-99.0
	OPT	0.0	0.8	-5.5		OPT	0.0	-32.2	-81.9
	+5	-6.6	-4.5	-9.7		+5	-5.0	-42.1	-97.1
	+10	5.1	-3.2	-18.8		+10	-10.5	-49.4	-99.1
Patna (Bihar)	-5	-2.8	-11.8	-21.8	Pune (Maharashtra)	-5	-4.9	-20.6	-48.0
	OPT	0.0	-3.1	-10.1		OPT	0.0	-14.4	-47.6
	+5	2.4	-0.3	-2.3		+5	2.2	-7.9	-43.3
	+10	1.2	-1.7	0.7		+10	-1.4	-15.2	-39.9
Burdwan (WB)	-5	-1.4	-7.5	-19.8	Satara (Maharashtra)	-5	-3.9	-7.3	-10.7
	OPT	0.0	-3.9	-7.7		OPT	0.0	-6.6	-13.5
	+5	-8.6	-9.4	-15.5		+5	-3.9	-5.0	-12.5
	+10	-15.0	-19.6	-24.1		+10	-3.4	-10.1	-17.1

In an another study by Kumar *et al* (2015), the potato crop duration in the IGP is projected to decrease due to climate change. The evapotranspiration (ET) is projected to increase while the water use efficiency (WUE) for potato yield is projected to decline in future climates as a consequence of low threshold temperatures for decline in WUE and yield than the ET. Results indicate that the upper threshold for ET decrease is ~23 oC while that for WUE is 15 oC. The optimal temperatures for tuber yield is ~17 oC and thus the reduction in WUE in future climates is discernable. Climate change is projected to reduce potato yields by ~2.5, ~6 and ~11% in the IGP region in 2020 (2010-2039), 2050 (2040-2069) and 2080 (2070-2099) time periods. Change in planting time is the single most important adaptation option which may lead to yield gains by ~6% in 2020 and its combination with improved variety or additional nitrogen may be required to adapt to climate change leading to positive gains by ~8% in 2020 and by ~5% even in 2050. However, in 2080 adoption of all the three adaptation strategies may be needed for positive gains. Intra-regional differences in the impact of climate change and adaptation gains are projected; positive impact in northwestern IGP, gains in Central IGP with adaptation and yield loss in eastern IGP even with adaptation.

The impacts on productivity and production varied among different agro-ecological zones. The north-western plains, comprising the states of Punjab, Haryana and areas of western UP and northern Rajasthan, are least vulnerable with possible increases of 3.46–7.11% in productivity, and with simple adaptation measures like change in planting time and proper selection of cultivars, the potato production may be sustained at current levels. The eastern and southern states appeared more vulnerable to tuber yield losses of 4–19% in future climate scenarios because simple adaptation measures were not found to be effective. The potato crop in Orissa and plateau regions of Gujarat, Karnataka, Maharashtra, and other areas in south India would be most vulnerable due to warming and associated drought conditions, with yield loss ranging from 6.58% to 46.51%. West Bengal, Orissa, and plateau regions would require technological interventions and adaptation through breeding heat- and drought-tolerant cultivars to arrest the impending decline in potato productivity and production in the future climate scenarios. Intensification of potato cultivation in the least to moderately vulnerable regions, with simple adaptation measures of proper selection of cultivars and adjustment in planting time, offers opportunity to offset the decline in production in other regions (NATCOM, 2012).

Farmers' perception on climate change impact, adaptation and mitigation on potato farming in India

A study conducted at Agra district by Saxena and Anuj Kumar (2019) with respect to Farmers' perception on climate change impact, adaptation and mitigation on potato farming showed that they have made their own adjustments in management practices to minimize the negative effects of climate change. Their responses on the issue are as follows.

- In order to maintain adequate level of humidity of the soil, almost all the farmers of the selected villages are dependent on alternative sources of irrigation, either from surface water (canal and minor) or ground water (tube well); for maintaining crop yield majority of potato farmers are using pesticides and fertilizers.

- Regarding cost of adaptation and mitigation, respondents viewed that the cost alternative sources of irrigation, pesticides, fertilizers and the warehousing of harvested crops for safe storage near the fields is around 5000 per hectare.
- They also viewed that though government provides for subsidy on the fertilizers, it is hardly available perhaps because of insufficient stock. Hence, they are bound to buy fertilizers from private dealers, which further enhance cost of production, thus, economically not feasible.
- Due to vulnerability of potato yield and high cost of production, a few farmers are thinking about crop replacement, i.e., from potato to wheat, while some (especially youth) are planning to quit from agriculture occupation.

Combined influence of change in temperature and CO_2 on potato yield

Dua *et al* (2013) studied the impact assessment of climate change on potato productivity in Punjab for three potato cultivars of late (Kufri Badshah), medium (Kufri Jyoti) and early (Kufri Pukhraj) maturity groups was carried out for A1FI scenario of temperature and atmospheric CO_2 of the years 2020 and 2055. The simulation study was done using WOFOST crop growth model for potential production at 13 locations in Punjab. The results from the simulation study were interpolated using kriging technique to generate maps of potential productivity and the changes thereon. It was estimated that rise in temperature alone will result in change in productivity of Kufri Badshah from +11.6% (Amritsar) to –10% (Fatehgarh) in 2020, whereas the change in productivity of Kufri Jyoti will be from +11.6% (Amritsar) to –11.6% (Fatehgarh) and of Kufri Pukhraj from +12% (Amritsar) to –11.5% (Mansa). During this period, CO2 fertilization is expected to increase tuber productivity from +3.9% to +4.5%, depending upon cultivar and location. However, in 2055, a mean decrease of 17.9 (Kufri Badshah), 21.1 (Kufri Jyoti) and 22% (Kufri Pukhraj) is likely in the productivity due to rise in temperature only, while the expected rise in CO2 is likely to bring about 17.3 (Kufri Badshah) to 18.5% (Kufri Jyoti) increase in potato productivity. It is estimated that under the combined influence of change in temperature and CO2, the productivity of potato cultivars will not be affected in 2020 over the baseline scenario, but will decline in 2055 (Kufri Badshah, –2.62%; Kufri Jyoti, –4.6% and Kufri Pukhraj, –5.3%), when the total geographical area of Punjab is considered. It is further shown that if the present distribution of potato acreage within Punjab remains unaltered in future, there will be benefits from climate change as the potential productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj will increase by 3.3%, 3.1% and 3.6% in 2020, although the potential productivity will again decline to baseline values in 2055 (+0.1%, –1.5% and –1.9% respectively).

Growing degree days and potato yield: Global climate change may increase production of potato in Punjab, Haryana and western and central UP by 3.46 to 7.11% in A1b 2030 scenario, but in rest of India,

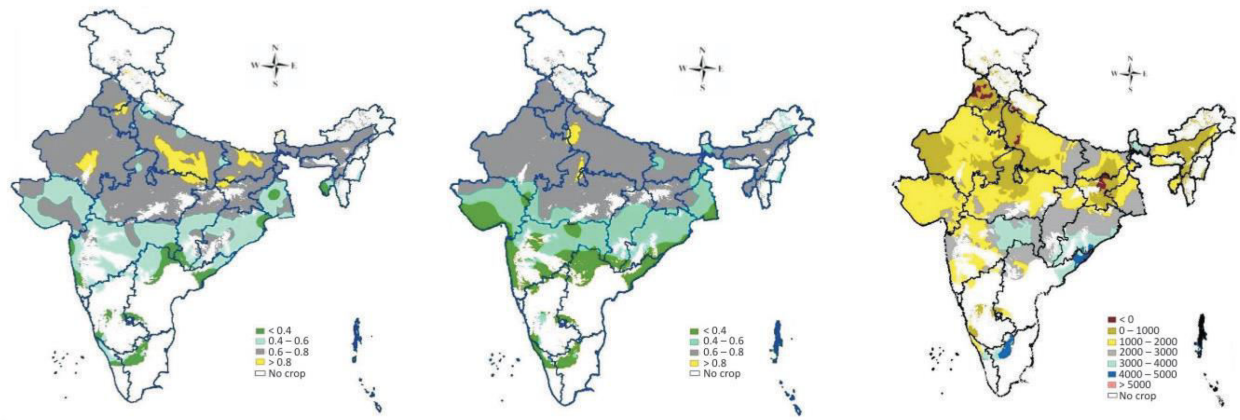

Fig.01: The harvest index under baseline (left) and climate change (middle) scenario of potato in India and change in stress degree hours (right) for potato cultivation in climate change scenario (Adapted from ICAR, 2012).

particularly West Bengal and southern plateau region, potato production may decline by 4 - 16%. It is primarily the mean minimum temperature during tuber growing period which affects potato yield. The increase in temperature due to climate change may decrease harvest index (HI) in large parts of Maharashtra, parts of Karnataka and Andhra Pradesh. Even though, in the traditional potato growing belt in the Indo-Gangetic plains, the HI may remain more or less the same but pockets of high HI likely to diminish. Analysis on the stress degree hours in winter potato growing regions showed that under the baseline scenario, most of the Indo - Gangetic plains region experienced 1000 to 5000 degree hours of stress due to a combination of both maximum and minimum temperatures. However, under climate change scenario (A1F1) the temperature stress increased further and the area with severe stress (9000 to 13000 degree hours) is projected to increase significantly in large parts of Maharashtra, Jharkand, Odisha and Gujarat. Similarly, pockets with extreme stress (>13000 degree hours) are projected to increase (ICAR, 2012).

Future action plan

Simulation studies indicate that climate change is likely to reduce yields of potato with spatial variations. Some regions will benefit from climate change. An integrated approach is needed to quantify climate change impacts. Moreover, adaptation and vulnerability assessments are required for bridging knowledge gaps. These strategies can accelerate the development of 'adverse climate-tolerant varieties' or 'climate-resilient varieties'. Adaptation technologies and regional assessments are required for minimizing the adverse impacts and maximizing the benefits, if any, due to climate change.

Suggested References

Dua, V.K., B. P. Singh, P. M. Govindakrishnan, Sushil Kumar and S. S. Lal. 2013. Impact of climate change on potato productivity in Punjab – a simulation study. Current Science Vol. 105(6): 787-794.

Ewing, E.E. 1997. Potato. In Wien H.C. (ed.) The Physiology of Vegetable crops. CAB International, Wallingford, UK, pp. 295-344

ICAR. 2012. Climate Change and Indian Agriculture: Impact, Adaptation and Vulnerability – Salient Achievements from ICAR Network Project, 2012, Eds. S. Naresh Kumar, Anil Kumar Singh, P.K. Aggarwal, V.U.M. Rao and B. Venkateswarlu. IARI Publication p. 32.

Mani, Muthukumara, Sushenjit Bandyopadhyay, Shun Chonabayashi, Anil Markandya, and Thomas Mosier. 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards. South Asia Development Matters. Washington, DC: World Bank. doi:10.1596/978-1-4648-1155-5. License: Creative Commons Attribution CC BY 3.0 IGO.

NATCOM. 2012. India: Second National Communication to the United Nations Framework Convention on Climate Change. MoEF, Govt. of India. PP: 340.

Naresh Kumar S, Govindakrishnan PM, Swarooparani DN, Nitin Ch, Surabhi J, Aggarwal PK. 2015. Assessment of impact of climate change on potato and potential adaptation gains in the Indo-Gangetic Plains of India. International Journal of Plant Production 9(1):151-170.

Singh, J.P., S.S. Lal and S.K. Pandey. 2009. Effect of climate change on potato production in India. Central Potato Research Institute, Shimla, Newsletter 40:17-18.

Singh, J.P. and S.S. Lal. 2009. Climate change and potato production in India. ISPRS Archieves XXXVIII-8/W3 workshop proceedings. Impact of climate change on Agriculture.

Saxena, S.P. and Anuj Kumar. 2019. Economic analysis of climate change impact, adaptation and mitigation on potato farming in India with special reference to Agra district. Indian Journal of Economics and Development. Vol 7 (3):1-7.

Chapter -28

NUTRITIONAL ASPECTS OF POTATO AND EFFECT ON HUMAN HEALTH

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Introduction: Potato (scientific name - *Solanum tuberosum L.*) is one of the most common and important food sources on our earth, potato is now on the world table in vegetables as the world's third largest food crop, and an important part of food, it is difficult to imagine food without potato. One of the most popular and recognized food is potato. Potatoes have spread around the world so quickly and are so widely accepted because they are store of energy and nutrition, including vitamins, minerals and essential organic compounds and have everything they need for health benefits. It is necessary as a staple diet for the world's greater population. Eating potatoes regularly ensures a good supply of water and ions in body. The reason for this is that potatoes are rich in potassium and eating potato with peels is always beneficial. It also contains calcium, iron and phosphorus. Potato contains several biochemical properties such as starch content, ascorbic acid, reducing sugars, non-reducing sugars, total sugars, phenolic content, flavonoids, polyamines, carotenoids, which are highly desirable in the diet because of their favorable effects on human health. Potatoes are known to have large amounts of vitamin C. Typically, a 100 gram contains about 20 mg of vitamin C. Additionally, it also contains vitamins A and B. The amount of water in potato is about 70-80 percent of their weight. Potatoes contain about 17% starch and are one of the best natural sources of starch. Potato is a very efficient food crop and staple food and produces more dry matter, protein and minerals per unit area in comparison to cereals. Apart from being a rich source of starch, potatoes contain the good quantity of small molecules and secondary metabolites which play an important role in a number of processes. In addition to supplying energy, potatoes contain a number of health promoting antioxidants such as phenolics, flavonoids, folates, anthocyanins and carotenoids and phenol content. Phenolic compounds play an important role in determining their organoleptic properties and symbolize as a large group of minor chemical constituents in potatoes. The range of flavonoids content in potatoes varies from 200 to 300 µg / g fresh weight. The flavonoids were reported to be catechin, epicatechin, eriodyctiol, kaempferol and naringenin. Flavonoids such as anthocyanins present in substantial amounts in pigmented flesh potatoes and range vary between 5.5 and 35mg/100 g fresh weight in potato tubers. Purple or red fleshed potato cultivars had two times the flavonoid concentration than that of white-fleshed cultivars and their concentration was significantly higher in skin.

The magical quality of potatoes is that most people around the world love potatoes. Potato diet can be prepared in dozens of ways. Various dishes can be prepared from roasted, fried, chopped and mashed potatoes.

Carbohydrates: The amount of total carbohydrates present in potato includes all of the sugar, starch and fiber. Potatoes are considered a starchy vegetable and healthy carbs. Carbohydrate is almost the major dietary source of metabolic energy and the main energy-providing nutrient in potatoes is carbohydrate basically in the form of starch. Two types of carbohydrate exist in potato 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. Glucose, sucrose and fructose are the main sugar present in potatoes.

Protein: Potato on a fresh weight basis contains about 2% protein which is considered as high quality protein. The high nutritive value of potato protein can be understood when its composition is compared with that of whole wheat. Apart from histidine, it contains substantially more of all the essential amino-acids this superiority is particularly striking for lysine, the amount present being similar to that in a typical animal protein. Proteins are important constituents of cellular membranes as well as various cytoplasmic structures. The essential nitrogen fraction in a potato tuber is protein nitrogen. In countries, where potato consumption is high this vegetable 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-thirds 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.

Fat: Potatoes are both fat-free and cholesterol-free. Potatoes are a virtually fat-free food and average fat content of potato is 0.1%., when boiled, baked or steamed. The little fat present in tuber gives palatability. About 60-80% of the fatty acid content is composed of unsaturated fatty acids (linoleic acid).

Vitamins: Of all the vitamins present in potatoes, vitamin C is in the predominant amount, which is a water-soluble and its main component is ascorbic acid. 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. Besides vitamin C, 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. The levels of some vitamins and minerals are reduced with cooking, but this can be minimized by baking or boiling with the skin on.

Minerals: Many types of important minerals and trace elements are present in potato and 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) reduce the risk of hypertension and stroke and help in 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: Potatoes also contain a variety of phytonutrients that possess 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. 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 mechanisms' 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. Potential nutritional and therapeutic properties of potato polyphenols are gaining attention of nutritionists. Potato tubers represent a significant source of antioxidants in human nutrition. Colored-flesh potatoes are a good source of health-benefiting dietary polyphenols. Potatoes should be considered as vegetables that may have a high antioxidant capacity depending on their flesh composition. Purple flesh potatoes contain anthocyanins in 69–350 mg anthocyanins/kg fresh weight range. The amount depends on whether the tuber flesh is coloured totally or only partially. A positive correlation between antioxidant activity and the content of total polyphenols and anthocyanins was found, concluding that mainly these compounds play essential role in antioxidant capacity of potatoes. Potato germplasm shows huge variation in terms of the phenolic content. The phenolic compounds are present in the potato peel and flesh; however, the peel is reported to have the highest amounts (Ezekiel et al., 2013). In potatoes, one of the most abundant flavonoids is catechin, ranging between 0 and 204 mg/100 g dry weight. Flavonols like quercetin and kaempferol rutinose are also present in potato tubers.

Dietary fibre: The inclusion of dietary fibers in food has become increasingly popular because of their positive effects on gut function and health, such as improved laxation and modulating intestinal microbiota populations. Some starch escapes digestion in the small intestine and on reaching the large intestine acts similarly to dietary fiber. The starch that is not digested is called resistant starch. 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 potatoes 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 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. Potatoes are a very popular food source for human health. 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.

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 greasy 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 to towards fattening. Potatoes are not contributing towards fattening because potato itself contains very low quantity of oil (0.1%) and it is absorbing oil only when deep fried.

Health Benefits of Potato: Since potatoes are primarily carbohydrates, they are easy to digest and this is why potatoes are a good diet for infants or people who are not able to work hard to digest, but require energy. Potatoes have high amount of fiber. It increases peristaltic motion and increases the secretion of gastric juice, which makes digestion easier and prevents conditions like constipation and protects the body from serious conditions like colorectal cancer. Health benefits of using potatoes include the ability to improve digestion, lower cholesterol levels, promote cardiovascular health, prevent cancer, and manage diabetes. These strengthen the immune system, reduce signs of aging, protect the skin, increase circulation, lower blood pressure and maintain fluid balance. Fiber in potatoes is also associated with scraping cholesterol from arteries and blood vessels, which improves heart health. Since potatoes increase the level of glucose in the blood, therefore, potatoes should be used in limited quantities for obese people or diabetic patients who are suffering from heart diseases.

Chapter -29

OVERVIEW OF POTATO PROCESSING IN INDIA

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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.

Potato is the fourth most important food crop and is a wholesome food. In India, potatoes have been utilized largely for consumption as fresh potatoes and the major part of potato harvest (approx. 68.5%) goes to domestic table consumption. Whereas, in the developed countries, table potato utilization is merely 31%, rest being frozen French fries (30%), chips and shoestrings (12%) and dehydrated products (12%). The processing of potatoes in the country was not in vogue till 90's and with the openings of organized processing by multinationals and indigenous players, potato processing industry has grown manifolds. During 2007-08 about 7% of potato production was used by processing industry and the sector is still increasing at a rapid rate. The pattern of Indian potato industry suggests that the demand for potatoes for processing purpose is expected to rise rapidly over next 40 years for French fries (11.6% ACGR) followed by potato flakes/ powder (7.6%) and potato chips (4.5%). The demand for processing quality potato is expected to rise to 25 million t during the year 2050.

Suitable areas for growing processing potatoes: Potatoes are grown in almost all agro-ecological zones in the country and different varieties are used in these zones depending on their productivity. Major quantity of potatoes is meant for consumption as table potatoes and is not suitable for processing. Dry matter and reducing sugars are the two parameters that are of utmost importance to the potato processing industries as described above. Although both of these traits are characteristic of a variety, but different environmental and agronomic conditions such as temperature during crop growth, day length, light intensity, soil type, availability of moisture, time of irrigation, rainfall, tuber maturity, *etc*. affect these traits. Out of all these parameters, temperature plays a major role in the dry matter and reducing sugars accumulation. Night temperature of 10°C or more during the last

30 days of crop growth improves the quality of the potatoes and produces potatoes with high dry matter and low reducing sugars. Areas suitable for potato processing in different parts of the country have been identified based on the temperatures during the later phase of crop growth (**Figure 1**). Generally varieties grown in the eastern and the southern parts of the country contain high dry matter and low reducing sugars.

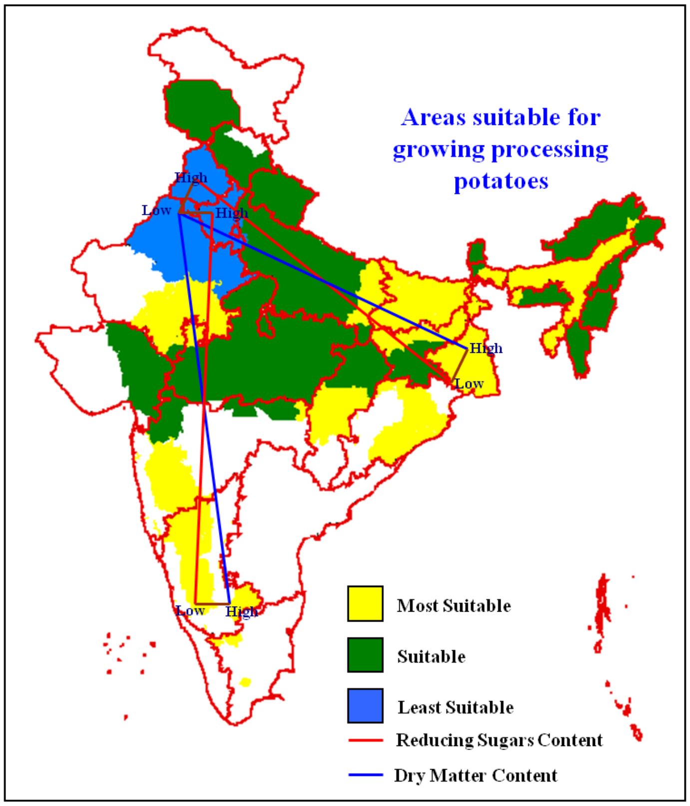

Figure 1: Map showing the areas suitable for growing processing potatoes.

Suitable Varieties: For preparing good quality potato chips, the dry matter of the tubers should be more than 20% and the reducing sugars content should be less than 150 mg/100g tuber fresh weight. If the level of reducing sugars is more than this, the fried product becomes dark in colour and unacceptable. The dark colour is formed due to a reaction called Maillard reaction between reducing sugars and amino acids. Maillard reaction takes place during the high temperatures of frying. For ranking of colour in potato chips, colour cards have been developed by ICAR-Central Potato Research Institute (ICAR-CPRI), Shimla. These colour cards have scores of 1-10, higher the colour score more is the browning. A colour score up to 4 is acceptable while 5 and above is unacceptable (**Figure 2**). The Maillard reaction which produces dark colouration in potato products is also responsible for production of another un-advantageous trait 'Acrylamide' as a by product of the reaction between amino acid asparagines and reducing sugars. Since acrylamide has been categorized as a carcinogen, there is high concern for its concentration in the processed potato products. All the Indian varieties have been profiled for the formation of acrylamide in the chips and French fries and the results have clearly shown that the varieties known for good processing quality having low reducing sugars also produce less acrylamide in the products and hence, it is recommended that for processing of potatoes, only processing varieties *viz*., Kufri Chipsona-1, 2, 3, 4, Kufri Himsona and Kufri Frysona should be used (**Table 1**). Growing of processing varieties in the identified suitable areas may ascertain the required quality for processing in potatoes.

Figure 2: Colour cards for potato chips.

Table 1: Important characters of some Indian potato varieties determining processing quality

Variety	Shape/Size	Dry matter (%)	Reducing sugars (mg/100g f. wt)	Acrylamide (µg/Kg f. wt)
Kufri Chipsona-1	Oval/Large	21-24	45-100	< 100
Kufri Chipsona-2	Round/Large	21-25	44-93	<100
Kufri Chipsona-3	Round-Oval medium	22-24	30-50	< 200
Kufri Chipsona-4	Round	21-23	60-140	< 200
Kufri Frysona	Oblong/ Large	22-23	<100	< 100
Kufri Himsona	Oval/ Medium	20-25	<50	< 200
Kufri Jyoti	Oval/Large	18-21	106-275	< 800
Kufri Lauvkar	Round/Large	18-20	200-250	< 300
Kufri Chandramukhi	Oval/large	18-20	250-324	< 500

These varieties are expected to reach to the farmers in coming years and are expected to 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. 3: 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 which 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 the production of high quality French Fries and is being utilized by the industries for this purpose.

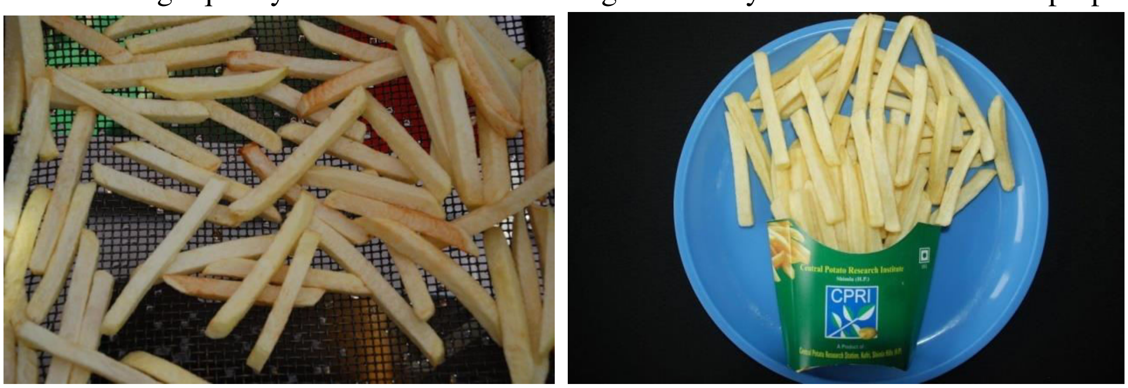

Fig. 4: French fries at frying and as sold from CPRI

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. 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. 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. As ingredient in custard, cream, candies and chewing gums. In textile industry it gives the finished cloth a smooth surface and better feels 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 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 sheets.

Fig. 5: Dehydrated chips

Scenario of potato processing

Organized sector : Potato chips production by the organized sector increased rapidly after the introduction of the liberalization policy of the government of India. The organized sector in the country produces about 30,000 tonnes of potato chips per year (Rana, 2011). Popularization of potato chips by companies such as Frito Lay India has led to fast incremental growth in potato chip manufacturing capacities. Frito Lay India and ITC retained approximately 31.55% share of potato chips market during 2010-11. Besides these, some other organized players as of today at National and regional levels include, Haldiram, Kishlay, Balaji, Uncle chips, *etc*. The demand for potato chips is likely to increase further, because of its increasing popularity as a convenient fast food especially in urban areas. The second popular product is potato *lachha* and *lachha* market is also dominated by branded manufacturers. *Aloo bhujia*, which contains potato only as one of the ingredients, is also quite popular and the *Aloo bhujia* market is dominated by Lehar and Haldiram.

Unorganized sector : Potatoes are being processed at small scale in rural India. Potato processing in the unorganized sector is of considerable importance in a country like ours where majority of the population cannot afford to purchase potato chips produced by the organized sector which costs Rs. 300 per kg. Potato chips produced by the unorganized sector costs Rs. 150 to Rs. 200 per kg. In India approximately 377 thousand tonnes of potato chips are prepared by unorganized sector (Rana, 2011). In Kolkata alone there are about 200 small units producing processed products from potatoes. Small scale potato processors are found in almost all cities and towns in the country and they produce a variety of products like potato chips, potato *lachha*, potato *bhujia*, potato pops, potato *papads*, dehydrated potato chips *etc*. Dehydrated potato chips and potato flour are being produced by several small scale potato processors in western UP.

Although the price of the potato chips produced by the unorganized sector is low, the quality of the chips is poor compared to that produced by the organized sector. The chips produced by the unorganized sector can have up to 80% browning, up to 50% broken pieces and 10% green chips.

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. 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.

Chapter -30

INTER-CROPPING AND POTATO BASED CROPPING SYSTEMS

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Cropping system is the kind and sequence of crops grown on a given area of soil over a period of time. It may be a regular rotation of different crops in which the crops follow a definite order of appearance on the land or it may consist of only one crop grown year after year on the same area. Within the scope of this definition, the term cropping system is often used interchangeably with multiple cropping, which in essential represents a philosophy of maximum crop production per unit area of land within a calendar year or some other relevant time unit minimum soil degradation. In retrospect we find that in India the concept of cropping system is as old as agriculture. Old permanent manuring experiments of Coimbatore, initiated during 1909 under irrigation condition with a cropping system comprising three crops in a year and multiple cropping by vegetable growers are some interesting examples.

Prevalent Cropping Systems in India: In practice, the farmer's decisions with respect to choice of crops and cropping systems is influenced by several forces related to infrastructure (household and custom hired storage facilities, transport facilities, post harvest handling and processing etc.), socio-economic factors (farmers' resources base, land ownership, size and type of land holding, dietary habits and household needs of food, fodder, fuel, fibre and finance; labour requirement and availability etc.), technological developments (level of mechanisation, irrigation facilities, improved varieties, plant protection needs etc), soil and climate, trade and marketing, all operating interactively at micro-level.

The economic return or monetary gain per unit area and time is one of the major considerations for adoption of a certain cropping system at farm as well as regional level. Its relative importance however, decreases under subsistence level of farming but increases with level of commercialization. Since profitability of the system as a whole or a component thereof, depends entirely upon input costs and process of the produce, it is highly vulnerable to changes in government policies, trade and market forces operating at a given point of time.

Yadav *et al.* (1998) have tried to enlist the major cropping systems of primary, secondary and tertiary importance, in terms of their spread in each district of the country. They identified more than 250 double cropping systems being followed throughout the country. But it is estimated that only 30 major cropping systems are prevalent in the country barring the areas under mono cropping due to moisture or thermal limitation. These 30 systemsare rice-wheat, pearlmillet-gram, pearlmillet-mustard, pearlmillet-sorghum, cotton-wheat, cotton-gram, cotton-sorghum, cotton-safflower, cotton-groundnut, maize-wheat, maize-gram, sugarcane-wheat, soybean-wheat, soybean-gram, sorghum-sorghum, groundnut-wheat, sorghum-groundnut, groundnut-rice, sorghum-wheat, sorghum-gram, pigeonpea-sorghum, groundnut-groundnut, sorghum-rice and groundnut-sorghum.

This is a very common observation that a large diversity of cropping systems exist under rainfed and dryland areas with an overriding practice of intercropping, due to greater risks involved in cultivating larger area under a particular crop. While in areas with assured irrigation only a few cropping systems are followed, they have a considerable coverage across the region and contribute significantly to foodgrain production at national level. In regions with assured irrigation facilities the major cropping systems are: rice-wheat, rice-rice, rice-groundnut, cotton-wheat, maize-wheat, pearlmillet-wheat, sorghum-wheat and sugarcane-wheat.

Designing new Cropping Systems: This has been one of the most favourable aspects in the past, to achieve the objectives of cropping systems research. Voluminous data have been generated, suggesting alternativecropping systems for diversified eco-edaphic conditions and resource base.

In bio-energetic terms, crop production may be viewed as conversion of visible spectrum of total electromagnetic radiation into chemical energy through the photosynthetic apparatus of crop plants. In crop production, efficiencies at several levels of organisation ranging from cellular level to eco-sphere are to be considered (Nairand Singh, 1973). Thus, biological efficiencies of cropping systems are governed by and dependent on several factors, most decisive being the type of crops, crop combinations, land use, nutrient and water management and agro-climate. The efficiency of a cropping system however has been viewed differently by different people depending upon their area of interest. For example:

- For a biological scientist the system's efficiency may be total biomass (dry matter) production per unit time per unit area.
- For an economistthe system's efficiency may be in terms of net returns per unit time or benefit: cost ratio, and
- For a resource management societies the system's efficiency is judged by use of efficiency of land resources (in temporal or spatial dimensions) and inputs (water, nutrients etc) in terms of yield per unit of resource used.

Nevertheless, a farmer wants a balance mix of higher biological productivity and economic returns with lesser risk for say more stability over a period of time under fluctuating environmental situations, saving on inputs and minimum degradation of soil resources with adequate infrastructural support in terms of input supply and marketing. As a result the new multiplecropping systems developed through research, rarely found favour with the farmers, unless duly supported by input supply and infrastructure. But wherever a prevalent cropping system becomes unsustainable, due to any reason, it is replaced by a new emerging system, many a time introduction of new crops or development of new crop varieties through technological innovations triggers the change and paves the way for new cropping systems which are relatively more productive/ profitable than the existing ones. These changes are necessitated by several reasons, such as:

1. Incidence of certain disease(s)/ insect pest(s) in epidemic form ina component crop.
2. Changes in labour availability patterns due to some social/ economic variations.
3. Changes in pricing structure of inputs/ products.
4. Creation of demand for certain commercial crop(s) on account of some socio-economic or political decisions which favour development of processing industry or international trade for some crop(s).
5. Technological breakthroughs, such as development of new genotypes in preferential crops, making their cultivation feasible in non-traditional areas.

As a consequence of any one or more than one of above actions, farmers' decisions swing in favour of better alternative crops, and new systems emerge at macro-level. During past 50 years researchers have been trying better alternative cropping systems to cater to diverse needs of farmers under different farming situations. These alternatives are continuously modified to commensurate with changing scenario on adoption of a new system. In general, while designing alternative cropping system, following common approaches are followed:

- Crop intensification
- Crop diversification
- Cultivar options

However, in practice, all these three approaches become inseparable. More often than not, all of them need to be considered as building blocks of a new system. Intensification is generally achieved by introducing an additional component crop in a predominant sequential, intercrop, or other multiple cropping systems by desirable adjustments in cultivars of one or all the component crops.

Potato based cropping system: The potato based cropping sequence recommended for different regions of the country is given below.

Bihar: Paddy-Potato-Mungbean; Groundnut-Potato- Mungbean

Punjab: Maize-Potato-Wheat ; Paddy -Potato-Wheat; Potato-Wheat-Green manure crop

Assam: Potato-Mung-Paddy (Transplanted)

Gujarat: Groundnut-Potato-Bajra

Madhya Pradesh: Soybean -Potato-Okra

Central Plains Zone: Rice–Potato–Japanese mint, Rice-Potato-Onion

Uttar Pradesh: Rice-Potato-Cowpea, Rice-Potato-Okra, Rice-Potato-Green Gram, Maize+BlackGram-Potato-Onion

Intercropping systems: Practice of raising two or more than two crops in mixed stands (sowing crop-mixtures without maintaining discrete rows for each crop), has been one of the typical characteristics of traditional agriculture in India. Component crops of the system were, in general dissimilar in nature in respect of rooting, growth cycle or nutrient water use pattern. This not only provided an assurance against failure of one crop or the other, due to vagaries of weather or disease/ pest epidemics in rainfed agriculture, but also enabled the farmers to enhance productivity through more efficient use of land, water and solar energy in vertical dimension. However, with the ingress of modern methods into agriculture, i.e., crop management with high input responsive varieties, assured water supply, higher fertilizer use, chemical control of diseases/ pests etc., culminated into declining popularity of this practice. But subsequently, it was widely recognised that intercropping systems (sowing two or more than two crops in distinct but proximate rows), designed on principle of scientific base in crop production, hold a great promise in increasing the land productivity under Indian conditions. Significant advantages in land-use efficiency, crop productivity and monetary returns in intercropping as compared with sole cropping of component crops, have been recorded throughout length and breadth of the country covering diverse agro ecological situations. Intercropping results in more efficient use of solar energy and harnessing benefits of positive interactions in crop associations. These advantages are, in general more pronounced in wide spread crops and stress environments.

Potato based intercropping: Potato being a short duration and fast growing crop is an ideal for intercropping with other crops. It can be successfully intercropped with sugarcane, as the cultural operations and resources used in both the crops are mutually complimentary. The potato-fennel and potato-onion intercropping in Haryana; potato-mustard and potato-linseed in Uttar Pradesh; and potato-wheat intercropping in Bihar are some of the profitable crop combinations. There are number of potato based intercropping system adapted in the country. Some of them are given below

1. **Potato+maize:** Intercropping of potatoand maize is economically more viable as compared tosole potato or sole maize. Potato crop in the intercropping systemoffers high return whereas maize provides insuranceagainst risks involved in potato crop. Intercropping ofpotato and maize is becoming popular in potato growing areas of north Bihar district. Besides,potato being a short duration crop with shallow rootsystem leaves significant residual nutrients and otherinputs which get utilised by the long duration inter-cropsthereby increasing environmentalsustainability.
2. **Sugarcane+potato:** Intercropping of sugarcane and potato has been very remunerative. For raising sugarcane and potato together, it is necessary to plant cane at 90 cm distance in the frist week of October with 75 kg nitrogen per hectare in furrow at planting. The levelling is done and one row of potato in the centre of sugarcane rows is planted. The distance between potato plants within rows is kept 15 cm. An extra dose of 60 kg nitrogen per hectare is applied to potato crop at planting. Sugarcane crop is irrigated according to the needs of potato crop. The potato crop will be ready for harvesting in January. Potato yield from intercropping ranges from 120 to 130 quintals per hectare which is about 50% of the yield obtained from pure crop of potato while yield of cane is not affected adversely as compare to pure crop of sugarcane. A doe of 75 kg nitrogen per hectare is applied to sugarcane crop after harvesting the potato.
3. **Potato+French bean:** It has been found that for Southern hills the potato + French bean intercropping at 75:50 population recorded significantly higher potato equivalent yield, land equivalent ratio and net returns over sole potato.

Conclusion

Multiple cropping systemcan assure an ecological balance and better use of resources. Fore going discussion reveals that crops yield increase with intercropping due to higher growth rate, reduction of weeds, pests and diseases and more efficient use of resources. Potato generally grown in a wider spacing which provides scope for intercropping/ multiple cropping with different crops. Pest and disease damage in inter-cropping/ diversified cropping is smaller ascompared tosole cropping.Intercrops maintain soil fertility as the nutrient uptake is made from both layers and also addition of legumes crop in the system also helps in sustaining the quality of the soil.

Suggested References

Yadav, R.L., Prasad, K., Gangwar, K.S. and Dwivedi, B.S. 1998. Cropping Systems and resource use efficiency. Indian Journal of Agricultural Sciences **68**: 548-558.

Nair, P.K.R., Singh, A.and Modgal. S.C. 1973. Cropping patterns involving rice andtheir management. Indian Journal of Agricultural Sciences**43**:70-78.

Chapter -31

POTATO GENETIC RESOURCES

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Genetic resources are collection of large number of genotypes representing genetic diversity of a crop species and its wild relatives. The centres of origin of crop species are the richest source of genetic diversity. Prof. S. M. Bukasov and his co-workers were the first to explore the centres of diversity of tuber bearing *Solanum* species during 1925-26 and in subsequent years to collect from remote and non-accessible areas the old land races, and primitive and wild species. In later years, explorations were done by scientists from other countries as well and valuable genetic material collected. Presently, the International Potato Centre (CIP), Lima, Peru, a CGIAR institute holds the largest potato germplasm collection. Other important collections are available with N.I. Vavilov Institute of Plant Industry, St. Petersburg, Russia; United States Potato Introduction Project (NRSP-6), Sturgeon-Bay, Wisconsin, USA; Dutch German Potato Collection (CGN), Wageningen, The Netherlands; Institute of Plant Genetics and Crop Plant Research (GLKS), Gross-Lusewitz, Germany; Commonwealth Potato Collection (CPC), Scottish Crop Research Institute (SCRI), Dundee, Scotland and Instituto Nacional de TecnologiaAgropecuaria (INTA), Balcarce, Argentina.

The total gene pool available for research and breeding purposes can be classified into 5 distinct classes, viz., i) present and past commercial varieties, ii) breeding lines and stocks in on-going breeding programmes, iii) old land races, iv) primitive edible wild species and their hybrids, and v) wild species. The wild and primitive species are valuable for their resistance to wide range of biotic and abiotic stresses. Land races possess quality characteristics and varieties and hybrids are of importance because of their adaptation and agronomic characteristics.

Potato germplasm collection in India: ***Collection:*** In India, the first attempt to collect indigenous variability of potato was made in 1940's. About 400 samples were collected from different parts of the country. Within this mass of variability, 16 varieties were identified as known exotic cultivars, while the rest were grouped into 16 distinct morphotypes whose original identity could not be established (**Table 1**). These cultivars represented some of the earliest introductions and their clonal variants, and were termed as *desi* varieties. Morphologically, these varieties resembled subsp. *andigena.* Among indigenous varieties Phulwa, Darjeeling Red Round and Gola were popular in the plains, whereas, European varieties Craig's Defiance, Great Scot, Up-to-Date and Magnum Bonum were popular in the hills.

Table 1 Indigenous and exotic potato varieties in India (Pushkarnath, 1969)

Indigenous varieties	Exotic varieties
Chamba Red, Coonoor White, Coonoor Red, Darjeeling Red Round, Desi, Dhantauri, Gola Type A, Gola Type B, Gola Type C, Phulwa, Phulwa Purple Splashed, Red Long Kidney, Sathoo, Shan and Silbilati	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

After the establishment of the Central Potato Research Institute (CPRI) in 1949, collection, conservation, evaluation and documentation of potato germplasm, and its utilization, became a regular activity at the institute. Acquisition of exotic germplasm from different countries continued. This activity was accelerated after the establishment of the International Potato Centre (CIP) at Lima, Peru in 1972. Over a period of time, however, some of the old indigenous collections got riddled with viruses and were lost. To retrieve these, and also to collect any other variability not available in the collection, surveys were conducted during 1983-1992 in Uttar Pradesh, Bihar, West Bengal, Assam, Meghalaya and Himachal Pradesh. In all 621 samples were collected, studied for various morphological characters and grouped into 125 morphotypes.

In India, the CPRI presently holds a modest collection of over 4,500 accessions, comprising of cultivated species (subsp.*tuberosum*and *andigena*), parental lines and wild/semi-wild tuber bearing *Solanum* species (**Table 2**).

Table 2. Potato germplasm holding at CPRI, Shimla

Material	**No. of accessions**				**No. of donor countries**
	Tuber	***In vitro***	**True seed**	**Total**	
a) Tuberosum (Cultivars / parental lines) **Indian**					
Cultivars bred at CPRI	56	60	-	**60**	
Advanced hybrids	86	50	-	**96**	
Indigenous varieties	51	107	-	**107**	
Indigenous samples	97	42	-	**97**	
Exotic	1837	2700	-	**2840**	30
b) Andigena	723	77	-	**762**	5
c) Wild/ semi-cultivated sps.	123 (42 species)	130 (29 species)	294(70 species)	**540 (125 species)**	5
Total germplasm				**4502**	

This is the largest potato collection in South Asia. These germplasm accessions have been imported from 30 countries based on national requirement. The institute, at present, has in its collection about 123 wild species consisting of diploids, triploids, tetraploids, pentaploids and hexaploids.

Conservation

At CPRI, the available germplasm is being maintained by *in vivo* clonal propagation, *in vitro* clonal propagation and sexual propagation.

***Field gene bank orIn vivo clonal propagation*:** The germplasm is maintained through clonal propagation in glasshouses at Shimla and as duplicate sets in fields at Kufri and Jalandhar (**Fig. 1**). All *S. tuberosum* subsp. *tuberosum*and a part of subsp. *andigena*accessions are maintained and multiplied to facilitate their evaluation for adaptability to different agro-climatic regions as well as for resistance/tolerance to various biotic/abiotic stresses. This is the traditional method of conservation and germplasm are exposed to viral and mycoplasmal diseases resulting in degeneration of germpalsm stocks. Loss of material due to natural calamities and loosing identity due to mechanical mixtures or wrong labelling are the other risks associated with this method. Labour and maintenance costs are also high.

Fig. 1. In vivo clonal propagation

True potato seed or sexual propagation: True potato seeds (botanical seeds) produced through sexual propagation, are easy to produce and maintain in disease free condition. The wild and semi-cultivated potato species are presently maintained in true seed form. True seeds are produced by selfing and/or sib-mating. Sib--mating is often resorted to in diploid species most of which are self-incompatible. True seeds for short-term storage are maintained at 10-15^{0}C at the CPRI, and for long-term storage in cold modules at the National Bureau of Plant Genetic Resources, New Delhi. Preservation of germplasm as true seed is less laborious and inexpensive as true seeds have low moisture content and can be kept at low temperature for many years. In addition it is easier to maintain the material free of pathogen as only few viruses are known to be seed transmitted.

***In vitro conservation*:** The ability of plants to grow under aseptic conditions has resulted in development of *in-vitro* techniques for germplasm conservation. By this technique, nodal cuttings are micropropagated on MS media containing 40 g/litre sucrose and 20 g/litre mannitol. Plantlets are incubated under16 h photoperiod at 5-6^{0}C. Under these conditions, potato plantlets can be preserved up to 30 months without sub-culturing. This method has several advantages, viz., a) maintenance round the year in diseases-free condition, b) safety from natural calamities, c) possibility of conserving large number of genotypes in limited space, and d) easy exchange in *in vitro* form. Presently, more than 3,000*tuberosum*accessions are conserved in this form (**Fig.2**). Disadvantages are that growth retardants may alter plant morphology and can induce DNA methylation (Harding, 1994) and soma-clonal variation (Kumar, 1994).

Fig. 2. Slow-growth in-vitro conserved potato germplasm

Cryo-preservation: This is the best method to date for long term conservation of vegetatively propagated plants. By this method plant material is frozen at ultra low temperature around -196^{o}C of liquid nitrogen. This technique was derived from the observations that in temperate areas plant species could survive below freezing temperatures. At ultra low temperatures, cell division, metabolic and biochemical processes are arrested and thus the plant material can be stored without deterioration or modification for a long period of time. Tissues can be stored virtually indefinitely with low labour costs and little space. Work input is needed mainly at the beginning when samples are prepared and cooled. Once in storage, only refilling of liquid nitrogen is needed. Other advantages are prevention of infections and genetic changes. Further, the degree of cleanliness is highest for cryopreserved explants than *in vitro* and field cultures. Cryopreservation is only useful for long term storage, because the material is normally not ready for immediate utilization and re-warming and growth of plant material takes some time.

Evaluation

To make best use of genetic resources in breeding programmes, it is necessary to have sufficient description and evaluation data on desirable as well as undesirable traits in a gene pool. Where such information is not available, passport data on characteristics of the natural habitats of species are of great importance. For example, late blight resistant species are found in Mexican gene pool, where late blight fungus (*Phytophthorainfestans*) has been found to reproduce sexually. Similarly, frost resistance is found in species capable of growing at altitudes above 3,500 meters. Some important sources of resistance to major potato diseases and pests, and to abiotic stresses are listed in Table 3.

Table 3. Wild species as sources of resistance to various diseases

Diseases		Sources
Viruses -	PVX	*S. acaule, S. berthaultii, S. brevicaule, S. chacoense, S. commersonii, S. curtilobum, S. phureja, S. sparsipilum, S. sucrense, S. tarijense and S. tuberosum* ssp. *andigena*
	PVY	*S. acaule, S. chacoense, S. demissum, S. gourlayi, S. phureja, S. rybinii, S. stoloniferum, S. tuberosum*ssp. *andigena*
	PLRV	*S. acaule, S. brevidens, S. chacoense, S. demissum, S. etuberosum, S. raphanifolium, S. stolonifrum*and *S. tuberosum*ssp. *andigena*
Late blight	Vertical	*S. cardiophyllum, S.demissum, S. ediense, S. stoloniferum*and *S. verrucosum*
	Horizontal	*S. berthaultii, S. bulbocastanum, S. chacoense, S. circaeifolium, S. demissum, S. microdontum, S. phureja, S. pinnatisectum, S. polyadenium, S. stoloniferum, S. tarijense, S. tuberosum*ssp*andigena, S. vernei*and *S. verrucosum*
Wart		*S. acaule, S. berthaultii.*
Common scab		*S. chacoense, S. tuberosum*ssp. *andigena*
Bacterial wilt		*S. chacoense,S. microdontum, S. phureja, S. sparsipilum*and *S. stenotomum*
Cyst nematodes		*S. acaule, S. berthaulti , S. boliviense, S. bulbocastanum, S. capsicibaccatum, S. cardiophyllum, S. demissum, S. gourlayi, S. kurtzianum, S. leptophyes, S. multidissectum, S. oplocense, S. sparsipilum, S. spegazzinii, S. sucrense, S. tuberosum*ssp. *andigena*and *S. vernei*
Root knot nematode		*S. bulbocastanum, S. cardiophyllum, S. chacoense, S. curtilobum, S. hjertingii, S. kurtzianum, S. microdontum, S. phureja, S. sparsipilum and S. tuberosum*ssp. *andigena*
Aphids		*S. berthaultii, S. bukasovii. S. bulbocastanum, S. chomatophilum, S. infundibuliforme, S. lignicaule, S. marinasense, S. medians, S. multidissectum, S. neocardenasii, S. stoloniferum*
Frost		*S. acaule, S. ajanhuiri*
Heat and drought		*S. acaule, S. bulbocastanum, S. chacoense, S. commersonii, S. gourlayi, S. megistacrolobum, S .microdontum, S. ochoae, S. papita, S. pinnatisectum, S. spegazzinii* and *S. tarijense*
High protein content		*S. phureja* and*S. vernei*.

Evaluation of genetic resources is a regular activity at CPRI, Shimla and its regional stations located in different parts of the country. In early stages of potato research in India, large numbers of European varieties were evaluated to identify cultivars adapted to temperate long day conditions (hills) and sub-tropical short day conditions (plains). Simultaneously, attention was paid to identify suitable parental lines for Indian potato breeding programmes. The germplasm accessions were thus evaluated for economic characters like adatabililty, resistance to late blight, bacterial wilt, wart, potato tuber moth, powdery scab, charcoal rot, hopper burn, stem, tuber dormancy, tuber dry matter and protein content, nutrition, keeping quality, early planting, foliage maturity, processing attributes and cold sweetening.

The germplasm accessions have been studied for flowering and fruiting behaviour and True Potato Seed (TPS) attributes. These have also been characterized for morphological traits like tuber skin colour, tuber shape, eye depth, flesh colour (**Fig. 3**) and flower colour as per descriptor of the International Board for Plant Genetic Resources (now IPGRI). The germplasm accessions found promising for various characters have also been studied for combining ability). A list of good general combiners for various characters is given in **Table 4**.

Fig. 3. Tuber size, shape, skin colour, eye depth (A), and tuber flesh colour variability (B) in potato germplasm

Table 4.General combining ability of some germplasm accessions (Gopal and Gaur, 1997)

Characters	**General Combing ability**		
	Good	**Average**	**Poor**
Tuber yield	CP2000 (I-1062), CP2110 (CFK69.1), CP2334 (AL575), CP2346 (F-6), CP2370 (Muziranzara), CP2378, (Poos.16), Katahdin, K. Jyoti, K. Badashah, K. Bahar, EX/A-680-16, EX/B-687	CP2407 (Montsama), CP2417 (MEX 750838), K. Jeeven, K. Kundan, K. Khasigaro, K. Dewa, Up-to-date, EX/A-679-10	CP1710 (Kerr Pondy), CP2132 (Tollocan), CP2351 (Tobique), CP2401 (CIP702867)
Tuber Number	CP2378, (Poos.16), CP2413 (Piratini), K. Kuber, K. Khasigaro, K. Dewa, EX/A-680-16, EX/A-723, EX/A-687	CP2346 (F-6), CP2351 (Tobique), CP2401 (CIP702867), CP2417 (MEX 750838), Dekama, Up-to-date, K. Jeeven, K. Sheetman, K. Kundan	CP1710 (Kerr Pondy), CP2334 (AL575) CP2370 (Muziranzara), CP2407 (Montsama), CP2132 (Tollocan), CP2416 (MEX750826), Katahdin, K. Jyoti, K. Badashah, K Bahar
Average tuber weight	CP2334 (AL575), Katahdin, K. Jyoti, K. Badashah, K Bahar, EX/A-680-16	CP2407 (Montsama), CP2416 (MEX750826), CP2417 (MEX750838), CP2346 (F-6), CP2370 (Muziranzara), CP2378 (Poos.16), Dekama, Up-to-date, K. Jeeven, K. Kundan, EX/B-687	CP2401 (CIP702867), CP2413 (Piratini), CP2132 (Tollocan), CP2351 (Tobique), K. Sheetman, K. Kubar, K. Khasigaro, EX/A679-10, EX/A-723
Tuber dry matter	CP2346 (F-6), CP2370 (Muziranzara), CP2378 (Poos.16), CP2416	CP2334 (AL575), CP2407 (Montsama), CP2413 (Piratini)	CP2351 (Tobique) CP2401 (CIP702867),

	(MEX750826), CP2417 (MEX750838),		
Resistance to late blight	CP1673 (Dr.Mclntosh), CP2030 (G.6246), CP2333 (AL624), CP2378 (Poos.16)	CP2011 (CIP676082), CP2370 (Muziranzara), CP2381 (CFI69.1), Desiree	CP2013 (Atzimba), CP2110 (CFK69.1), Dekama, K. Badashah
Resistance to early blight	EX/A-680-16	CP2132 (Tollocan)	CP1710 (Kerr Pondy), EX/A-723

Suggested References

The information on passport data, morphological characters and reaction to various biotic and abiotic stresses of subsp. *tuberosum* and subsp. *andigena*collections, available at the CPRI, has published from time to time in the form of germplasm catalogues (Pal and Pushkarnath, 1951; Pushkarnath, 1964; Gaur *et al*., 1984a; Gopal *et al*., 1992; Birhman*et al*., 1998; Kumar *et al*., 2005d ; Kumar et al., 2008).

Pal, BP and Pushkarnath, 1951. Indian potato varieties. ICAR, New Delhi. Misc. Bull. 62, 63 p.

Pushkarnath, 1964, *Potato in India- Varieties*. ICAR, New Delhi. 466p

Gaur PC, PC Misra and NM Nayar. 1984a. *Catalogue of potato germplasm collection group Tuberosum*. CPRI, Shimla. Tech. Bull. No.13. 38 p.

Gopal J, RK Birhman and CL Khushu. 1992. *Inventory of potato germplasm* (*group Tubrosum*) *collection*, CPRI, Shimla. Tech. Bull. No. 36, 47p.

Birhman, RK, J Gopal, SK Kaushik, GS Kang, R Kumar, TA Joseph and SK Luthra. 1998. Inventory of Potato Germplasm (Group Andigena Collections). CPRI, Shimla. Technical Bulletin NO-46, 51p.

Kumar V, J Gopal, R Kumar, SK Luthra, SK Kaushik and SK Pandey. 2005. Inventory of cultivated potato germplasm. CPRI, Shimla. Technical Bulletin No 70, 162p.

Kumar R, V Kumar, J Gopal, SK Luthra and SK Pandey. 2008. Inventory of Potato Germplasm (Group Andigena) Collection. CPRI Shimla. Technical Bulletin No 86, 100p.

Future thrusts

Central Potato Research Institute is the National repository for potato germplasm collection in India. Efforts are being made to improve quarantine facilities to handle large import of germplasm to augment the available collection. Infra-structural facilities are also being strengthened to maintain large collection in *in vitro.*

The present-day Indian potato varieties have a narrow genetic base for most of the economically important characters. The genetic base of 59 potato varieties developed over past 60 years can be traced back to only 91 parents. Most of these parents represent tetraploid potato cultivars with negligible representation of *S. tuberosum* subsp. *andigena* and wild/cultivated species. There is need for better utilization of *S. tuberosum*subsp. *andigena,* which is adapted to short days and is suitable for sub-tropical plains. Agronomically improved parental lines with acceptable tuber shape, colour, depth of eyes and maturity need to be developed from *andigena* source and assessed for combining ability for economic characters for better utilization in breeding programmes. Potato tuber moth and Bacterial wilt are major problems of the crop in mid hills and in the plateau region. So far no reliable resistance source have been reported for both of them. Hence, the available potato genetic resources need to be extensively evaluated for these traits. Other characters of interest are processing attributes including cold chipping and nutritional components for which the collection needs to be exploited.

The under exploitation of wild and cultivated species in variety improvement programmes is primarily due to long time required in developing desirable parental lines. Gene bank collections, therefore, need to be transformed into "working collections". In this context, biotechnology can offer opportunities for horizontal introgression of genes into cultivated potato across the trans-specific barriers. Characterization of accessions for specific genes in terms of their allelic constitution is also required to be done. Work on DNA fingerprinting needs to be strengthened to have a catalogue for monitoring genetic integrity of germplasm collection from time to time to make the system WTO and TRIPS compatible. In nutshell, a core collection and focused approach holds the key to utilization of potato genetic resources in future.

Chapter -32

INDIAN GOOD AGRICULTURAL PRACTICES (GAP)

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World market is witnessing an increasing demand for healthy and hygienic food. Local as well as global consumers are getting serious about healthy, hygienic food and cautious about chemical residue in food and its consequences on health. Also, agriculture production is facing complex problems like climate change, increase in biotic and abiotic stresses, deterioration of natural resources, rising cost of cultivation etc. which has put forward many challenges to produce quality food. This changing scenario has led to the genesis of Good Agricultural Practices (GAP) with the objective to develop common standards and procedures for food production and marketing. The concept of GAP is based on fundamental principles of safe and quality food production, conservation of environment and natural resources, sustainable farming and economic and social sustainability. Food and Agriculture Organization (FAO) describe GAP as collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability (FAO, 2003).

IndGAP certification scheme: Quality Council of India (QCI) has launched IndGAP certification scheme in September, 2014 with the objective of production of safe and hygienic food at the Indian farms and providing the opportunity of farm certification to a local standard at low cost. IndGAP is inclusive of GlobalGAP standards, best practices, prevalent industry standards and related ISO standards and relevant guidelines. The IndGAP standards comprises of control points and compliance criteria as per national farming practices and regulatory requirements. The scheme is framed as per the growing need of quality and safe food in domestic and international market. It takes into account not only the large farms but also address the small and marginal farmers. The focus of IndGAP standards is to address hygienic and quality food production taking into consideration workers' health and safety, conservation of the environment and farm biodiversity, waste management and recycling etc. The IndGAPBasic is meant for small or marginal farmers or for those who are interested to introduce quality farm production for fresh consumption or for processing. Whereas, IndGAP Premium is targeted for large farms or farmer's group interested to seek certification for their farm produce, either for fresh consumption or for processing purpose.

Advantages of IndGAP certification

- Enables farm produce to be globally accepted by following GlobalGAP norms.
- Ensures better price realization to the produce in domestic as well as international market.
- Secure and strengthen the livelihood of small and marginal farmers.
- Ensures safe, hygienic and quality food production.
- Create new market opportunities for farmers and exporters.
- Facilitates capturing new market advantages by modifying management in supply chain.

- Helps to safeguard the worker's health and safety at working places.
- Minimize wastage of natural resources.
- Creating trust among producers, suppliers, traders and consumers.

Scope of certification

- **IndGAPBasic:** This covers the basic requirement of GAP and is applicable for all farming practices in sustainable manner for maintaining quality and food safety of agriculture of agriculture produce. This standard covers control points and compliance criteria mainly for farms that are either small or marginal or the ones that aspire to introduce quality in their farms for the farm produce in fresh unprocessed form or for further processing.
- **IndGAP Premium:** It encompasses control points and compliance criteria for any farm wanting to be assessed for global standards for farm produce in fresh unprocessed form or for further processing. The main components of this standards are all farm base module and crop-based module:

  a) All farm based module

  b) Crop based module

  - Fruits and Vegetables
  - Combinable crops
  - Tea
  - Green coffee

Key components of IndGAP

Site selection

- Risk assessment of new sites for vicinity to industries, brick kilns, toxic waste, heavy metals, industrial and urban effluents, river, canals all possible contamination, land reclamation, irrigation water quality and drainage etc should be done. It helps in appropriate crop management.
- If irrigation is required, the farm should have access to reliable source of water.
- Risk management plan should be prepared to minimize all identified risks.
- Previous years' meteorological data should be considered for judging the suitability of the site for a particular crop production system.

Soil conditions/management

- Soil testing for precise nutrient application, soil amendments, site-specific nutrient.
- Physico-chemical analysis of soil, mapping of field's nutrient status to understand the suitability of the land for a particular crop and cropping system.
- Follow region specific recommended package of practices for cultivation.
- If the soil is prone to erosion, then adoption of soil conservation (cultural or mechanical) techniques is essential.

Seed material

- Grow most suitable variety recommended by central and state agencies as per region/agroecology.
- Adopt recommended agro-technologies for the selected variety.
- Quality of planting material viz., seed source, seed health, purity, seed treatment to be critically followed.
- Keep all required records in compliance with national/ state legislation and GAP standards.

Field management

- Precision in variety specific planting for optimum seed rate, planting depth and geometry, plant population etc.
- Practice of crop rotation.
- Keep record of previous years cropping sequences.
- Optimum soil tilth and judicious soil preparation.

Nutrient management

- Soil test based, variety specific and mandatorily integration of organic and inorganic sources.
- Ensure supply of micro-nutrient requirements of a crop.
- Organics, green manure and recycled material should be the first choice.
- Risk assessment of well treated/ composted material is necessary for disease transmission, weed seed dispersal and heavy metal content.
- The sources of organic manures, their nutrient content must be known.
- Farmyard manure, sheep/ poultry manure, oil cakes or slaughterhouse wastes must be fully decomposed prior to their application.
- Use of raw human sewage, municipal and industrial sludge is completely banned.
- Bio-fertilizer (specifically microbial) should only be applied after recommendation from technically competent source.
- Extra requirement of a crop should be met by judicious use of inorganic products only after utilization of organic sources. Their source and nutrient contents should also be known.

Water management

- Water quality should be tested and assured for its use in irrigation, post-harvest washing, treatment etc.
- Region and variety specific water requirement should be known and accordingly a plan can be prepared for judicious and efficient use of water.
- Risk assessment to be done for probable microbial, chemical and physical pollutants in irrigation water.
- Implement adequate measures to prevent the flow of contaminated water into fields.
- Proper drainage, water harvesting and conservation methods should be followed at farm site.

Weed management

- Adopt recommended, crop specific integrated weed control strategy.
- Initial flush of weeds to be effectively controlled to ensure weed free environment for crop.
- Cultural (crop rotation, hot weather cultivation, green manuring, proper seedbed preparation, precise planting and placement of manures and fertilizers, mulching etc.) and mechanical (manual or mechanical intercultural operations) weed control measures to be prioritized.
- At last, use of only recommended herbicides with prescribed doses applied at right crop growth stage.

Disease and pest management

- Prepare a comprehensive crop protection plan.
- Follow recommended integrated pest and disease management practices.
- Cultural, bio-agents and biological control measures should be preferred.
- Use of chemicals should be restricted as a last resort with technical advice and recommendations.
- Only registered plant protection products recommended for specific crop should be used.
- Observe pre-harvest intervals for specific plant protection products.
- Do not repeat the spray schedule without any recommendations.
- When chemical pesticides are used, the residue analysis of final product should be carried out through certified laboratory.

Harvest and post-harvest management

- Physiological maturity period of the cultivated variety should be known and harvesting to be done accordingly.
- Harvesting, handling, packaging and storage must be done as recommended.
- Storage and packing space should be covered, ventilated, maintained clean and contamination free.
- Storage area must be kept free from animals and rodents and follow proper measures for their control.
- Follow pest control procedures for storage/ packing space.
- Different varieties must be stored separately with proper labels and signs to avoid their mixing.
- Method for sorting, washing, grading and drying should be well defined and equipment should be well synchronized and calibrated.
- Standards of grading, purity of produce must be strictly followed.
- Water used in washing should be of required standards and quality.
- Proper norms should be followed for packaging material, weight per packet, handling of farm produce during temporary storage and container loading.

Storage of agro-Inputs

- Fertilizer should always be stored in a separate, covered, clean, dry place and away from plant protection chemicals and farm produce.
- Similarly, agro-chemicals should be stored in separate, sound storage under cool, dry and secured condition away from farm produce.
- Storage space should be well protected from spillage, leakage and seepage to avoid surrounding contamination.
- Provide facilities for accurate measurement of chemicals.
- Mixing of chemicals can be done in storage facility.
- Spillage can be dealt with by equipping mixing area with containers of absorbent inert material like sand.
- Surplus mixture or tank washing should be disposed-off at designated fallow area in the farm.
- Empty containers of plant protection products can only be used for the same product at farm, otherwise safe mechanism is to be followed for their disposal.
- Similarly, expired chemicals should either be disposed-off by following proper procedure or securely maintained in storage.

Personnel

- Key resource person at farm (farmer and supervisor) must be familiar with all aspects of crop production.
- Workers should also have training on specific skills, hygiene and safety aspect.
- Persons responsible for plant protection measures at farm must have training for integrated pest and disease management.
- Workers must be provided with proper gears/ safety cloths during application of plant protection products for their personal safety and health.
- Train the supervisor and workers to maintain hygiene during handling, sorting, washing, grading and packing of produce.
- All workers should have proper knowledge and training for their respective work such as handling and application of chemicals and fertilizers, operating farm machines and equipment, health and safety measures, wearing of protective gear, clothing and shoes etc.
- Minimum one worker is to be trained in first aid assistance and must be present during all the farm operations.

Equipment

- All machinery used in fertilizer and chemicals application, harvesting and post-harvest handling should be calibrated as prescribed by the manufacturers.
- Machinery and equipment should be in good condition and maintained at a regular time frame.
- Regular and cleaning of equipment parts is important.

- The material (specifically metal) coming into direct contact should be of good quality to avoid any contamination. Equipment that pose a risk of hazardous metallic contamination of the harvested crop should be avoided.
- Records of their regular maintenance and calibration should be maintained.

Workers health, safety and welfare

- A farm should have a written risk assessment document for various operations which should be updated periodically.
- There should be a written policy on health, safety and hygiene. This will include risk assessment issues viz., accident, emergency, hygiene etc.
- Adequate precautions to be taken to prevent on farm accidents of farm equipment/machinery.
- A comprehensive procedure for handling emergency situations should be developed in local language and in pictorial format at farm. It should include farm and building map, farm address, contact person responsible for worker's welfare, nearest communication point of phone, important phone numbers (ambulance, hospital, fire brigade and police), emergency exits, location of fire extinguishers, emergency cut off for electricity, gas, water supply etc.
- Permanent warning signs should be prepared in readable ways to indicate hazardous sites such as fuel tank, plant protection storage, workshops, electricity control panel, disposal area for chemicals, etc.
- Electrical installations, plant protection storage, fuel tanks and risky equipment must have adequate safety measures.
- Provide designated areas and clean, hygienic facilities for hand washing, eating, and toilets etc.

Record keeping and internal inspection

- Maintain a minimum record of past two years or more from the date of the first/ previous external inspection as advised by the certifying agency.
- Keep a record of all farm operations with exact date (ploughing, sowing, weeding etc.), fertilizers (stock, source, quantity applied and time of application etc.), irrigation scheduling, weed control schedule, plant protection product (chemicals, doses and mode of application etc.) with exact dates of application.
- All the IPM measures, various approaches adopted for disease and pest management, chemicals including their storage, crop stages and quantity used etc. should be recorded.
- Maintain a record of harvesting procedures, handling and storage, etc.
- Minimum one internal self-assessment per year to be taken against the required standards.

Traceability

- Each consignment of produce must be legibly marked with details of variety, month and year of harvest, name, address of grower etc., following trade practices/ legal requirements.
- Likewise, there should be documented identification and traceability system of produce so that produce can be traced back to registered farm including particular field and tracked forward to the immediate customer.

Waste and pollution management, recycling and reuse

- Identify and list all possible waste products and source of pollutants.
- Prepare a comprehensive, documented strategy after review of current practices for minimum wastage during production, recycling and re-use of waste.
- Disposal procedure for non-recyclable materials should exist at the farm.
- Facility should be developed for on farm organic waste composting.
- Farm and premises should be kept free of litter and waste.
- Farm must have separate identified areas for storing/ decomposing different types of litter and waste.

Environment and Conservation

- There must be a written action plan for improving habitats and to increase farm biodiversity.
- A baseline survey of flora and fauna should be done and aftereffects on agriculture should be studied to improve the action plan.
- Unproductive site (lowlands or unfertile soils) may be identified for conserving natural flora and fauna.
- Fuel efficient farm machinery and equipment should be selected to minimize the use of non-renewable energy.
- Renewable sources of energy like solar, wind etc., may be integrated in farm power supply plan.
- Regular maintenance and servicing of equipment should be done for efficient energy consumption.
- Maintain a record of all the activities for external audit.

Complaints

- Complaint procedure must be in place and made available on request for GAP related issues. This should have an appropriate recorded follow up action.
- A documented recall procedure for produce should be adopted and person responsible for taking decisions must be identified.
- Recall procedure must be speedy, transparent and accurate. For this, GlobalGAP traceability and recall standards may be followed.

Subsidy for this scheme

- Agriculture and Processed Food Export Promotion Scheme of Agriculture and Processed food products Export Development Authority (APEDA) for the Medium Term Expenditure Framework (2017-18 to 2019-20). (http://apeda.gov.in/apedawebsite/Announcements/SchemeGuidelinesMTEF27042018.pdf)
- Ministry of Agriculture for mission on Integrated Development of Horticulture has subsidize the IndGAP certification cost (https://midh.gov.in/PDF/midh(English).pdf).

ICAR-CPRI has already compiled IndGAPBasic and IndGAP Premium protocols for potato production as per Quality Council of India's guidelines. The institute is working on technical compliance of GlobalGAP for exporting quality potato production.

Useful sites:

Quality Council of India: http://qcin.org/india-good-agriculture-practices.php
GlobalGAP: https://www.globalgap.org
ICAR-CPRI: http://www.cpri.icar.gov.in

Chapter -33

RECENT APPROACHES IN NUTRIENT MANAGEMENT IN POTATO

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Precise and timely application of inputs are becoming domineering need in present day agriculture to make farming more efficient and environment friendly. A persistent balanced supply of nutrient elements is essential for normal plant growth. Nutrient management today is handling a complex dynamics of integrating soil, crop, weather, and management practices to achieve the best balance for maximizing profit while contributing to the conservation of our resources. It aims to achieve the goals of optimizing nutrient use efficiency, yields, crop quality, and economic returns, while reducing off-site transport of nutrients that may impact the environment. Several approaches have been advanced suiting to different production systems and with advancement of science several smart management options has progressed. Important issues to be addressed for smart management of nutrients are achievable optimum yields and/or crop quality, the available management options (including sources, timing and method of application, and timing of nutrients using a budget based on all sources and sinks active at the site) and the management of soil, water, and crop to minimize the off-site transport of nutrients from nutrient leaching out of the root zone, surface runoff, and volatilization (or other gas exchanges). In addition in plant system, nutrient interactions also needs to be governed for better production level and quality. Several approaches like soil test crop response, targeted yield equations, site specific nutrient management, real time N management using chlorophyll index, diagnosis and recommendation integrated system (DRIS), variable rate application technology, use of GIS and remote sensing controlled release formulations for targeted delivery of inputs through nano or polymeric materials is of tremendous interest in achieving smart soil nutrient management. Recent times it has become almost imperative to develop recommendations using decision support systems based on various models and fine tune in season nutrient application depending upon real time information on crop health.

General recommendations: The optimum rate of NPK fertilization in different zones based on tuber yield response in trials conducted in different potato growing agro-climatic zones in India is given. Processing varieties of potato Kufri Chipsona 1 and Kufri Chipsona 3 and the likes grown specifically to produce large processing grade tubers require higher rate of fertilization by 33 to 50% than recommended. Fertilizer management of potato crop is usually based on averages on regional basis known as package of practices. These recommendations take into account the general growing conditions of the regions including soil health, climate/weather and cultivars grown in that part. However, this approach give most crude recommendation as taking single value for thousands of hectare crop area of any agro-eco region is too much simplification of facts to be exact or precise. Such an approach results in suboptimal or excessive application of inputs resulting in inefficient utilization of costly fertilizers on one hand and risks environmental degradation on the other.

Soil test basis: Soil testing can in general be used for assessing the suitability of soil for potato or other crops cultivation. However, more specifically soil testing is important for establishing the nutrient supplying capacity of soil and developing the fertilizer manure application schedule for any crop. While simply testing the soil pH, EC, OC, texture can give idea of soil being suitable for any given crops. For assessing nutrient supplying capacity of soil and quantification of amount, source, method and time of external nutrient application, there is need to do very precise chemical analysis. The analysis must suit to particular soil type and agro-climatic situations. The test values may not indicate quantitatively the amount of nutrient present in the soil but it must correlated well with the uptake and yield levels.For potato crop important parameter needed to be tested for judging nutrient supplying capacity involve soil organic matter, available nitrogen, phosphorus, potassium, secondary nutrients (Ca, Mg, S) and micro-nutrients.

Organic matter is important as it improves soil fertility (nutrient supply) and has a great influence on the soil's physical environment and population of micro flora and fauna in the soil. In addition, soils rich in organic matter are known to be sufficient in micronutrients *viz*., Zn, Cu Fe and Mn. The test for estimation of organic matter content in the soil by Walkley and Black method (1934) where in organic matter is oxidized with chromic acid-sulphuric acid is frequently used in soil testing laboratories.

Nitrogen, potassium and phosphorus are the three major nutrients required in terms of their removal and uptake by the potato tubers and haulms and thus are to be applied in substantial quantities. In potato crop nitrogen is the first limiting nutrient in all type of soils. Likewise, potassium is the second major limiting nutrients in alluvial, red soils and brown hill soils whereas, phosphorus is the second major limiting nutrient in acidic soils. The soil test choice, therefore, depends upon the type of soil. It is more valid in case of P whose availability depends upon the form of P present in the soil.

Nitrogen: Organic carbon has been a very good indicator of available N, as major part of N in soil is present in organic form which has to be mineralized in NH_4^+ and NO_3^- from before being absorbed by potato plants. NO_3^- N being present as a tiny fraction of total N gives an idea at what rate organic N is being mineralized for uptake by plant. Chemical methods based on oxidation of organic matter are available for assessing the soil N availability. Some of the tests currently used for judging N availability to potatoes are total N, $KMnO_4$ -oxidisable N, $K_2Cr_2O_7$-oxidisable N and organic matter. The tests involving mild chemical oxidation of organic N which correlates well with N uptake is widely being used for judging the N availability. Although, total N gives a true picture of soil N but in soil testing it is seldom used as total N estimation by Kjeldahl method is a time consuming process. $KMnO_4$-oxidisable- N (Subbiah and Asija,1956) is based on oxidation of soil organic matter in alkaline $KMnO_4$ medium (NaOH) and is commonly used in soil testing laboratories in the country. Likewise, $K_2Cr_2O_7$-oxidisable N (Sharma and Sud, 1981) is based on oxidation of organic matter under acidic conditions using H_2SO_4 and holds good for all type of soils. In heavy soils of Patna (with considerable amount of clay and organic matter) in eastern Indo-Gangetic plains, the potato response to N was significantly related to NO_3^- content in the soil.

Phosphorus: Plant requirement is mainly met by $H_2PO_4^-$ ions in acidic soils and HPO_4^{2-} and $H_2PO_4^-$ ions in neutral and alkaline soils. Therefore soil pH plays a vital role in governing the availability of P to the plant. Phosphorus is retained in soil as insoluble P compounds of Fe, Al and Mn in acidic soils and Ca and Mg in alkaline soils, hence the choice of method for estimating P depends upon the quantitative amount of each fraction present in the soil and also pH of the soil. Bray P (0.03 N NH_4F in 0.25 N HCl) method is able to differentiate absorbed and acid soluble forms of P and thus useful for soils having high amount of Al and Fe compounds. On the other hand, Olsen's method (0.5 M $NaHCO_3$, pH 8.3) extracts phosphate from Fe and Al only partly and low Ca activity prevents the precipitation of liberated phosphate as calcium phosphate. It has been found to be a good index of judging P availability in alluvial and black soils containing Ca and Mg forms of P. For acidic hill soils, organic carbon test is equally effective in predicting P and K availability to potato.

Potassium*:* The dynamic equilibrium between different form of K (fixed, non-exchangeable and exchangeable) in the soil at any time governs the K availability to the plant. The choice of method for assessing the K availability from the soil depends upon the soil type, soil capacity to release K and nature of crop species, its ability to utilize K from soil pool and fertilizer/manure. A wide range of chemical extractants have been used in the soil testing laboratories with each method having its own advantage. The validity of each test further depends upon its ability to correlate crop response to the amount of K extracted by that method.

In potato, most frequent tests used is 1N ammonium acetate and it has been found to be good index for judging K availability to potatoes in acidic (North western and eastern hills), alluvial (Indo-Gangetic plains) and black (Plateau) soils. Exchangeable K determined by Morgan method is equally good for alluvial soils. The Q/I parameters *i.e.* intensity of K in relation to its capacity in the soil has also been found to be positively associated with K availability to the plant.

For the soil test of S, $CaCl_2$ or Ca $(H_2PO_4)_2$ containing 500 ppm P are most commonly used as extractant for measuring S availability to the potato crop. Availability of SO_4^- S from organic S bound with soil organic matter is closely associated with various soil tests. For other secondary elements *i.e.* calcium and magnesium, the most appropriate method is 1N ammonium acetate having pH 7.0 where in the two cations Ca^{2+} and Mg^{2+} are completely exchanged by NH_4^+ ions from ammonium acetate in absence of excess $CaCO_3$. The amount of Ca and Mg can be best estimated volumetrically by EDTA method. The former can also be conveniently determined by flame photometer.

The Di-ethylene tri-amine penta-acetic acid (DTPA) test for micronutrients availability in the soil *viz.* Zn, Fe, Mn and Cu has found wide application in potato. Among other methods for micronutrients availability in soils, use of 0.1N HCl and 0.05N HCl+0.025 N H_2SO_4 have also been used for estimating Zn and Cu held by soil organic matter. Trehan and Grewal (1985) found that NH_4HCO_3-DTPA test has advantage over other methods as it is able to estimate K, Ca and Mg in the same extract in addition to micronutrients.

Interpretation of soil test value: Moderation in rate of fertilization is possible on the basis of soil test value (STV). Soil test based fertilizer recommendation results in fertilizer economy through balanced application and enhances tuber yield. Soil tests are more reliable, convenient and efficient as they are performed before planting the crop to decide on rate of fertilization precluding nutrient imbalances in the crop. The safe level is the nutrient concentration in the soil is maintained appreciably above the critical deficiency concentration for optimum potato production.

One approach in the interpretation of soil test values involve determining a fixed value below which crop is likely to response nutrient application. These estimates are called **critical limits**. For this purpose most widely used method was developed by Cate and Nelson (1956 & 1971) in which % yield or % Bray yield is plotted in scattered diagram against soil test values within a particular soil group but varying in soil nutrient availability indices. Further, points are tried to be divided into two groups responsive and non-responsive. This can be done graphically (Fig.1) or statistically. In statistical technique the soils can be classified into more than two classes *viz.* low, medium and high ranges of nutrient level.

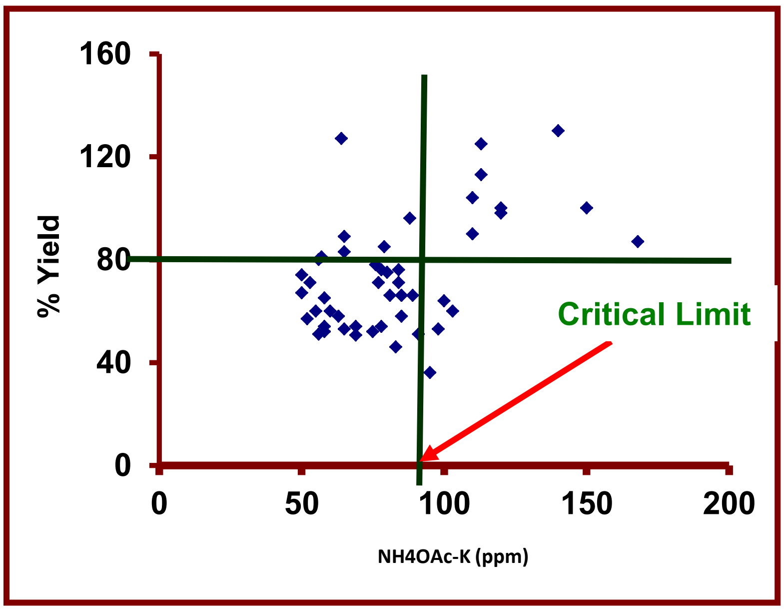

Fig. 1. Graphical representation of soil test value for available K against % yield

Targeted yield concept: Target yield concept takes account of total nutrient requirement of the crop and nutrient supplying capacity of the soil. In this approach, it is assumed that there is a linear relationship between increasing yield level and nutrient uptake by the crop and for obtaining a particular yield, the plant must up take a definite amount of nutrients. The total requirement of nutrient for a given yield level is calculated on the basis nutrient concentration. The fertilizer requirement is estimated taking into consideration the contribution from soil available nutrients. The needed parameters to be experimentally obtained for a given soil type, crop and agro-climatic conditions for formulating fertilizer recommendation for targeted yield are nutrient requirement of crop for unit quantity of produce, the per cent contribution from soil available nutrients to total uptake and the per cent contribution from the applied fertilizer nutrients to total uptake.

The yield targeting equations are reasonably good in predicting nutrient requirement, though, it has some limitations. It must be used for similar soils with similar range of soil test values, occurring in a particular agro-eco-region, yield target chosen should not be unduly high or low and should be within the range of experimental yields obtained and recommended agronomic practices should be followed while raising crops.

The target yield approach matches fertilizer application with soil available nutrients and crop requirements as they vary across the field. Precision fertilization on soil test and target yield based fertilizer prescription equations increase the fertilizer use efficiency as compared to the recommended fertilization of potato.

Site-specific nutrient management (SSNM) is an approach for feeding crop with nutrients as and when needed. In this approach there is possibility to dynamically adjust fertilizer use to optimally fill the deficit between the nutrient needs crop and the nutrient supply from indigenous sources, including soil, crop residues, and manures. In this approach mainly three nutrient elements (N P & K) need of crop is taken into account adjusted to season and location specific situations. The demand for N is strongly related to growth and development stage of crop. In order to achieve high yield, potato must not starve N supply at different stages up to tuber bulking. The SSNM approach envisages fertilizer N application in more number of doses to ensure the supply of sufficient N in synchronisation with the crop need at the same time not putting pressure on environment. Most convenient way can be to meet N crop need by rapidly assessing leaf N content, which is closely related to photosynthetic rate and biomass production and is a sensitive indicator of the N demand during the growing season. A chlorophyll meter like SPAD can provide a quick estimate of the leaf N status can effectively be used for real time N management. To make it more cost effective leaf colour chart has been developed for rice crop. This needs to be developed for high N requiring crop like potato also. For optimum use of P and K to overcome their deficiencies, to avoid the mining of soil and to allow best N management approaches based on decision support system with underlying the scientific principles of models, whereby, fertilizer P_2O_5 and K_2O rates are obtained from an estimate of attainable yield target (obtained from over fertilized reference plots, **OFR**) which must be realistically attainable and either the P- or K-limited yield determined by the nutrient omission plot technique (**nutrient omission plot**).

In nutrient omission plot technique, one plot is grown with abundant fertilizer supplements (NPK plot or NPK plus micronutrient plot) and the yield thus achieved is used to calculate the full demand for P and K. The attained yield can serve as a yield target. Other plots, without added P fertilizer or without added K provides an estimate of P-limited and K limited yield. The yields are then used to estimate optimal rate fertilizer P_2O_5 and K_2O rates, which overcome P and K deficiencies and include sufficient P and K to prevent depletion of soil fertility arising from their long-term removal.

Model based approaches: One recent approach on fertilizer recommendation for potato was based on QUEFT (Quantitative Evaluation of the Fertility of Tropical Soils) model. The model was calibrated for SSNM (site-specific nutrient management) of NPK in potato crop. For calibration of QUEFTS model, extensive review of literature was carried out and the data were collected and compiled on initial nutrient status, nutrient applied, uptake and yield under different experiments carried out at different locations during last 15 years. For working out the relationship between yield and nutrient supply, four steps were followed in the model; determination of indigenous nutrient supply, determination of the uptake of N, P and K as functions of potential supply of N, P and K (from soil + fertilizer), estimation of yield ranges as functions of actual uptakes of N, P and K when they are maximally accumulated and maximally diluted, and estimating the final yield by combining three yield ranges (one each for N, P and K) considering NPK interactions.

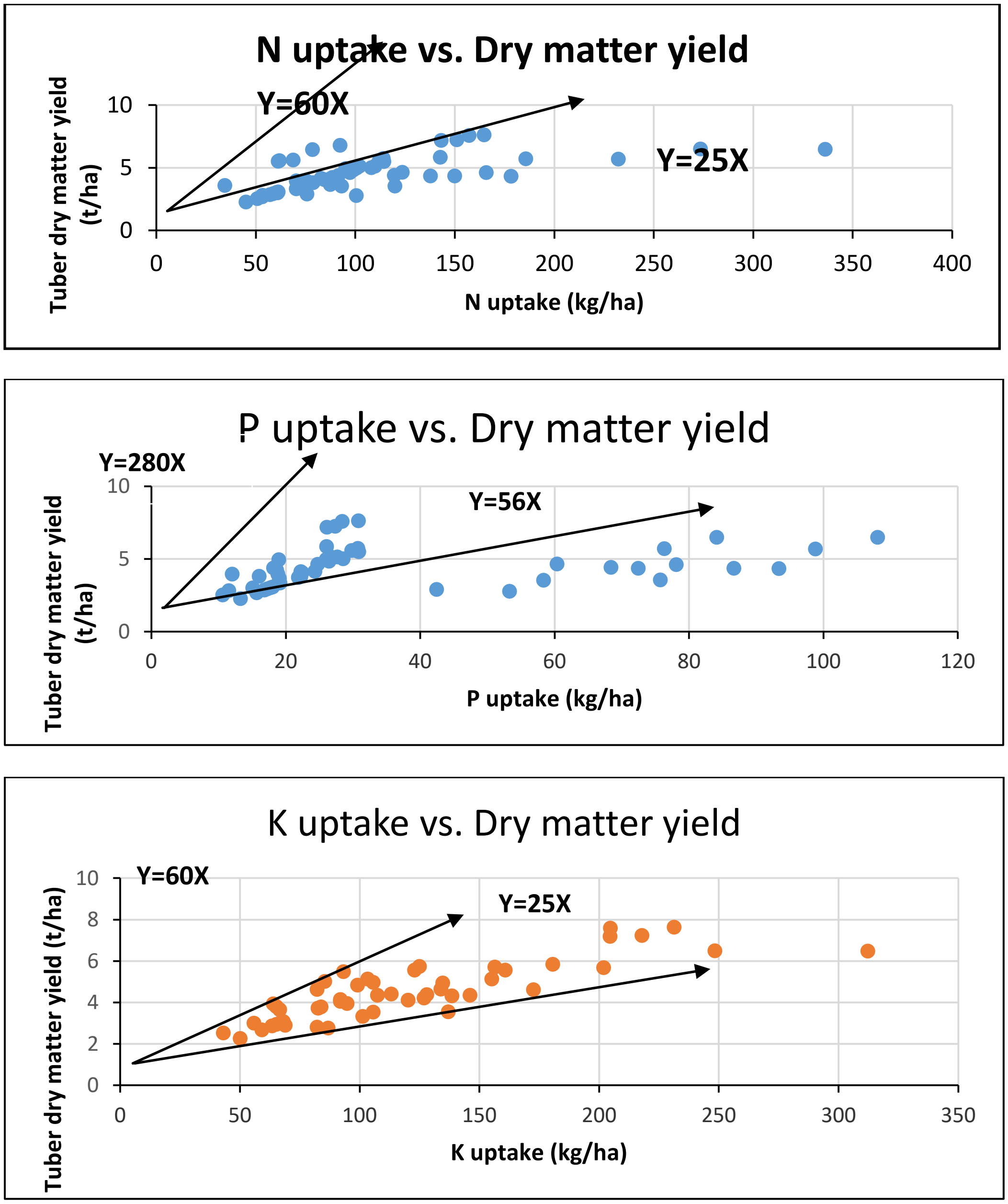

Figure 2. The relationship between tuber dry matter yield and NPK uptake. The upper and lower lines indicate tuber yields with maximum dilution and accumulation of nutrients.

Real time N management: The environmental concern about NO_3^- pollution from heavily fertilized crops has led to development of chlorophyll meter based technique for efficient N fertilization. The SPAD chlorophyll meter is one of the most commonly used tool for nondestructive diagnosis of leaf chlorophyll content which in term is supposed to be the function of N content in leaf, provided other management variable are not much different. Minolta SPAD 502 measures light transmission in the red (650 nm) and near infrared (940 nm) parts of the spectrum to estimate leaf chlorophyll content. In crops like rice and wheat the SPAD has been extensively used for in season real time fine tuning of N application for its quantity and time of application. At many places it has been shown that crop based approaches to manage N is an improvement over soil based approaches, particularly for in season decision making on N application. Studies have found the critical limits of SPAD value was 48.03, 44.80 and 36.89 at 25, 40 and 60 DAP, respectively and the best period to detect N deficiency in potato for corrective N-fertilization was found to be 33-47 DAP. However, further studies under rainfed conditions in hills and with different cultivars in plains it was observed that SPAD values are dependent on rainfall, irrigation schedule, other nutrient status of soil and other seasonal variations (radiation etc.). Therefore, fixing a critical SPAD value for N application may not hold good always. To improve upon this, use of an **over fertilized reference plot** (OFR) is advocated where the crop does not show any sign of N stress. The top dressing with certain amount of N fertilizer to the test crop is done when SPAD value reaches 95 to 90% of that of over fertilized reference plots.

GIS, remote sensing and precision farming: Remote sensing and GIS based technologies are being utilized increasingly and effectively for sustainable agricultural development and management. Recent developments in precision agricultural technologies are also very exciting. Remote sensing has been used in soil mapping, terrain analyses, crop stress, yield mapping and estimation of soil organic matter. **Spatial mapping of available nutrient** in potato growing pocket has very well been done in many parts of India using remote sensing and GIS tools. This involves classification of satellite imagery to delineate potato growing area and then strategically sampling soil from these areas using GPS so that entire pocket is covered in systematic manner. Further these soil samples are analyzed for desired soil properties and interpolation of these values is done using geo-statistical tools like kriging etc to cover unsampled area and geo-spatial maps are developed for different nutrients. These maps can be classified giving reasonable range of soil properties for getting limited number of management zone and further recommendation map can be developed for the entire pockets.

Further remote sensing in combination with GIS at high resolution is being extensively used in precision farming because of its capacity to monitor spatial variability. Grid sampling at certain spacing, analysis of these samples for desired properties interpolation of these analyses results to unsampled locations by geo-statistical technique and further classification of these maps into limited number of management zones are important steps in precision farming. Another approach to make it more economical with some compromise on precision is to divide whole region into production level management zone, sub-region of a field having similar yield limiting factors and nutrient and other inputs are applied accordingly.

In **precision farming**, however, the input variable such as fertilizer are applied in right amount at right place and right time (variable rate application technology) as per the demand of the crop rather than prophylactic application. Thus it helps to improve nutrient use efficiency, economy and sustainable use of natural resources with minimizing wastage. Variable rate technology (VRAT) is application of input taking account of spatial variability of soil so that no part of the field is over fertilized or under fertilized. It is well known that soil properties are not uniform across the land escape and therefore, uniform application of fertilizer cannot give maximum efficiency. There are variety of VRAT available that can be grouped broadly into two types, namely **GPS/Map based** or **sensor based**. In map based methods application rate of input/fertilizer is based on digital prescription map which has been developed based on soil information, crop information, remotely sense images and numerous other informations sources. These systems have ability to determine location of machine in field and relate the position to the prescription map to decide the application rate. Thus, the concentration of input changes as applicator move through the field based on information stored in map.

While, in sensor based systems input is dispense at the rate sensor signals, based on soil properties and crop characteristics while on go. It uses basically a ground-based soil or crop canopy reflectance sensing, technically a type of remote sensing, is used to assess crop/soil condition and determine nutrient input recommendations. It does not required map or positioning systems. Based on instant information, a control system calculate the input/nutrient need of soil and transfer the information to controller/dispensing unit which delivered the input to the location measured by the sensor. Unlike aerial or satellite sensing, ground-based sensing need not be compromised by clouds and the sensors can be attached directly to an applicator so that the fertilization can be accomplished within seconds of crop sensing. Both these systems have limitations and advantages, therefore, some systems have also been developed to take advantage of both the methods.

Conclusion: Nutrient management in potato has evolved through phases and a paradigm shift has taken place. No more it only objective is increasing yield, but it has to address the complex dynamics of integrating soil, crop, weather, and management practices to achieve the best balance for maximizing profit while contributing to the conservation of our resources. Therefore, it need to achieve the optimum nutrient use efficiency, yields, crop quality, and economic returns, while reducing off-site transport of nutrients that impact the environment. From region based approach to model based expert system and decision support systems the nutrient management has progressed a long way. Further, we are progressing towards precision farming. However, challenge still remains how these recommendations get adopted at farmers' field.

Suggested Readings:

SP Trehan, NC Upadhayay, KC Sud, Manoj Kumar, MK Jatav and SS Lal. 2008. CPRI Technical Bulletin No. 90: Nutrient Management in Potato. pp: 64.

KC Sud, NC Upadhayay, SP Trehan, MK Jatav, Manoj Kumar and SS Lal. 2008. CPRI Technical Bulletin No. 91: Soil and Plant Tests for Judicious Use of Fertilizer in Potato. pp: 80.

Manoj Kumar, M K Jatav, V K Dua, S P Trehan, S S Lal and N C Upadhyay. 2014. Methodology to map spatial variability of available nutrients in area of intensively growing potato (Solanum tuberosum) using remote sensing and GIS. Indian Journal of Agricultural Sciences 84 (3): 396-400.

Singh SP, Kumar M, Dua VK, Sharma SK, Sadawarti MJ and Roy S (2019) Leaf chlorophyll meter-A non-destructive method for scheduling nitrogen in potato crop. *Potato Journal* **46**(1): 73-80

Chapter -34

DUS test in potato: Identification of important characters

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The identification of varieties of potatoes and other crops is important at all stages of production. DUS testing is a way of determining whether a newly bred variety differs from existing varieties within the same species, whether the characteristics used to establish Distinctness are expressed uniformly and that these characteristics do not change over subsequent generations. Testing the distinctness, uniformity and stability (DUS) of crop varieties is a statutory requirement before varieties can be entered into the Registers of Cultivars (National Lists) and/or granted Plant Breeder's Rights (PBR). New (candidate) varieties should be distinct from all other varieties whose existence is a matter of common knowledge, and also sufficiently uniform and stable with respect to the characteristics used to demonstrate distinctness. 'Common knowledge' is broadly defined to include all known varieties, i.e. any variety entered into or subject to an application for PBR, varieties grown commercially, held in publicly accessible reference collection, or of which there is a published description (UPOV 2002).

The responsibility for DUS testing of potato varieties in India lies with the Central Potato Research Institute (CPRI), Shimla, which is the national institute for potato research and development. Currently a set of 51 DUS characters in potato are defined by CPRI and being used for distinguishing new variety.

I. Planting material for DUS testing

The Protection of Plant Varieties and Farmers" Rights Authority (PPV&FRA) shall decide when, where and in what quantity and quality of the planting material (seed tubers) are required for testing a variety denomination applied for registration under the Protection of Plant Varieties and Farmers" Rights (PPV&FR) Act, 2001. Applicants submitting planting material from a country other than India shall make sure that all customs and quarantine requirements stipulated under relevant national legislations and regulation are complied with.

- 300 fully matured, skin cured tubers immediately (not later than 15 days) after harvest for each year of testing. The diameter of the tubers to be delivered should be between 35 to 50 mm.
- Planting material supplied should be visibly healthy, not lacking in vigor or affected by any pest or disease or mechanical damage.
- The tubers shall not have undergone any chemical or bio-physical treatment unless the competent authority allow or request such treatment. If it has been treated, full details of the treatment must be given.

II. Conduct of test

1. The minimum duration tests should be 2 independent similar growing seasons with reference to the ecosystem of the candidate variety submitted for DUS test.

2. The tests should normally be conducted at two test locations. If any important characteristics of the variety cannot be seen at these places, the variety may be tested at an additional location.

Test plot details:

Test plot design Bed size: 4.8 m^2

Number of rows: 4 Row of 2 m length

Row to row distance: 60 cm Plant to plant distance: 20 cm

Number of replications: 3

Observations should not be recorded on the plants in border rows.

III. Methods and observations

1. The characteristics described in the Table of characteristics should be used for the testing of varieties for their DUS test.
2. For the assessment of Distinctiveness and Stability, observations shall be made on 30 plants (10 plants per replication). For the assessment of Uniformity of characteristics on the plot as a whole (visual assessment by a single observation on group of plants or parts of plants), a population standard of 1% with an acceptance probability of 95% shall be applied. In case of sample size of 120 plants, the number of off-types shall not exceed. Unless otherwise indicated all leaf/ leaflet characteristics will be observed on 4th fully developed leaf from the top of the plant.
3. For the assessment of colour characteristics, latest Royal Horticultural Society (RHS) colour chart shall be used.

IV. Grouping of Varieties

It will be very difficult task to test the candidate variety for distinctness against all the varieties in reference collections or in common knowledge. Therefore it requires careful selection of varieties of common knowledge to be grown in the trial. The candidate varieties for DUS testing shall be divided into groups to facilitate the assessment of Distinctiveness. The following characteristics shall be used for grouping of Potato varieties:

a) Lightsprout: Predominant colour (Characteristic 1)

b) Stem : Predominant colour (Characteristic 11)

c) Flower: Corolla colour (Characteristic 29)

d) Tuber: Predominant skin colour (Characteristic 43)

V. Characteristics and symbols

1. To assess Distinctiveness, Uniformity and Stability, the characteristics and their states as given in the Table of characteristics (Section VII) shall be used.

2. Notes (1 to 9) shall be used to describe the state of each character for the purposes of digital data processing and these notes shall be given against the states of each characteristic.

3. The optimum stage of plant growth for assessment of each characteristic is indicated in the sixth column of Table of characteristics is described below:

Growth stages Code 30 days after withdrawal from cold storage 30

Full foliage growth (50 days after planting) 50

Full flowering: about 50% of flowers open, main period of flowering 65

Ripening stage (foliage turns yellow, after 90 days of planting) 90

Harvest maturity (115 days after planting) 115

4. Type of assessment of characteristics indicated in column seven of the Table of characteristics is as follows:

MG : Measurement by a single observation of a group of plants or parts of plants

MS : Measurement of a number of individual plants or parts of plants

VG : Visual assessment by a single observation of a group of plants or parts of plants

VS : Visual assessment by observations of individual plant or parts of plants

Descriptors for characterization of potato

S. No.	**Characteristics**	**States**	**Note**	**Example varieties**	**Stage of observation**	**Type of assessment**
1	**2**	**3**	**4**	**5**	**6**	**7**
14.	Plant: Wing	Poorly developed Highly developed	1 2	Kufri Muthu, Kufri Megha Kufri Chipsona -2, Kufri Badshah	50	VG
15. (+)	Plant: Wing type	Straight Wavy	1 2	Kufri Badshah, Kufri Jeevan Kufri Swarna, Kufri Chipsona-2	50	VG
16. (*) (+)	Leaf: Structure	Open Intermediate Close	1 2 3	Kufri Sindhuri, Kufri Red Kufri Kanchan, Kufri Ashoka Kufri Jyoti, Kufri Kundan	50	VG
17. (*) (+)	Leaf: Anthocyanin colouration of rachis	Absent Present	1 9	Kufri Bahar, Kufri Sherpa Kufri Sindhuri, Kufri Red	50	VG
18. (*) (+)	Leaf: Anthocyanin colouration of midrib	Absent Present only at the base Present throughout	1 2 3	Kufri Muthu, Kufri Bahar Kufri Sindhuri, Kufri Badshah Kufri Kanchan, Kufri Arun	50	VG
19.	Leaf: Length	Small (<16 cm) Medium (16-20cm) Large((>20 cm)	3 5 7	Kufri Muthu, Kufri Kundan Kufri Dewa. Kufri Jawahar Kufri Lauvkar, Kufri Safed	50	MS

20. (*)	Leaf: Width	Narrow Medium Broad	3 5 7	Kufri Badshah, Kufri Megha Kufri Anand, Kufri Chamatkar Kufri Lauvkar, Kufri Jyoti	50	MS
21. (*) (+)	Leaf: Leaflet (lateral) shape	Narrow lanceolate Lanceolate Ovate lanceolate Ovate Oval	1 2 3 4 5	Kufri Red Kufri Chipsona-2,Kufri Dewa Kufri Bahar, Kufri Badsah Kufri Jawahar, Kufri Kuber Kufri Arun	50	VG
22.	Leaflet: Waviness of margin	Weak Medium Strong	3 5 7	Kufri Himalini, Kufri Giriraj Kufri Pukhraj, Kufri Swarna Kufri Red, Kufri Dewa	50	VG
23.	Leaflet: Glossiness of upper side	Weak Medium Strong	3 5 7	Kufri Swarna, Kufri Sindhuri Kufri Chandramukhi, Kufri Sutlej Kufri Himalini, Kufri Girdhari	50	VG
24.	Leaflet: Pubescence of blade at apical rosette	Absent Present	1 9	Kufri Himalini Kufri Sindhuri, Kufri Badshah	50	VG
S. No.	Characteristics	States	Note	Example varieties	Stage of obs	Type of assment
1	2	3	4	5	6	7
43. (+)	Plant: Time of maturity	Early Medium Late	1 2 3	Kufri Chandramukhi, Kufri Ashoka Kufri Bahar, Kufri Jyoti Kufri Sindhuri, Kufri Red	90	MG
44. (*)	Tuber: Predominant skin colour	Whitish cream Yellow Orange Brown Pink Red Reddish purple Purple Dark purple-black	1 2 3 4 5 6 7 8 9	Kufri Jawahar, Kufri Jyoti Kufri Kuber, Kufri Kumar - - Kufri Kanchan Kufri Red, Kufri Arun - - -	115	VG
45. (*)	Tuber: Secondary skin colour	Whitish cream Russeted Yellow Pink Red	1 2 3 4 5	-- -- -- Kufri Jeevan --	115	VG

		Purple Dark purple-black	6 7	Kufri Safed -		
46. (*) (+)	Tuber: Distribution of secondary skin colour	Absent Confined to eyes Present on eye-brow only Spectacled(only around eyes) Splashed Stippled	1 2 3 4 5 6	Kufri Jawahar, Kufri Jyoti Kufri Safed, Kufri Jeevan -- -- Kufri Dewa -	115	VG
47.	Tuber: Skin type	Smooth Rough	1 2	Kufri Chandramukhi Kufri Sheetman, Kufri Lalima	115	VG
48. (*) (+)	Tuber: Shape	Flattened Round Ovoid Oblong Pear shaped Long-oblong Reniform Irregular	1 2 3 4 5 6 7 8	Magnum Bonum Kufri Red, Kufri Chamatkar Kufri Bahar, Kufri Jyoti Kufri Surya -- -- -- --	115	VG
49. (*) (+)	Tuber: Depth of eye	Protruding Shallow Medium deep Deep	1 2 3 4	-- Kufri Jyoti, Kufri Chandramukhi Kufri Bahar, Kufri Lalima Kufri Sindhuri, Kufri Dewa	115	VG
50.	Tuber: Colour of eye	Whitish cream Yellow Orange Brown Pink Red Reddish purple Purple Dark purple-black	1 2 3 4 5 6 7 8 9	Kufri Jawahar, Kufri Jyoti -- -- -- Kufri Jeevan -- -- Kufri Safed --	115	VG
51. (*)	Tuber: Predominant colour of flesh	White Cream Yellow Reddish purple Dark purple	1 2 3 4 5	Kufri Kumar, Kufri Lauvkar Kufri Arun, Kufri Chipsona-1 Kufri Chamatkar, Kufri Pukhraj -- --	115	VG

52. (*)	Tuber: Secondary colour of flesh	Absent White Cream Yellow Reddish purple Dark purple	1 2 3 4 5 6	Kufri Lalima, Kufri Giriraj -- -- -- -- Kufri Red	115	VG
53. (*) (+)	Tuber: Distribution of secondary colour of flesh	Outer cortex Inner cortex Outer medulla Inner medulla Vascular ring Mottled	1 2 3 4 5 6	-- -- -- -- -- Kufri Red	115	VG

Chapter -35

AGRONOMIC PRACTICES AND RECOMMENDATIONS FOR POTATO PRODUCTION

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Potato production in India during 2016-17 was 46.60 million tons from 2.17 million ha area with a productivity of 21.47 t/ha (FAOSTAT). Potato being a semi perishable commodity, has not remained unaffected by the developments in the past decades. The Institute has released 65 varieties including seven processing, three water use efficient varieties and developed suitable production, protection and post-harvest handling technologies during this period. The potato productivity in the country could be increased by 15-25% by using modern methods of irrigation with the judicious use of other production inputs. With the use of micro-irrigation &fertigation technique, the crop productivity can be increased up to 40 t/ha alongwithsaving of 20-25% fertilizer nutrients. The progressive potato growers in various states particularly in UP adopted these technologies which increased the area by 5.6 times, productivity by 2.8 times and production by 15.3 times since independence. At present, the Uttar Pradesh contributes approximately 30.4% in national production as it produces 15.6 m t potatoesfrom area of 0.61 m ha with the yield of 25.3 t/ha which is almost similar to the national average. The UP state has some suitable seed growing areas in western part *viz.*Saharanpur, Muzaffarnagar, Shamli, Meerut, Baghpat, Hapur, Ghaziabad and Bulandshahar.

Hot weather tillage:Two-three deep ploughing during summer (May-June) are quite beneficial to keep potato fields free from weeds, pests&diseases like common scab and black scurf. The deep tillage is also advantageous in conserving moisture as it improve water retention capacity of soil.

Green Manuring:Green manuringof *dhaincha*(Sesbaniaspps.) or cowpea should be done in rainyseason before potato planting. Green manuring improve OC content and moisture retention capacity in potato field. The practice of green manuringcan reduce the doses of NPK nutrients by 20-30% and improve potato yield and quality both.

Selection of soil:Potato prefers loamy and sandy loam soils with neutral pH (5.5–7.5) having good drainage and aeration system. Higher or lower soil pH should be adjusted with the application of soil amendments for better nutrient availability and reduction of soil and tuber borne diseases like common scab etc.

Land preparation:The sub-soiling operation is better for loosening the soil once in two to three years. It should be performed during the month of May- June for breaking hard pan just below the plough layer. If sufficient soil moisture is not available in the field, then one pre-planting (Palewa) should be done before potato planting. Plough the field with a moldboard plough or disc harrow up upto a depth of 20-25 cm followed by two tilling and cross planking. The field should have fine tilth and leveled for efficient use of irrigation water and proper drainage.

Cropping system: Potato crop fits well in different cropping and inter-cropping systems. At least one leguminous, vegetable or green manure crop should be included in the systems. Continuous raising of potato crop should be avoided on the same field to avoid weeds, pest and diseasesbuild up etc. Hence, two to three yearscrop rotation should be adopted for good yield of potato. In the rainy season, paddy, maize, fodder, vegetables and green manuring crops are better options, while in summer the succeeding crops are cucurbits, vegetables, maize, green gram and fodder. The inter-cropping of potato with sugarcane and mustard arealso very good alternative for small and marginal farmers.

Varieties:The potato varieties released by the Institute for table purpose can be divided into three groups as per their maturity period; early (70-80 days), main (90-100 days) and late (100-110 days). However, the variety Kufri Surya is most suitable for planting early in the season (second fortnight of September to first fortnight of October). Further, the potato cultivars have two categories namely tableand processing purposes. The potato varieties are recommended for cultivation in UP state -

Table 1.**Potato varieties suitable for ware and processing purposes for Uttar Pradesh state.**

Potato varieties			**Duration (days)**	**Yield (t/ha)**
Table/ware purpose	Early	KufriChandramukhi	70-80	20-25
		KufriAshoka	70-80	25-30
		KufriPukhraj	70-80	30-35
		Kufri Surya	70-80	25-30
		KufriKhyati	70-80	30-35
		Kufri Lima	70-80	25-30
	Medium	KufriBahar	90-100	30-35
		KufriPukhraj	90-100	35-40
		KufriKhyati	90-100	35-40
		KufriSadabahar	90-100	35-40
		Kufri Gaurav	90-100	35-40
		KufriGarima	90-100	35-40
		Kufri Mohan	90-100	35-40
		Kufri Ganga	90-100	35-40
		KufriArun	90-100	35-40
		KufriNeelkanth	90-100	35-40
		KufriLalima	90-100	20-25
	Late	KufriBadshah	100-110	30-40
		KufriAnand	100-110	40-45
		KufriSindhuri	100-110	30-35
Processingpurposes		KufriChipsona 1	100-120	30-35
		KufriChipsona 3	100-120	35-40
		KufriChipsona 4	100-110	35-40
		KufriFrysona	110-120	35-40
		KufriFryOm	100-110	35-40

Seed and seed preparation:The seed tubers should be removed from cold store at least 10 days before planting. Keep the seed bags in pre-cooling chamber of cold store for at least 24 hours. Do not bring the seed bags directly out side from cold store as this will result in rottage due to immediate exposure to high temperature. Seed tubers should be spread in shed or cool place for sprouting. Un-sprouted and rotted tubers should be removed. Normally, the tubers with thick sprouts of 0.5-1.0 cm size are best for planting. The dormant tubers will delay the emergence and too long sprouts will break during planting. The well sprouted tubers of 30-50 g size should be taken to the field in seed trays or baskets for planting.

Seed source:Seed should be obtained from a reliable source preferably from a government seed agencies. The potato growerscan also maintain their seed stock by multiplying seed at their farm following seed potato production techniques. It is better to replace the seed every 3-4 years after to maintain varietal purity and health standards to obtain optimum yield.

Seed preparation:Seed tubers should be removed from cold store atleast 10-15 days before planting. These tubers should be spread in thin layers under shade in diffused light for proper and healthy sprouting. Blind and rotted tubers should be removed from the seed lot. Use basket or crates for transporting sprouted tubers to the field for planting.

Seed size and planting: Use well sprouted seed tubers of 30-50 g size (3-5 cm diameter) which is most economical. Planting of ware crop is done at 60 cm row spacingwhile plant to plant at 20 cmdistance in the ridges. In case of processing varieties, the row spacing at 67.5 cm and plant to plant distance of 20 cm (for chips) and 25 cm (for French fries) are recommended.The planting depth of 8-10 cm should be maintained for uniform emergence.

Time of planting: Potato require day and night temperatures (25-32 ^{0}C and 3-5 ^{0}C, respectively) for better growth and development during crop season. The planting should be done in second fortnight of September for early crop, second fortnight of October for main/seed crop, and mid-November to end of December for late crop of potato. However, for main crop, the optimum mean temperatures are 25-26 ºC,but maximum day temperature should be less than 32 ºC while minimum temperature should range between 18-20 ºC.

Methods of planting:Ridge and furrow method is most commonlyused for potato planting. Put the seed tubers in furrows already drawn during fertilizer application followed by ridging. It can also be done manually with spade and *khurpi* with the help of animal drawn moldboard plough and tractor drawn two or four rows planters.Wide raised bed planting (two/ three row; base 120 cm) should also be followed under micro-irrigation methods.

(a) Traditional planting- In this system, the field is leveled before ridge and furrows are made at 30 cm each by using ridger. The height of the ridges should be around 20 cm. The well sprouted seed tubers should be planted in the ridges at 60x20 cm spacing at 10 cm depth. The findings highlighted the importance of economize irrigation water alongwith 15-25% higher yield of quality potatoes under drip & sprinkler irrigation methods against furrow irrigation.

(b) Raised wide bed planting: In the two and three rows raised bed planting, the broad ridges/bed: furrows of required dimensions (60x30 cm and 90x30 cm spacing, respectively) should be formed in the field. In double row planting, the tubers should be planted at 20 cm inter-row and 15-20 cm intra-row spacing under drip irrigation, and at 20 cm intra-row spacing under sprinkler irrigation. While in triple row planting with micro-irrigation methods, the tubers should be planted at 20 cm inter row and 20 cm intra-row spacing at 10 cm depth on each bed.

i) Double/paired row raised bed planting-Under drip irrigation, the raised beds of 20 cm height and 90 cm width are formed at a spacing of 120 cm between the centers of two adjacent beds. That is the gap between the beds is 30 cm. The paired rows of potato should be at 20 cm with 100 cm gap. In the double/paired rows raised bed planting at 120 cm distance alongwith single drip placed on each bed, the tubers should be planted at 20 cm inter-row and 15-20 cm intra-row spacing at 10 cm depth (83,333 to 1,11,111 plants/ha).In this planting system the number of rows per hectare remains same.

Whereas, in case of double/paired rows raised bed planting at 90 cm distance under drip and sprinkler irrigation, the tubers should be planted at 20 cm inter-row and 20 cm intra-row spacing at 10 cm depth with 1,11,111 plants/ha. The raised beds of 20 cm height and 60 cm wide are formed at a spacing of 90 cm between the centers of two adjacent ridges/beds. That is, the gap between the beds is 30 cm. The paired rows of potato should be at 20 cm with 70 cm gap. In this system the number of rows per hectare increases.

ii) Triple row raised bed planting:In the triple rows raised bed planting at 120 cm distance, three rows are brought together at 20 cm inter-row spacing on each bed, and the tubers should be planted at 20 cm intra-row spacing at 10 cm depth with 1,25,000 plants/ha. The raised beds of height 20 cm and width 90 cm are formed at a spacing of 120 cm between the centers of two adjacent beds. That is the gap between the beds is 30 cm. The triple rows of potato should be planted at 20 cm (row to row) with 80cm gap. In this system the number of rows per hectare are 1.5 times more than the paired rows bed planting system under drip and sprinkler methods of irrigation.

Fertilizers and manure:The available nutrient status of soil and recommendations provided in the Soil Health Card should be followed. If green manuring has not been donein potato field then apply 15-20 t/ha well rotten FYM before planting. Only half dose of phosphorus and potassium is required to be applied through inorganic fertilizers with this quantity of FYM. The doses of 180-80-100 kg/ha of nitrogen, phosphorous and potash is recommended for ware and seed crop of potato, while processing varieties require 270-80-150 kg/ha doses of these nutrients, respectively. Apply half of nitrogen and full dose of phosphorous and potash at planting while remaining half dose of nitrogen should be applied at the time of earthing up. The fertilizers should be applied in furrows at about 5 cm below the seed tubers so that tubers do not come in the direct contact of fertilizers.The micro-nutrient should only be applied on soil test basis.

Irrigation: In conventional furrow irrigation method, the first irrigation should be given 8-10 daysafter planting for quick and uniform emergence in the field. The second irrigation is given 21-25 days after planting just after earthing up. The subsequent irrigations should be applied at 10-12 days interval in the light soils whereas in medium soils at 12-14 days interval. Potato crop should not face moisture stress at stolon formation and tuberization stage. The irrigation should be stop about 10-12 days before harvesting in early crop. However, in main crop, stop the irrigation 10-12 days before haulm cutting when 40-50% plants have shown senescence.

Inter-culture and weeding: The inter-culture operations*viz*. hoeing, weeding and earthing up help in managing the weeds in potato field. Integrated weed control should be followed and chemicals should only be used where weeds cause significant economic yield loss. Cultural (crop rotation, summer ploughing, proper seed bed preparation, mulching etc.) and mechanical (inter-cultivation) methods should be given preference. Inter-cultivation, weeding and earthing up of crop is done at 20-25 days after planting when potato plants are of about 8-10 cm height. Remaining dose of nitrogen is also applied before earthing. However, the weeding and earthing-up operations are not required under drip irrigated cropdue to low incidence of weeds in field. fluchloralin @ 0.7-1.0 kg/ha should be applied as pre-planting herbicide to control the weeds. The pre-emergence herbicide metribuzin (@0.7-1.0 a.i. kg/ha) should be sprayed just after planting at optimum moisture in potato field, while post-emergence application of paraqute (@ 0.4-0.6 a.i. kg/ha) is recommended up to 5% emergence of potato plants.

Plant protection: In early crop, white fly and leaf hopper are controlled by 1-2 spray of insecticide imidacloprid @ 5.0 ml/ 10 lit, and mites are controlled by spray of dicofol 18.5 EC or quinophos 25 EC @ 2 l/ha after emergence of crop. If damage is noticed in main crop at any stage due to defoliaters/ caterpillars than spray the crop with cypermethrin 25 EC (0.3 ml/l) or deltamethrin 2.8 EC (0.1 ml/l) or chlorpyriphos 20EC (2.0 ml/l). While, white fly or aphids can be controlled by 1-2 spray of imidacloprid. In case of late blight, prophylactic spray with 0.2% mancozeb 75% WP or chlorothalonil 75% WP or propineb 70% WP are recommended from second fortnight of November, if weather is cloudy with moderate temperatures (16-20 ^{o}C) and relatively higher relative humidity. Foliage should be thoroughly drenched with these chemical sprays which can be repeated at 10-12 days intervals, if congenial weather persists. Scouting of fields should be done to locate primary infection patches, these should be drenched with fungicide and whole plants should be buried in soil. When late blight infection appears, than spray 0.3% water solution of dimethomorph+ mancozeb or cymoxanil+ mancozeb or fenamidone+ mancozeb. Soil and tuber borne diseases are controlled by treating seed potatoes with 3% boric acid for 15-20 minutes before storing in cold storage.

Harvesting and post-harvest management: Early crop is harvested at 60-70 days after planting for getting remunerative price in early season. In main crop, it is done as per maturity period of a variety.The harvesting is done 10-12 after haulm cutting for proper skin setting while tubers are in soil. Harvesting should be finished by first fortnight of March as the maximum temperatures remain below 32 ºC. Tuber skin is cured by keeping tubers in heaps of 1.5m height for 10-15 days under shade and coveredby crop residues of 25-30 cm thickness to avoid their greening. All damaged and rotted tubers should be removed before heap making. Grade the tubers as per market demand in different sizes *viz.* large (above 75 g), medium (25-75 g) and small (<25 g) and pack them in juteor synthetic leno bags of 40 kg capacity. The care should be taken to avoid greening of potatoes. Potato bags should be kept in cooler place before sending to the market or cold stores.

Potato storage: Potatoes can be stored up to June in non-refrigerated traditional stores or heaps under shade to avoid distress marketing. Anti-sprout suppressant (CIPC) can be usedin traditional methods. Long term storage of potatoes can be done in refrigerated stores either at 2-4 ºC without anti-sprout suppressant or with improved cold storage technology at 10-12 ºC with 2-3 fogging of CIPC (35 ml/ton) to avoid cold induced sweetening.

Chapter -36

USE OF CHEMICALS IN AGRICULTURE

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Many farmers choose to use chemicals to keep weeds and pests free from destroying their crops and to add more **nutrients** to the soil. There are three different kinds of pesticides; herbicides, insecticides and fungicides. All three of these pesticides are used to kill different kinds of pests that can be found on a farm. Farmers that make the decision not to use any chemicals are called organic farmers. The development of chemicals to protect agricultural crops is an important activity within the chemical industry. Without them, many crops would suffer dramatic losses. Some of these chemicals, the insecticides, are also very important in combating human and animal diseases. The environmental and toxicological properties of these chemicals have improved considerably over the last six decades. Research aims to produce chemicals that are not just potent but are specific for the required purpose, whilst not affecting the environment in any other way. Because pests may develop resistance to crop protection chemicals there is a continual need for new products to be developed.

Three groups of chemicals dominate this part of the chemical industry (Figure 1). They are:

Herbicides: Substances that kill or inhibit growth of unwanted plants (weeds)

Insecticides: Substances that kill arthropod pests, i.e. insects and mites

Fungicides: Substances that destroy or prevent the growth of pathogenic fungi

All three are **pesticides**.

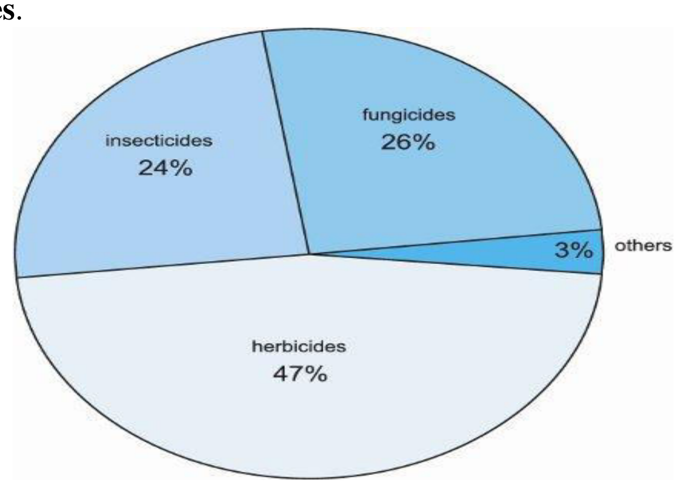


Figure 1 Global sales of crop protection chemicals

The effectiveness of a pesticide is the result of the proper 3D-assembly of specific groups in the chemical structure of its active ingredient. If several compounds of a given chemical class have related efficacies, they include a set of groups as a common minimum basic feature responsible for the best fit for the specific molecules in the biochemical target molecule (e.g. a protein) of the pest. This set of groups is called the toxophore.

Development of new chemicals: It is estimated that it costs about œ150-200 million to discover a new product, test it thoroughly for its action and its safety for the environment, and develop manufacturing techniques for its synthesis. It takes an average of 10 to 15 years to do this so it is small wonder that, worldwide, only about 12 chemicals are introduced each year. However, these chemicals are key to the efficient production of food (Figure 2).

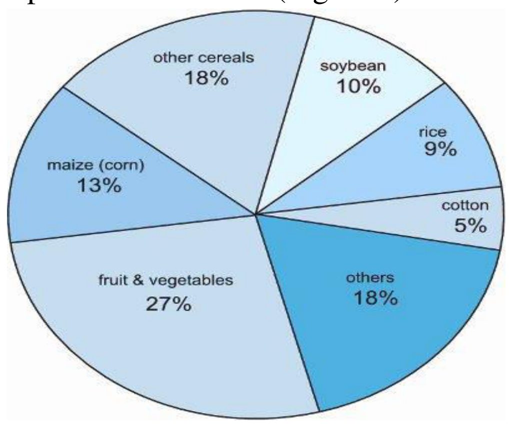


Figure 2: Sales value of crop protection chemicals worldwide by type of crop

Sometimes mimicking nature's own way of protecting plants can provide the answer to cost-efficient synthesis of effective crop protection chemicals. The pyrethroids, used as insecticides, are examples of this process. Another is a class of fungicides, the strobilurins, which mimic the natural fungicide strobilurin, a derivative of p-methoxypropenoic acid.

There is a continual search for pesticides with reduced risk. These are used in small amounts, are not susceptible to pests developing resistance, and have low toxicity for non-target organisms (humans, birds, fish and plants). Ideally non-target organisms do not have the same target which is affected by the pesticide or do not share the target's vulnerability that is exploited by the pesticide.

There are many hundreds of pesticides in use and being developed. This unit describes some specific examples currently being used from each of the three groups -herbicides, insecticides and fungicides.

Herbicides: Herbicides are used to control the growth of unwanted plants (weeds). Modern herbicides generally act by restricting growth. They inhibit the action of one or more of the many receptors that catalyze reactions which are essential to the growth of the plant. There is one group however, the auxins, that kill by overstimulating growth. With selective herbicides, either the target in the weed is affected more than that of the crop, the herbicide is degraded more quickly within the crop, or the uptake or translocation of the active ingredient differs from that of weeds. Non-selective herbicides kill crops as well as weeds.

Herbicides can act in several ways:

direct contact with plant tissues, for example, leaves; paraquat is a typical contact herbicide

- by translocation (systemic herbicides),whereby the compound has the ability to be absorbed by aerial plant parts and is transported to roots (basipetal translocation); glyphosate and growth hormones belong to this group
- by root uptake and transportation, to the upper parts of the plant (acropetal translocation)

- through a combination of both methods; triketones are an example of this group as they are transported downwards and upwards.

Insecticides

The world market for insecticides is dominated by compounds interfering with the nervous system of pest invertebrates, since this target organ usually provides rapid control. Insecticides acting on target sites such as acetylcholinesterase (organophosphates and methyl carbamates), voltage-gated sodium channels (pyrethroids), nicotinic acetylcholine receptors (neonicotinoids) and ligand-gated chloride channels (macrocyclic lactones and phenylpyrazoles) account for more than 75% of total insecticides sales (Figure 5).

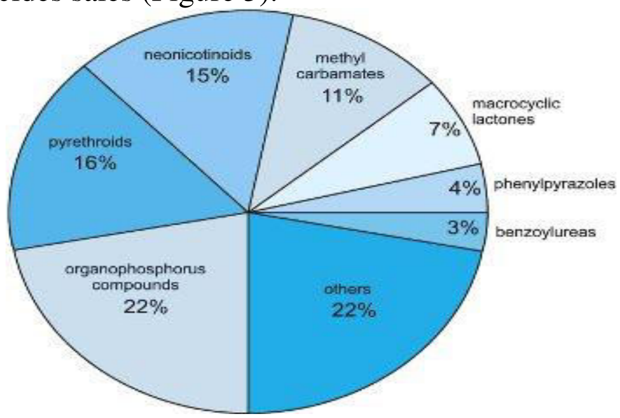


***Figure 5**: World market share of insecticides*

Other mechanisms such as interference with insect development are usually more selective (either by distinguishing between species or by their life cycles), but such compounds are generally much slower in their action.

Pesticides – Also known as agricultural chemicals – are substances that are used to protect plants against pests. They include herbicides to kill weeds, fungicides to get rid of diseases and insecticides to kill bugs. Those chemicals are unfortunately not only getting rid of the unwanted but can also cause harm to our health and the environment.

Pesticides or plant protection products contain at least one active substance and are used to:

- protect plants against pests and diseases;
- influence how much the plants grow;
- preserve plant products;
- kill or prevent the growth of undesired plants;

Fungicides: The term fungicide normally applies to synthetic chemical compounds that kill fungi or inhibit their growth. However, certain biological organisms can also be used to control fungal infections, which include mildews, rusts and leaf spots.

Some fungicides offer protection against the development of fungi (termed protective), and others cure the plant by eliminating the fungus (termed curative).

Nearly all modern fungicides (except for inorganic salts) degrade in aerobic soils and therefore they are environmentally friendly, the rate of degradation depending on the temperature and humidity.

Since fungi rapidly develop resistance to these chemicals, it is necessary to be able to draw on fungicides from different chemical classes and with different sites of action. The compounds discussed here are representatives of each important chemical class but the list is not exhaustive.

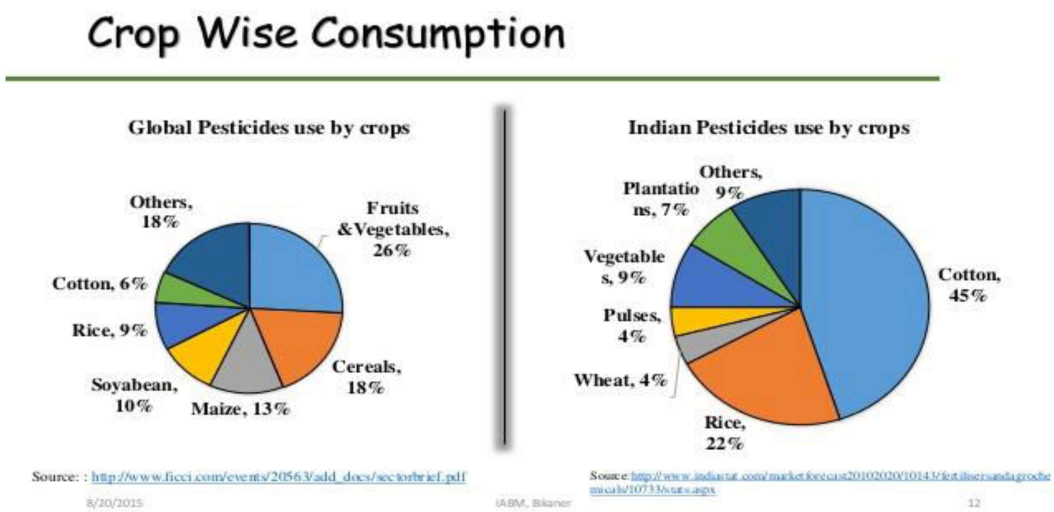
(a) Triazoles: They offer protection against a wide range of fungi that occur in cereals, rice, beet, trees, vegetables and flowers.

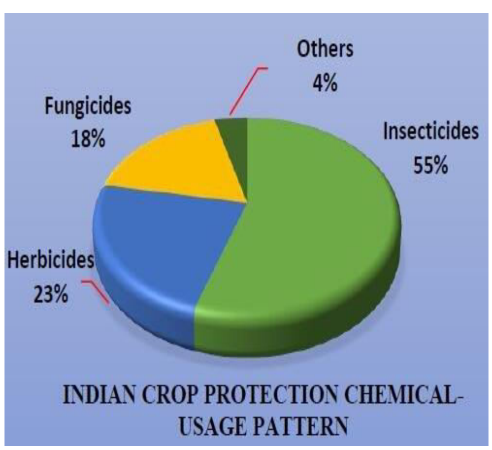
(b) Strobilurins: The development of a chemical class called strobilurins was inspired by the study of a group of naturally occurring fungicides, for example, strobilurin A.

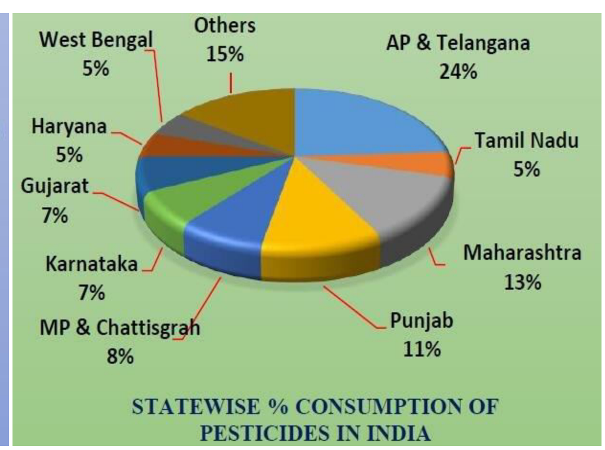
(c) Carboxamides: Carboxamides are so named as they contain the carboxylic acid amide (-CO-NH_2) or related group. As with the strobilurins, they interfere with the production of ATP.

(d) Fungicides with a 'multi site action': Besides fungicides which act mainly on one target enzyme, several fungicides with a 'multi site action' are commercially available.

(e) Specific fungicides with activity against downy mildews: Since downy mildews are a special class of plant pathogens causing severe damage mainly in grapes and potatoes a number of specific fungicides active only against this kind of plant diseases are available.:







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