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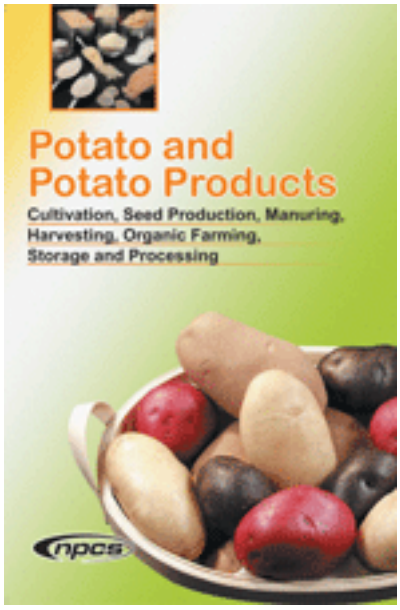
Potato and Potato Products Cultivation, Seed Production, Manuring, Harvesting, Organic Farming, Storage and Processing



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Potato ranks fourth position in the world after wheat, rice and maize as non cereal food crop. Potato is probably the most popular food item in the Indian diet and India is one of the largest producers of potato. It is used in many ways like vegetable, potato wafers/chips, powder, finger chips etc. Potato tubers constitute a highly nutritious food. It provides carbohydrates, vitamin C, minerals, high quality protein and dietary fiber. Potato is a rich source of starch and it is consumed mainly for its calorific value, also contains phosphorus, calcium, iron and some vitamins. Boiling potatoes increases their protein content and almost doubles their calcium content. It is vastly consumed as a vegetable and is also used in various forms such as starch, flour, alcohol, and dextrin and livestock fodder. It is estimated that about 25 % of the potatoes, which are spoiled due to several reasons, may be saved by processing and preservation of various types of processed products. The potatoes can be processed for preservation and value addition in the form of wafers/ chips, powder, flakes, granules, canned slices. Potato granules are used for the preparation of various recipes, to add to vegetable and non vegetable recipes and to enhance the quantity as well as to enrich the food value. There is a huge potential for processed potato products such as potato flakes, potato powder, frozen potatoes, frozen French fries, potato chips/wafers are one of the most popular snack items consumed throughout world. International trade in potatoes and potato products still remains thin relative to production, as only around 6 percent of output is traded. High transport costs, including the cost of refrigeration, are major obstacles to a wider international marketplace. The industry is still growing at a rapid pace where French fries are showing the highest growth followed by potato chips and potato powder/flakes. It is by far the largest product category within snacks, with 85% of the total market revenue.

This book basically deals with origin, evolution, history and spread of potato, potato products, quality requirements for processing, morphological, size and shape, defects, biochemical, dry matter, reducing sugars, phenols, inheritance, morphological attributes, tuber shape, growth cracks, hollow heart, internal rust spots, greening, biochemical attributes, glycoalkaloids, dry matter, reducing sugars, enzymic browning, development of varieties for processing, areas suitable for growing processing potatoes, processing quality of Indian potato varieties, processed potato products, dehydrated products at village level, potato chips, french fries and flakes commercial production, grading manual for frozen French fried potatoes for frozen French fried potatoes, areas of production, varieties, receiving, determining the quality and condition of raw potatoes for frying purposes, determining the quality and condition of raw potatoes for frying purposes, etc.

The present book covers complete details of potato cultivation and processing in proper manner. This book is an invaluable resource for agriculture universities, students, technocrats and entrepreneurs.

Tags

Agro Based Small Scale Industries Projects, Agro Techniques for potato production of quality potato seed, Commercial Postharvest Handling of Potatoes, Cultivation of Potato, Favourable Conditions of Growth for Potato, Food Processing Industry in India, Get started in small-scale food manufacturing, How long does it take to grow a potato?, How to Easily Plant and Harvest Potatoes, How to Grow and Store Potatoes, How to Grow Organic Potatoes, How to grow Potato : Vegetable Gardening, how to grow potatoes , How to plant potatoes?, How to start a food manufacturing business, How to Start a Food Production Business, How to Start a Potato Production Business, How to start a successful potato processing business, How to Start Food Processing Industry in India, How to Start Potato Processing Industry in India, How to Store Potatoes, Most Profitable Food Processing Business Ideas, Most Profitable Potato Processing Business Ideas, new small scale ideas in Potato processing industry, organic farming potatoes, Organic Potato Production, planting potatoes from potatoes, post-harvest technology and utilization of potato, Potato and Potato

Processing Technology Book, potato by products, potato cultivation in india, potato cultivation pdf, potato cultivation techniques in india, potato farming business plan, potato farming methods, potato farming process, Potato Processing and Uses, Potato Processing Industry in India, potato production in india, Potato Production, Processing and Technology book, Potato Seed Production, Potato Value Added Products, Potatoes: Planting, Growing and Harvesting Potato Plants, Potential value-added products and uses, Process Technology Book for Production of Potato, Setting up and opening your potato processing Business, Starting a Potato Farm - Startup Business, Starting a Potato Processing Business, true potato seed production technology, Use of Manure in Potato Production, Value Added potato processing, Value added products from potato, Value addition to potatoes, Value-Added Food Processing Technologies, Value-added food products processing, Value-added offerings increase in potato category, What are potatoes made out of?, what are seed potato

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Sample Chapter:

ORIGIN EVOLUTION HISTORY and Spread of Potato

INTRODUCTION

Potato rightly called the vegetable that changed history provided both the spark and the fuel for centuries to the social change. While conquering the world it was banned and lauded cursed and praised feared and loved until humanity welcomed it into its home and hearth. Today as one of the world s major non cereal food crop potato is grown in more than 148 countries in a wide variety of soils and climates surpassed only by wheat rice and maize in total production. Yet till 16 h century it was unknown to the people of Europe Asia Africa and North America. The crop has a fascinating history of its origin evolution and spread in the world stretching to nearly 7000 to 9000 years back. Some of it is well documented while other has been chronicled from the archaeological remains and historical evidences.

ORIGIN

The potatoes of the South America where it grows wild in nature present the widest diversity of forms in tuber shape size colour taste etc. indicating its origin in South American continent. The main cultivated potato species Solanum tuberosum L. a tetraploid (2n=4x=48) is believed to have originated from Andes of Peru and Bolivia in South America more specifically in the basin of lake Titicaca on Peru Bolivian borders from its wild diploid ancestors many of which may be extinct now. Two main centres of diversity of tuber bearing Solanum species are Central America and Andean region of north western Argentina. Peru and southern Bolivia. The species grow in a wide variety of habitats from semi desert conditions of northern Argentina southern Bolivia and Mexico to the high rainfall subtropical forests of Central and South America. Thus potato shows a wide adaptation to altitudes right from the sea level to nearly 5000 masl.

Archaeological evidence

Spectacular and beautiful ceramics were excavated dating from the Moche cultures in northern Peru (c. AD 1 600) and the Chimu peoples (c. AD 900 1450) as well as. Huari or Pacheco urns from the Nazca valley in southern Peru (c. AD 650 700). These ceramics depicting many forms of potatoes were from coastal areas. Therefore it is presumed that the potters obtained potatoes by barter or other means from farmers in the highlands where potatoes were actually cultivated . Surprisingly these ceramics are restricted to Peru and none was recovered from Colombia. Ecuador Bolivia Argentina or Chile even though the potato is certain to have been an ancient crop in these countries also. Actual remains of the potatoes were also recovered infrequently from tombs dwellings and rubbish heaps including chuno or tunta from some archaeological sites. Archaeological remains of potatoes from the Chilca valley near Lima have been radiocarbon dated to 7000 years before present. There is much later evidence from rubbish heaps graves and food stores of potato cultivation at 4500 to 3500 years before present.

The Chilca valley evidence based on excavations in Mexico and elsewhere takes the origin of potato cultivation back to an age when maize first became cultivated crop in Mexico and places it with the approximate time of agricultural origin in the New World. From studies between these old potatoes and the distribution of existing primitive cultivated potatoes and the wild species most similar to them it seems highly probable that the first ever potatoes were cultivated in the northern Bolivian region of Lake Titicaca/Lake Poopo.

Historical evidence

The conqueror of Peru Francisco Pizarro may well have been the first European to see potatoes in 1533 but there is no actual (historical) record of this event. The first historical record is of 1537 when a band of

Spaniards led by Jimenez de Quesada penetrated into the highlands of what is now Colombia. This was followed by accounts of Lopez de Gomara for potatoes in southern Peru and by Pedro Cieza de Leon in the area of what is now southern Colombia and northern Ecuador. Potatoes in Chile received first mention by Sir Francis Drake in 1578.

The native names of the potato also indicate its ancient and widespread cultivation since they differ completely from the main Red Indian languages that were spoken in the areas where the potato was first growing. Thus in the Chibcha language of Central Colombia the names iomza iomuy etc. were used in Quechua the language of the Inca Empire the usual name was papa. In Bolivia the Aymara Indians used the words amka and choque whilst in Chile the Araucanians gave it the name poni. The Spaniards adopted the name papa for the potato which was used throughout their South American colonies. In Europe neither batata nor papa for potato was ever adopted because the Spaniards first encountered sweet potato and not having a name for a similar tuber they used the Indian word batata. Subsequently other tuberous plants that they found in their American colonies were given the same name. Potata and potato are clearly cognate forms of batata consequently the word papa which is still in vogue in whole of the Spanish Latin America never spread outside this area even though the plant itself is now grown in most parts of the world. We can say with some certainty that the historical evidence clearly corroborates archaeological evidence about the origin of the cultivated potato from the Andes of South America.

EVOLUTION

The wild potatoes occur only in the Americas. They seem to have evolved by means of geographical and ecological isolation rather than by genetic incompatibility. The picture regarding the evolutionary relationships of various species is not very clear. However the cultivated species were at one time confined to the Andes of South America and the lowlands of southern Chile in both cases being adapted to the cool temperate climates of these regions. The related wild species are much more widespread. There are seven cultivated tuber bearing Solanum species vie. S. stenotomum S. ajanhuiri S. phureja S. chaucha S. juzepezukii. S. tuberosum ssp. andigena S. tuberosum ssp. tuberosum and S. curtilobum occurring in a polyploid series with a basic chromosome number of 12 and ranging from diploid to pentaploid. Several of them are fairly similar to each other and for that reason were classified by Dodds as groups of S. tuberosum rather than distinct species. Their probable evolutionary relationships are shown in Fig. 1.

The diploid species S. Stenotomum is grown from central Peru to central Bolivia and is believed to be the most primitive probably having been derived from the diploid wild species S. leptophyes or possibly S. canasense both of which still occur in the central part of its distribution area. At least four wild potato species are widely believed to be involved in the process of evolution. Evidence indicates that hybridization of S. stenotomum with the weedy species S. sparsipilum and subsequent chromo some doubling produced the tetraploid S. tuberosum subsp. andigena in the central Andes. Some workers however consider that the tetraploid Andean potatoes are derived from S. stenotomum by simple chromosome doubling. This tetraploid sub species was carried by ancient people into southern Chile where it became adapted to the long day length to evolve into subsp. tuberosum. A similar process in Europe caused the same development to take place under the long day conditions. However it may also be stated that certain authors believe that subsp. tuberosum from Chile and Europe differ from subsp. andigena by certain cytoplasmic factors that it may have acquired from some wild diploid species such as S. chacoense.

In pre conquest days the cultivated diploid species S. phureja evolved from S. stenotomum through a process of artificial selection by Andean farmers in lower warmer eastern valleys and acquired shorter dormancy so that three crops could be grown in a year.

In contrast natural hybridization of 5 stenotomum with the wild frost resistant species S. megistacrolobum gave rise to the diploid S. ajanhuiri. The F hybrid produced the Yari group of varieties and a probable back

cross to the cultivated parent gave rise to the Ajawiri group of varieties. Similarly the F cross from a series of hybridizations between S. stenotomum and the wild tetraploid species S. acaule gave rise to a highly sterile triploid S. juzepczukii which incorporated the strong frost resistance of S. acaule. A further natural cross between S. juzepczukii and S. tuberosum subsp. andigena produced the only slightly less frost resistant pentaploid species S. curtilobum. This evidently involved a 2n gamete from S. juzepczukii and a normal gamete from S. tuberosum subsp. andigena. A series of crosses between S. stenotomum and subsp. andigena have given rise to the triploid hybrids named S. chaucha.

We thus have a network of cultivated species or species groups which evolved chiefly in the central Andes of Peru and Bolivia involving four original wild species viz. S. acaule. S. sparsipilum S. leptophyes and S. megistacrolobum. All but two of these cultivated potatoes have always been confined to that central area. However the diploid S. phureja has extended northwards into Ecuador Colombia and Venezuela whilst the tetraploid S. tuberosum spread into southern Chile.

HISTORY

Early history

In South America potato was the most productive source of main food for centuries for the people in the high Andes and southern Chile. Potatoes were dried by Andean Indians to make chuno for use during food shortage between successive crops caused by frost or other unfavourable growing conditions. Chuno is a freeze dried potato powder of the bitter frost resistant potatoes grown at 3 600 to 4 400 masl. The process requires a dry climate with high day and very low night temperatures allowing freeze drying of potatoes for several nights followed by thorough washing for many days in running water. The long lasting chuno is finally prepared by thorough trampling of such potatoes by men and women folks to sqeeze water out of them and finally dehydrating them in hot sunny days and freezing nights for many days. Still an important food in the highlands of Peru chuno has been aptly extolled for its virtues in an ancient Incan adage Stew without chuno is like life without love .

The Spanish conquerors found potato being very widely cultivated in what are now Colombia Ecuador Peru and Bolivia and the Araucanian region of Chile. Following the conquest of Peru the Spaniards introduced potatoes in Spain and further spread it to many European countries including Italy Belgium Germany France Switzerland and Holland by the end of the 16th century. Initially potato was grown only as a curiosity in the Europe s botanical gardens and remained a shunned plant at best food for swine and country bumpkins2 for next two centuries. It bore the wrath for causing war and lust to tuberculosis rickets syphilis and obesity. Often it fell victim to its lineage being member of Solanaceae and having hallucinogenic and narcotic cousins as mandrake and deadly nightshade (Atropa belladonna) containing scopolamine and atropine like poisonous alkaloids used in ointments said to give witches the power to fly. Potatoes were banned being unworthy of human consumption by the Scottish clergymen as they were not mentioned in the Bible. Possibly the word spud (present day English nickname of potato) got its name being acronym for the Society for the Prevention of an Unwholesome Diet a 19th century activist group dedicated to keeping the potato out of Britain. The first edition of the Encyclopedia Britannica referred to the potato as a demoralizing esculent esculent being an ostentatious word for food. Russians referred it as Devil s apples while in France potatoes were thought to be fit only for animals and poor people. The potato s struggle for acceptance in Europe took place at every level from Kings Kitchens to slum street corners from the hallowed halls of parliaments to the battlefields of Seven Years War. Resistance to eating potatoes was so strong in parts of the continent that willing rulers virtually had to force potatoes down their subjects throats. In 1651 Frederick William of Prussia even issued an edict to cut off the nose and ears of any one refusing to plant potatoes. Frederick the Great still facing resistance more than a century later sent a wagonload of tubers to peasants in a famine stricken area only to receive a petulant reply. The things have

neither smell nor taste nor even the dogs will eat them so what use they are to us? forcing the great leader to hold an open air banquet where potatoes were served to prove that they are not only edible but also fit for royalty. French potato enthusiast Antoine Auguste Parmentier even had to trick peasants into stealing tubers from Louis XVI s Royal Gardens to convince them of the potato s virtues.

The crop remained a botanical curiosity till about the mid 18th century and was not grown in any western European country except Ireland where potatoes became the most profitable new crop mainly for human consumption and for pigs thriving well on potatoes. In Ireland the situation was very different where in the 16th century religious differences were cause for the feuds and unrest between the Norman Irish aristocracy and the English people. The common people depending and devoted to peaceful agriculture for livelihood were the chief sufferers when their cattle were driven off or slaughtered by one side or the other and their land and crops ravaged either by the Irish or English. During these years the miserable peasantry on the brink of starvation was driven to rely more and more on the potato as source of food. However when cattle food stores and standing crops were used or destroyed potatoes being underground escaped destruction. People realized this and did not harvest and store potatoes but dug them up as and when required with sufficiently leftover to serve as seed for the next crop. Thus the potato became the chief food of the people. In 1780 Young recorded that a barrel of potatoes containing 127 kg would last an Irish family of six persons for 6 days indicating on an average consumption of over 3.5 kg per person per day. Throughout the 18 h century none seems to have been aware of the danger to the economy of a nation dependent on a single crop. The warnings of Wakefield and by Curwen went unheeded till August 1845 when suddenly one warm rainy day in August an unknown malady (late blight) struck the Irish potato fields. Potatoes quickly rotted in the fields sending an unbearable stench across the countryside and repeating the same scene across whole of Europe. This was also true in 1846 1847 and 1848 resulting in famous famine and death of nearly 2.5 million and migration of one million Irish including the famous Kennedys and Reagans to North America.

One of the wars during the Hundred Years War in Europe was christened Kartoffel Krieg or the potato war between the Prussians and the Austrians acquiring its name when the contending armies ate up all the potatoes along the battle lines in Bohemia and then called off the fighting.

Bacterial Diseases of Potato and their Management

The potato crop is prone to many diseases caused by pathogenic fungi viruses mycoplasmas and bacteria. Bacterial diseases reported on potato are 1) bacterial wilt Ralstonia solanacearum 2) soft rot of stem and tuber 3) common scab 4) pink eye and 5) ring rot sepedonicus Devis et al. In India ring rot and pink eye do not occur. The leaf spot is a minor disease. Therefore the following chapter pertains to only two economically important bacterial diseases i.e. bacterial wilt and soft rot.

BACTERIAL WILT/BROWN ROT

Bacterial wilt/brown rot is the most destructive bacterial disease of potato. Besides potato the pathogen Ralstonia solanacearum (formerly Pseudomonas solanacearum and more recently Burkholderia solanacearum) also causes lethal vascular wilt diseases in more than 200 plant species belonging to at least 50 different plant families including several crops like potato tomato chilli brinjal pepper ginger and others. In India alone more than 130 plant species belonging to 47 genera have been reported to be infected by this pathogen. It is the first bacterial disease recorded in India from Pune district of Maharashtra in 1892. In different countries it is known by different local names such as bacterial wilt brown rot Granville wilt ring disease slime disease southern bacterial wilt etc. In India it is widely known as ghera and uktha bangle blight bangdi or paryya. The disease has a history of changing cropping pattern in some parts of the world. Potato cultivation was abandoned in Ranchi district of Bihar due to severe bacterial wilt infestation

forcing the farmers to shift to the cultivation of other crops. The disease is unpredictable as evidenced by recent outbreaks of bacterial wilt of potato in Europe. Resistance against bacterial wilt in potato is scarce and thermo sensitive in nature. Therefore it is apprehended that the disease might become more problematic particularly in the event of changes in cultivated varieties and global warming.

Distribution

The disease is wide spread in tropical sub tropical and warm temperate regions and has been reported from six of the seven continents. It is endemic in South Asian East Asian Southeast Asian and even in some central Asian countries. It is widely distributed throughout the Indian sub continent including India Pakistan Nepal and Bangladesh. In India R. solanacearum is prevalent in all the states excluding Punjab Haryana western part of Uttar Pradesh and Andhra Pradesh. The wide distribution of this pathogen is a reflection of its evolutionary success which is correlated with the extent of genetic diversity within a species. In fact the bacterium is notorious for its phenotypic diversity in respect to colony morphology races and biovars disease symptoms and host range. Modern techniques of molecular genetic analysis suggest that this bacterium probably originated from a common ancestor possibly at a single location near the equator. Further evolution of the bacterium then occurred with several wild hosts possibly in forest eco systems in geographically isolated areas creating plenty of diversity within this species.

Wilt incidence and economic losses vary from place to place season to season and the stage of crop damaged. Crop loss up to a maximum of 75% has been reported in potato from India.

Etiology

The etiology of the disease was first established by Erwin Frink Smith in 1896 and the bacterial entity was christened as Bacillus solanacearum nov. sp. and later as Pseudomonas solanacearum. The bacterium belongs to beta subclass of the Proteobacteria. With the introduction of molecular techniques generic nomenclature of the wilt pathogen underwent rapid change from Pseudomonas to Burkholdena to Ralstonia. Yabuuchi et al. 1992 proposed the new genus Burkholderia to accommodate RNA homology group II including Pseudomonas solanacearum with P. cepacia as type species. Later work based on 16S rRNA genes and polyphasic taxonomy showed dichotomy in genus Burkholderia hence a new genus Ralstonia was proposed with R. picketti as type species.

R. solanacearum is a Gram negative rod measuring approximately 0.5 0.7 x 1.5 2.5 mm. Virulent isolates are mainly non flagellated non motile and are surrounded by extracellular slime. Avirulent isolates are devoid of any extracellular slime usually bear 1 4 polar flagella and are highly motile. Polar fimbrae are present which are associated with twitching motility and spreading growth on solid media. Cells contain inclusion of poly (b hydroxybutyrate which are sudanophilic and refractile under phase microscope and commonly show bipolar staining. It is a chemoorganotroph with aerobic respiratory metabolism catalase and Kovac s oxidase positive the optimum temperature for growth varies from 27 37°C depending on the strain and nitrate is reduced to nitrite. R. solanacearum usually shows low level of salt tolerance growth is often inhibited by 0.5 to 1.7% NaCI. The bacterium lacks fluorescence phenazine and carotenoid pigments. A brown to black diffusive pigment is often produced on variety of agar media containing tyrosine.

Studies on host range physiology serology membrane protein pattern numerical taxonomy and bacteriophage susceptibility of the bacterium established highly hetero geneous composition of this species. However from a pathologist s point of view R. solanacearum has been delineated into five races on the basis of host range (Table 1) and five biovars on the basis of ability to use disaccharides and hexose alcohols (Table 2). Recent studies established existence of two broad RFLP divisions having only 13.5 percent similarity. In future creation of more RFLP groups can not be ruled out. Marked differences in geographical distribution of races and biovars is observed. Race I/biovar III and IV is most predominant in Asia. Race 3 biovar II is restricted to cooler region of the world including tropical highlands.

Table 1.

Diagnostics and detection

The disease can be best diagnosed by observing symptoms. Expression of the disease may start as partial collapse of foliage followed by recovery and subsequent complete death (Fig. 1). Tubers largely do not show any external symptoms but Figure 1. Potato plant showing bacterial wilt symptoms transversely cut tubers from wilted plants show vascular browning and in exceptional cases tubers might ooze out slimy depositions at eyes (Fig 2). Water soaked lesions on tubers lenticels have also been reported. Incipient infection of tubers Figure 2. Infected tuber showing bacterial ooze in vascular bundlecan be accentuated by incubating them at 30°C for six weeks and then tested for exudation of bacterial ooze in the tuber eyes. This test is advocated by the International Potato Center (CIP) Lima Peru. Potassium hydroxide (KOH) test is useful to differentiate R. solanacearum infection from C. michiganensis ssp. sepedonicus. Precise diagnosis may be sufficient to take up suitable remedial steps. However in many cases it needs to be followed by sensitive detection. Detection of the pathogen can be undertaken based upon the purpose need time and the cost. This involves isolation and culturing on SMSA medium followed by metabolic profiling (Biolog system) and proving the Koch s postulates (host test) using serodiagnostics (ELISA Immunofluorescence) and confirming through molecular methods (PCR Nucleic Acid Hybridization). Isolation of the pathogen in pure form can be avoided by adopting molecular detection techniques. Each of the above detection techniques has specific advantages and disadvantages in respect of specificity sensitivity time and cost. Each technique has a threshold level of bacterial population that can be detected (Table 3).

Table 3. Sensitivity of the different techniques used for detection of R. solanacearum from potato Method Detection level Remarks (cells/ml)

Post Harvest Handling of Potato

SIGNIFICANCE

The unawareness about post harvest handling practices accounts for about 10 15% wastage of tubers. Nearly 10 per cent of the total production is used as seed tubers. There is a large gap between the existing storage facilities and the actual requirement thereof in the country. At present the cold storage capacity in the country is about 10.3 million tonnes whereas the production of tubers is around 18 million tonnes. The post harvest losses can be minimized by generating appropriate techniques of tuber handling and storage. Public agencies and research organizations are engaged in reducing some of the problems associated with post harvest handling of potatoes.

Potato production in India has been increasing steadily during the last fifty years and the total production was 18 million tonnes in 1997 98. During the years of over production we are unable to store or utilize the surplus potatoes available in the country. Consequently we witness gluts at regular intervals which mean economic loss to the grower and wastage of precious food. Realizing the importance of storage and processing for better post harvest management of potatoes attempts were made at CPRI to study and understand the problems of potato storage during the hot humid summer months and the problems related to potato processing in India.

Post harvest improvement such as fast and cheap transportation storage and processing will help to make potato production more profitable for farmers by improving their access to markets raising local value addition and promoting greater competition among middlemen. The perishable nature of potatoes combined with the inadequate and expensive refrigerated storage facilities and their uneven distribution difficulties in transportation the adverse environmental conditions prevailing during the main storage and lack of significant processing of potatoes create market gluts around harvest time.

POST HARVEST LOSSES

The proper techniques during post harvest handling and storage should be used so that the losses due to physical causes like damage during digging transport to storage etc. and physico chemical changes like conversion of starch into reducing sugars shrinkage and weight loss due to transpiration and respiration rotting of tubers due to infection by micro organism etc. could be minimized. Post harvest losses result partly from insect damage and physical injuries like cutting by spades during harvest. Khatana et al. reported 6% wastage in the field however wastage may vary from 2 25% depending on the weather which governs insect infection.

Physiological disorders like black heart and low tempera ture injury are also a result of mal storage practices. It renders tubers inconsumable thus causing great loss to grower.

ENHANCEMENT OF SHELF LIFE OF POTATO TUBER

Avoid Mechanical Tuber Damage Including Internal Bruising

The damage can be controlled by reducing external forces imposed on the tubers during lifting and at various stages of handling by proper design and use of mechanical lifting and handling techniques. When the potato tubers get matured they are removed by digging with the help of spade or kudali due to which bruising is caused and skin is damaged. Splitting of tubers can be avoided by taking care during these operations. In prolonged storage internal bruising is caused by the pressure spots developed inside the tubers. The drizzling of rains on hills during digging make the harvested tubers more susceptible to rot by organisms like Pythium Phytopthora and Erwinia species. In the plains late digging of potato where temperature rises 25°C the injury get prone to cause bacterial soft rot and charcoal rot (Macrophomina phaseolina).

Sorting and Grading of Tubers

Sorting is necessary to remove diseased and damaged tubers. The storability is inversely related to size of the tubers so grading is essential. The tubers weighing more than 75g may be graded in to table purpose category. However the small size tubers about 13 31 mm diameter are preferred for seed purposes which can economically be kept under country storage. Seed tubers below 25 mm size are categorized as under size and more than 65 mm as over size. Suitability for processing of potato tubers is decided according to its shape size and depth of eyes and chemical constituents like tuber dry matter and reducing sugar content. Round to round oval potatoes are used for the preparation of chips while small sized tubers are used for canning large grade tubers (40 60 mm. diameter) are preferred for chipping and for preparation of French fries.

Wound Healing and Curing

Wound healing in potato tubers has an important bearing on storage losses. Potatoes have relatively tender skin at harvest and some damage occurs invariably wounds if not properly healed soon after harvest can result in excessive shrinkage and rotting during storage. Wound healing involves deposition of suberin. Wound healing is faster at higher storage temperatures. The process is slowed down at low temperature increased CO_2 concentration or by sprouts inhibitors used at the time of storage. Wound heating at 18°C is faster and it takes about 15 days whereas about 30 days are required at 12°C and at 10°C it is almost nil. For the formation of wound periderm initially the cells at the cut surface become suberized followed by the development of meristematic layer called phallogen or cork cambium a few layers below the cut surface. The cut off layers towards the out side by division in the phallogen become suberized cork cells making the periderm a barrier for evapouration to water and entry of micro organism.

For proper wound healing and curing potatoes after harvest are quickly dried kept outdoors in heaps in the field or under the shade of trees or in sheds undisturbed for some time. Heaps are covered with straw to protect them against frost and rains. The heaps may be 1 1.5 m high and 3.35 m wide at the base. Period

of 10 15 days is sufficient for proper curing.

Thomas observed the effect of temperature and gamma irradiation on wound healing in the variety Kufri Chandramukhi and concluded that the major cause for the bacterial soft rot in tubers when they are stored under high tropical ambient temperatures or when irradiated for sprout inhibition is the impairment of wound periderm formation.

Weight Loss

Weight loss consists of starch and moisture loss through evaporation. Harvested potato tubers are living organisms who breathe in oxygen and give out carbon dioxide water and heat as waste products from the organic process. This process is at the expense of stored starch in potato. The higher the temperature of the potato the greater the loss of starch and the potatoes age. Starch loss is responsible for 10% of the total weight loss of healthy potatoes after storage. Damaged potatoes age more rapidly and loss moisture. Stored potatoes lose weight mainly due to two physiological processes transpiration and respiration which can be reduced by increasing the relative humidity and reducing the temperature of storage atmosphere respectively. These losses are generally low as long as potatoes remain dormant. When dormancy is over there is an increase in these losses due to sprout growth. Higher weight loss is caused under the non refrigerated storage.

Transpiration was found to be the major source of weight loss during storage (18 30°C RH 80 90%) for a period of 4 months. Contribution of respiratory carbon loss to total weight loss was slight (3.96 6.07 %) Respiration rate measurement with infra red gas analyser showed higher rate of weight loss in sprouting tubers as compared to dormant one s while Mehta and Kaul reported that there was no correlation between respiration rate and weight loss during storage up to 10 weeks.

Dormancy

When freshly harvested potato tubers are placed under environmental conditions favourable for sprout growth sprouting does not normally occur. The time of onset of sprouting is determined by the length of the dormant period of the tubers. Long dormancy may be considered as an important component of good keeping quality. However storage trials conducted at Patna showed that the long dormant variety Kufri Sindhuri suffered maximum rotting and therefore it is not necessary that a long dormant variety should have a good keeping quality. An association between short tuber dormancy and earliness has been reported by Kaul and Mehta. Since weight loss and rotting tend to be higher in sprouted than in unsprouted tubers therefore long dormancy may be considered as an important component of keeping quality.

Storage Temperature

The temperature of storage is an important factor that determines the break of dormancy and the onset of sprouting. Storage trials carried out at Patna on various types of storage structures in decreasing order of temperature. Ordinary kutcha store a double walled insulated store (27 30°C). An underground cellar and a pre cooling room of a cold store (16 18°C) indicated that high storage temperature tend to retard sprouting. In the case of loose stored potatoes the difference in temperature between the potatoes at the bottom and the potatoes at the top must not exceed 0.8°C. Greater differences in temperature may give rise to condensation and germination in the potatoes at the top.

Treatment of Tubers Against Diseases and Insect

Potato tubers may carry various types of disease inoculums and nematodes. For disinfecting the tubers the fungicides (bavistin and benlate etc.) antibiotics (Streptocycline tetracycline etc.) and insecticides which are safer should be used. Nagaich and Upreti eradicated the leafroll and yellow diseases by keeping tubers in hot air at 40°C for two hours daily for 6 weeks. Chemicals like H_2SO_4 (1.75%) (Dutta and Thaplyal 1978) and boric acid 10% have been reported to be effective in control of black scurf and scabs. These diseases can also be controlled by treating seed tubers with organomercurial compounds.

Use of Growth Regulators Against Sprouting

Tubers are living entities as they respire. The respiration rate is influenced by temperature and O2/CO2 ratio. It regulates the process of sprouting. The respiration of potato causes breakdown of starch into simple sugars which supplies food material to buds during sprouting. Energy and simple sugars also encourage cell division of buds.

Growth regulators synthesised during respiration are involved in the process of sprouting. The relevance of GA Auxin and ABA during sprouting has been reported by various workers. Hemberge reported that the extract from dormant potatoes inhibited the coleoptile and inhibition activities remained higher during bud dormancy in treated coleoptile and decreased prior to sprouting. The compound was named as P inhibitor by Bennet Clark and Kefford. Later on Abscissic acid which was recognised as active component of the beta complex inhibitors has been isolated from potato tubers and confirmed its involvement in inhibition of sprouts. The mode of action of endogenous GA other growth promoters and Abscissic acid in regulation of sprouts is well established fact where GA activates the buds while ABA was found associated with dormancy of tubers. Finally Burton confirmed the involvement of ABA. The level of endogenous GA3 increases during termination of dormancy however various experiments have shown that not only ABA GA mechanism is associated with regulation of dormancy but other chemicals are also taking part in this phenomena.

Regulation of Sprouting in Stored Potato

Suppression of sprouting in the storage should be emphasized to maintain the tuber quality and to prolong the shelf life of ware tubers. The spray of various growth inhibitors like MENA 2 4 5 T Maleic hydrazide and CIPC etc. are useful for sprout suppression in storage.

Pre Harvest Application for Sprout Suppression

Maleic hydrazide (MH) has been found effective as sprout suppressant for table potatoes. The foliar spray of MH at the rate of 3000 ppm (approx 2 lit a.i./ha) remains effective during storage.

Spraying of MH 2000 to 3000 ppm (2 3 g/lit of water) at 2 3 weeks before harvesting has been reported to be effective in controlling the sprouting in storage at CPRI Shimla. At IARI New Delhi however it has been observed that the translocation of MH was not uniform to all the tubers and as a result only about 15% of the tubers showed positive effect on sprout control. MH is the chemical sprout suppressant registered for use in India. Trials were carried out with a liquid formulation containing diethonalamine salt of MH at Jalandhar Shillong Patna and Ootakamund. One spray of 0.3% MH equivalent 2 3 weeks before harvesting did not reduce the yield significantly and resulted in no significant changes in the contents of starch reducing sugar s or soluble proteins. The sprout growth was significantly suppressed by MH treatment. The content of MH residues in the tubers was within the permissible limits (30 60 ppm). Hence MH is a risk less sprout suppressant for ware potatoes.

Biotechnology for Production of Quality Planting Material

Biotechnological approaches are now routinely used to obtain pathogen free planting material in potato. Meristem culture was perhaps the first biotechnological approach successfully employed to produce virus free potato clones. The technique in combination with accurate and sensitive virus detection procedures has been highly successful over the years in elimination of major viruses from systemically infected potato clones. Methods have also been developed for mass multiplication of virus free mericlones using micro propagation. Virus free in vitro plantlets thus produced are either planted directly in the field for raising commercial crop or used for the production of microtubers in the laboratory or minitubers in greenhouses. These techniques have been successfully integrated in potato seed production programmes in many countries.

MERISTEM CULTURE

Over 30 viruses and virus like agents infect potato (Solanum tuberosum L.) plants. Potato viruses are systemic pathogens and therefore perpetuate through seed tubers. Thus the losses caused by viral diseases are not only confined to the year when infection occurs but continue as long as the diseased tubers are used as seed. While plants infected with bacteria and fungi respond to treatments with bactericidal and fungicidal compounds there is no commercially available treatment to protect virus infected plants. Being dependent on host for DNA replication and protein synthesis selective interference of viral multiplication by chemical means without adversely affecting the plant nucleic acid and protein synthesis is almost impossible.

The term meristem culture denotes in vitro culture of meristematic dome of actively dividing cells located at the extreme growing tip of the shoot along with a portion of the subjacent tissue containing one or two leaf primordia (Fig. 1). This piece of tissue is about 0.1 0.3 mm in size. In the absence of chemical control of viral diseases meristem culture is the only available method to eliminate viruses from systemically infected potato cultivars. This technique is based on the fact that in rapidly growing meristematic tips viruses are either absent or their concentration is very low. Despite the phenomenal success of meristem culture in elimination of plant viruses it remains still unclear as to why the apical/axillary meristems contain a little or no virus? There are several hypotheses.

Virus particles spread through vascular system but the vascular system is not developed in meristematic region.

Chromosome replication during mitosis and high auxin content in the meristem may inhibit virus multiplication through interference with viral nucleic acid metabolism.

Existence of virus inactivating systems with greater activity in the apical region than elsewhere.

However these hypotheses have never been proved unequivocally.

Various factors like size of the explant meristem location and cultural factors largely affect the success of virus elimination by meristem culture. In general larger the size of the meristem better the chances of its survival in vitro whereas smaller the size of the meristem better the chances of its being virus free. As the distribution of a virus within a plant is uneven especially towards the shoots tips meristem of varying sizes are used to regenerate virus free plants depending on the genotype and virus strain under consideration. It is difficult to excise apical meristems from terminal buds because they have more rudimentary leaves and leaf primordia than the axillary buds. There is however no difference between the apical (axillary meristems and in terms of survival or freedom from virus infection. Therefore axillary meristems are preferred to apical meristems in many laboratories for virus elimination.

Although it is possible to eliminate viruses from potato plants following meristem culture alone plant regeneration from meristems takes four to eight months and sometimes depending on the nature of the virus the percentage of virus free plants obtained from regenerated meristems is low. As a result meristem culture procedure is often combined with thermotherapy and/or chemotherapy to increase the likelihood of obtaining virus free plants.

THERMOTHERAPY

Growing host plants at higher temperatures significantly reduces replication of many plant viruses by disrupting viral ssRNA and dsRNA synthesis. Higher temperatures (35 37°C) cause disruption in the production and/or activity of virus encoded movement proteins (MPs) and coat proteins (CPs). MPs are involved in cell to cell movement of viruses through plamodesmata and plant vascular system while CPs play a role in the reconstitution of virus particles from replicated viral nucleic acids. Therefore thermotherapy of infected plants followed by meristem culture improves virus freedom even from relatively large size meristems. Reduction in virus titer is higher if the infected plants are exposed to elevated

temperature for longer periods. Current virus elimination programmes involve either growing of whole plants or in vitro cultures at temperatures close to the threshold of normal plant growth. The exact temperature and length of treatment vary with the virus and the heat tolerance of the host plant.

Meristem culture combined with thermotherapy is widely used for virus elimination in potato. The source plants infected with viruses are incubated in a growth chamber under light intensity of 30 50m mol m s at 35 37°C for 2 6 weeks. After respective periods of thermotherapy the meristems are excised and cultured on nutrient medium for regeneration.

Cold therapy followed by apical meristem culture has also been shown to successfully eliminate several viruses from infected plants. Viroids some of which are quite resistant to elevated temperatures have been effectively eliminated by cold therapy. Low temperature therapy (4 7°C) followed by meristem excision and regeneration has been used to eliminate potato spindle tuber viroid (PSTVd) from infected potato plants.

CHEMOTHERAPY

Chemotherapy involves the use of chemicals like antibiotics plant growth regulators amino acids purine and pyrimidine analogues to inactivate viruses or inhibit replication/movement of viruses in tissues. These chemicals can either be sprayed on growing plants prior to excision of meristems or incorporated into tissue culture media. As early as in 1954 eradication of PVX from potato tissue cultures by malachite green and thiouracil treatments was reported. Of all the chemicals tested for plant virus elimination synthetic nucleotide analogues like ribavirin (Virazole 1 D ribofuranosyl 1 2 4 triazole 3 3carboxamide) and DHT (5 dihydroazauracil) have been particularly effective in inhibiting different plant viruses. In vitro chemotherapy of meristematic explants with antiviral chemical ribavirin has been found to be most promising for elimination of major potato viruses. Though the exact mode of action of ribavirin on plant viruses is not understood following possibilities have been suggested

Ribavirin triphosphate a major derivative of ribavirin inhibits viral RNA polymerase synthesis.

Ribavirin 5 phosphate a derivative of ribavirin inhibits IMP dehydrogenase and thereby decreases the GTP pool and nucleic acid synthesis.

Ribavirin interferes with capping at the 5 end of viral mRNA leading to inefficient translation.

Other antiviral chemicals such as 8 azaguanine 5 fluorouracil 2 thiouracil and Para fluorophenylalanine have also been tested for virus elimination in potato. The concentrations of many antiviral chemicals required during chemotherapy to inhibit virus multiplication are very close to the toxic concentration for the host plant. In addition there is always a possibility of mutations when the plants are exposed to antiviral chemical. Therefore in vitro ribavirin therapy at low concentrations combined with thermo therapy has been used to eradicate viruses from infected potato cultivars. In such cases simply culturing the shoot cuttings can eliminate some viruses like PVY/A and PLRV in potato.

ELECTROTHERAPY

Electrotherapy of explants of infected potato plants has recently been reported to be an effective means for virus elimination. Potato stems infected with PVX were exposed to 5 10 or 15 mA for 5 10 minutes followed by immediate culturing of the shoot tips in vitro. The highest efficiency was obtained at 15 mA for 5 min and about 60 100% of the regenerated plantlets tested negative against PVX. Electrotherapy technique is yet to be tested against other potato viruses.

VIRUS DETECTION AND DIAGNOSIS

Even after taking all precautions to excise small meristem tips and subjecting them to various treatments favouring virus elimination ultimately very few virus free mericlones are obtained. Therefore meristem derived plants must be tested for virus freedom before using them as mother plants in micro propagation. Accurate sensitive and rapid detection of potato viruses is critical for identifying virus free mother plants and their integration into seed production programme. A wide array of serological and nucleic acid based

assays is available for accurate detection and diagnosis of potato viruses.
Enzyme linked immunosorbent assay (ELISA) dot immunobinding assay (DIBA) and immunosorbent electron microscopy (ISEM) are most widely used methods for detection of plant viruses. Serological assays involve trapping virus particles on a supporting surface to which a specific antiserum has been attached. An ELISA in a microtitre plate or dot blots on a nitrocellulose membrane are used to produce a colour reaction dependent on the virus concentration. In ISEM the trapped and negatively stained viruses are viewed under the electron microscope. ISEM is used when an available antiserum contains non specific antigens that reduce ELISA specificity. Protein A complemented immune electron microscopy (PAC IEM) a modification of ISEM makes use of protein A s high affinity for IgG to enhance trapping and minimize non specific trapping of virus particles. Over the years various modifications have been introduced in ELISA systems with increasing availability of monoclonal and polyclonal antibodies to reduce host antigen background reactions.
Nucleic acid hybridization is based on specific pairing between the single standard DNA or RNA and a complementary nucleic acid probe to form double stranded nucleic acid. Thus either DNA or RNA sequences may be used as probes for detection of plant viruses. Hybridizations are usually carried out on solid support (nitrocellulose or charged nylon) where the target nucleic acids are immobilized and the labelled nucleic acid probe is allowed to hybridize to them. RNA probes specific for Potato spindle tuber viroid (PSTVd) have been synthesized from a full length PSTVd cDNA. and used successfully for PSTVd detection in potato. Improvements in hybridization assays have been made in recent years using non radioactive detection systems. Nucleic acid probes can be labelled by incorporation of biotin 11 UTP or digoxigenin tagged DTP and can be detected by streptavidin or anti digoxigenin antibody enzyme conjugate respectively. Biotin labelled probes have been reported for PVS PVX and PSTVd. Polymerase chain reaction (PCR) combined with reverse transcription (RT PCR) has also been used for detecting picogram quantities of viral nucleic acid in infected tissues. With its relative simplicity and high sensitivity the PCR based methods will be increasingly used in future to detect and diagnose plant viruses.

MICROPROPAGATION

Micro propagation allows large scale multiplication of virus free potato micro plants. Nodal segments of virus free potato microplants are cultured on semisolid or liquid medium under aseptic conditions for obtaining new microplants. Murashige and Skoog s (MS) medium supplemented with 2.0 mgl D calcium pantothenate 0.1 mgl GA 0.01 mgl NAA and 30 gl sucrose is best suited for propagation of potato microplants in vitro. Cultures are usually incubated under a 16 h photoperiod (50 60m mol m s light intensity) at 24 °C. Usually three nodal cuttings (1.0 1.5 cm) are inoculated per culture tube (25x 150 mm) and the tubes are closed with cotton plugs. Within 3 weeks the axillary/apical buds of these cuttings grow into full plants. These plants can be further sub cultured on fresh medium. At an interval of every 25 days of sub culturing theoretically 3 (14.3 million) microplants can be obtained from a single virus free microplant in a year.
Virus free micro plants can be used for direct transplanting after hardening in the fields or nursery beds for production of normal tubers or minitubers respectively. Alternatively these plants can also be used for the production of microtubers in the laboratory. Microtubers are miniature tubers produced under tuber inducing conditions in vitro. These small dormant tubers are particularly convenient for handling storage and distribution. Many protocols have been developed for induction of microtubers in vitro. Most of the published work on potato microtuberization is focused on the use of cytokinins especially N benzyladenine (BA). Other substances like abscisic acid chlorocholine chloride (CCC) NAA triazoles coumarine acetic acid and jasmonic acid have also been used for induction of microtubers in potato. MS basal nutrient mixtures are universally used for potato microtuberization. Sucrose is the most effective carbon source and an

increase in its concentration to 8% induces early tuberization whereas concentrations above 8% are inhibitory.

Temperature and photoperiod are two important physical factors that affect potato microtuber induction in vitro. The optimum temperature for in vitro tuberization is 20°C with a constant temperature being more effective than alternating day night temperatures. Temperatures below 12°C and above 28°C have been found to be inhibitory to potato microtuber production. In general optimum microtuberization occurs under continuous darkness during cytokinin induced tuberization but a longer photoperiod with higher light intensity is required when cytokinin is not used.

At Central Potato Research Institute (Shimla) microtubers are induced in MS medium supplemented with 10 mgl BA plus 80 gl sucrose and the cultures are incubated under complete darkness at 20°C. Microtubers begin to develop epigeally 1 2 weeks after incubation depending on the genotype and are harvested after 60 75 days of incubation. In general 15 20 microtubers with an average weight of about 100 150 mg can be obtained from each flask/magenta box. Before harvesting the magenta boxes are shifted under diffused or artificial light at 20 24°C for 10 15 days for greening the microtubers. Thereafter green microtubers are treated with 0.2% Bavistin dried at 20°C packed in perforated polythene bags and stored under dark at 5 6°C till dormancy release. These microtubers are planted on nursery beds under aphid proof net houses (50 microtubers/m2) in seed producing areas of the Indian plains. The microtuber crop is allowed to mature in the nursery beds to produce minitubers.

True Potato Seed Technology

Potato unlike other solanaceous crops such as tomato brinjal chilli capsicum etc. is traditionally grown vegetatively by planting tubers called seed tubers. Because of ease in planting tubers and other cultural operations the vegetative or asexual mode of propagation became the standard cultivation practice soon after the ancient farmers domesticated the potato as a food crop. Nearly 2.5 3.0 tons of seed tubers are needed to plant a hectare of potato crop. Seed tubers are bulky containing nearly 80% water that makes their transportation from one place to another difficult and expensive. They however degenerate due to infiltration and accumulation of viruses when the same seed stocks are repeatedly used over the years resulting in serious yield losses. This necessitates replacement of old or diseased seed with fresh healthy seed. The production of healthy seed tubers is expensive and the low rate of tuber multiplication (normally 6 8 times) provides only a limited quantity of quality tuber seed. Further the low aphid areas suitable for producing healthy seed in the country lie in northern plains or higher hills and transportation of seed tubers to distant areas for producing table potatoes adds to the cost of seed and cropping. Therefore the high cost and inadequate availability of healthy tuber seed are most binding constraints in the production and productivity of potato in the country. To overcome this an alternate technology of true potato seed (TPS) or use of botanical seed for commercial potato production has shown great promise for producing both disease free and cheaper seed and thereby reducing the cost of cultivation.

ROLE OF TPS POPULATIONS

TPS is a sexually reproduced propagule in potato and results from the fertilization of ovules which develop into tiny seeds inside the fruit called berry. The seed thus produced is called TPS or botanical seed to distinguish it from the conventional tuber seed. True seeds have the potential to develop into full grown plants and produce tubers.

Potential and advantages of TPS technology

TPS has an edge over tuber seed for various attributes of potato production (Table 1) Thus it can effectively overcome some of the problems associated with seed tubers and can be used easily by the resource poor farmers to produce healthy planting material in any quantity as and when required. It offers many

advantages to the farmers to overcome weaknesses of clonally propagated tuber seeds.
Source of healthy planting material except potato virus T (PVT) and potato spindle tuber viroid (PSTVd) no other major pathogen is transmitted through TPS as they are filtered out during pollination and fertilization.
Saving seed tubers for consumption nearly 18% of the total tuber produce retained as seed can be used for consumption.
Low cost of cultivation Cost of planting material produced through TPS is approximately one tenth of the cost of quality seed tubers.
Easy storage TPS with 3 5% seed moisture can be stored for many years under ambient conditions in dark with practically no loss in germinability at least up to 5 years.
Easy and inexpensive transportation only 100g of TPS can replace 2 3 tonnes of seed tubers required for planting one hectare land.
Potato cultivation in non traditional areas TPS can be used for potato cultivation in areas deemed unfit for producing quality seed tuber due to unfavourable agro climate.
Fitness of potato in different cropping systems TPS can be used to fit potato in different cropping systems when tuber seed of correct physiological age is not available as and when required for planting the crop.
Environment/user friendly the pathogens unlike in clonally propagated crop are unable to affect the TPS crop due to in built resistance (multi line effect) for diseases/pests. Consequently less amount of pesticides is needed for spraying TPS crop. Thus TPS is not only cost effective but also environment friendly.

Constraints/shortcomings in the adoption of TPS technology

TPS presents following disadvantages which have been the major bottlenecks in adoption of TPS technology.
TPS produced crop takes about 15 20 days more for maturity compared to that from seed tubers.
Potato seedlings are vulnerable to environmental stress and damage due to insect/ pests and need more care/labour input especially during the initial phases of growth and establishment in transplanted crop.
Crop from TPS populations are less uniform in plant type/maturity tuber shape size and dry matter.
Further true potato seed has a dormancy of about 6 months. Low quality and dormant TPS usually does not germinate uniformly and produces slow growing seedlings that are highly vulnerable to transplanting shock. Thus plant maturity is extended and production of large tubers is delayed or small tubers are produced due to the usually short growing seasons in tropical areas. When high quality and non dormant TPS is sown the seedlings are uniformly ready for transplanting in only 3 weeks instead of 6 weeks. Seedlings from non dormant TPS unlike those from dormant ones are able to withstand bare root transplanting shock and grow vigorously soon after transplanting and to a size similar to those of plants grown from seed tubers.

Early history

South American farmers have been using TPS to revive their potato stocks from time to time. However the idea of exploiting TPS for commercial production of potato was conceived as early as 1949 in India when Dr. S. Ramanujam founder Director of Central Potato Research Institute (CPRI) carried out field trials on utilizing TPS for ware potato production. The self pollinated seeds of cultivar Thulwa which flowered under natural short pholoperiods during winter season in the eastern plains were used for growing the commercial crop. Seedlings from self seeds of Phulwa showed high degree of heterogeneity for most of the traits and resulted in poor yields due to inbreeding depression. This did not encourage the earlier efforts of growing a commercial potato crop from TPS. The programme of raising crop from true seed was resumed in late seventies after CIP was established in 1973. They identified TPS technology as one of their thrust area for the third world countries. The work was started in India at the Central Potato Research Institute Shimla and at International Potato Center (SWA Region). New Delhi. The efforts for reducing the problem of segregation in the progenies by developing inbred lines were given up. Instead the early efforts

concentrated on evaluation of open pollinated and hybrid populations developed through bi parental mating in tetraploid potato for identification of progenies with high productivity and low variability for maturity and tuber characters. Work was also taken up on standardization of agronomy of raising the crop through TPS. The studies were later extended to flowering behaviour induction of flowering under short photoperiod techniques of pollination TPS characteristics etc. Since 1985. The All India Coordinated Potato Improvement Project through its network of centres all over the country located in State Agricultural Universities (SAUs) has been involved in conducting trials mainly for evaluation of high yielding TPS populations.

Priority areas for TPS dissemination TPS technology has a wider scope for its adoption in areas where quality tuber seed of a variety can not be produced yields are extremely low due to availability of poor quality seed tuber storage and transportation are expensive skilled labour is available and consumers do not have any preference for specific tuber characteristics. In the Indian perspective TPS technology is suitable in the states of Maharashtra Madhya Pradesh Orissa north eastern hill states (in the first priority) where yields are extremely low (< 10t/ha) due to poor quality seed tubers Gujarat, South Bihar and West Bengal (in the second priority) where seed tubers of desired health standard can not be produced and are procured regularly from northern part of the country.

Economics of TPS technology

The high cost of potato cultivation in conventional system is mainly due to higher prices and planting rate (2.5t/ha) of tuber seed. The cost of planting material from TPS is merely one tenth the cost of tuber seed (Rs.25000 30000) for one hectare. Singh and Jee have shown higher net returns for seedling tubers (Rs. 19 552 ha) and seedling transplants (Rs. 19 174 ha) as compared to seed tubers (Rs. 11 566 ha) of a variety under Patna conditions. Another study also indicated higher net benefits (US$ 415/ha) from potato cultivation through seedling tubers than tuber seed due to reduced production costs and improved yields. Seedling tubers are planted at relatively lower rate (by weight) and are resistant to late blight than the existing varieties in the area. Thus the difference between the crops from TPS and traditional seed tubers primarily relate to lesser expenditure on planting material and use of pesticides in TPS raised crop compared to seed tuber crop. The price of seed tubers in India vary with the price of ware potatoes increasing rapidly as cold store stocks are exhausted.

Seed Production

SEED POTATOES

Healthy seed potato is an important input needed for harnessing technological benefits of potato cultivation. About 3.3 million tonnes of certified seed is required for the area existing under ware potato in the country 35 q/ha. When various types of seed is used (cut under size and whole tubers) But if the whole tubers of 30 80 g are used then 4.6 million seed is required for seed and ware potato 35 q/ha for 1.3 million hectare area. To produce this quantity of seed about 2.0 to 2.8 lakh hectare area is needed annually. The major constraints in attaining potato productivity are disease free seed and its higher seed cost.

The first scheme for seed production in India was started in 1941 at Shimla by the Imperial (now) Agricultural Research Institute New Delhi. Under the scheme partially disease free seed of exotic varieties used to be produced by intensive roguing in the hills. Lateron production of quality seed stocks of commercial varieties was taken up by mass selection. The selected apparenly healthy plants were multiplied at Kufri. Because of low aphid population in high hills of Himachal Pradesh quality seed of potato used to be produced in these high hills. Which becomes the main source of quality seed for plains? Seed potato posed many problems. These were (1) it became obligatory to have varieties that could perform well under diverse agroclimatic conditions of both temperate and subtropical plains. (2) Dormancy of hill grown

seed prevented immediate planting in the plains (3) mild hill climates harboured many soil borne diseases and the hill grown seed was a potent source of many soil and tuber borne diseases and (4) due to limitation of land in the hills the seed produced in the hills was Inadequate to meet the requirement of entire country. To overcome these problems and to reduce the dependence of the country on hill grown seed a survey was conducted to locate the aphid free zones in the country and it was found that seed potatoes could be successfully grown in many parts of the North and north central Indian plains under low or no aphid conditions with certain minimum precautions. This led to the development of Seed Plot Technique.

With the development of Seed Plot Technique a Scientific Seed Potato Production Programme of breeder seed was initiated at the CPRI in 1967 in a phased manner. The breeder s seed production method consists of selection of clones and indorsing of representative tubers (4 Nos) from each clone for their virus freedom some important points taken in to consideration as stated by Jr. Jan Morrenhof Virus free tubers by indexing and their field multiplications in stage 1 to 4 under strict supervision to protect the seed crop from degenerative diseases. Integration of meristem culture and micropropagation techniques in the initial stages of breeder s seed production can improve the quality of breeders seed. The breeders seed is further multiplied in foundation and certified seed stage.

As a rule seed tubers are used for planting. These tubers basically do not differ from tubers that are used for consumption purposes. Sometimes farmers use part of their own harvest as planting material for the next season. However in many places farmers do not use their own produce but purchase seed from reliable source every year or after a number of years. The reason is that not every potato is suitable to be used as seed and that not every area and every season is suitable for the production of seed. Further more not every farmer region or country possesses the skills and or the necessary equipments and infrastructure which are required for the production of good quality seed. The use of quality seed is not only the basis for high production and good quality but also of a sustainable production system. The difference between the use of seed potatoes of good or of inferior quality may express itself in yield differences of 20 to 50%.

Variety Some varieties can be grown in many places and have a wide range of adaptability others are meant for very specific purposes or for specific environmental conditions. Apart from production capacity an important varietal characteristic is the resistance to pests and diseases. Varietal purity is an important requirement for quality seed lots. Admixtures of other varieties will result in varying requirements with respect to agricultural practices like fertilizer harvest time etc. if rouged out before harvest. They will also affect the marketability and price.

Diseases It is essential to know which diseases/pests are important under prevailing conditions and the level of risk they impose. It can then be decided whether more or less strictness is required regarding their persistence in the seed. Relevant tolerance levels are established for each of them. In some cases the tolerance will be zero especially in the case of quarantine diseases which are known to be seed and soil borne and which are not generally present in the country or in a certain area. The seed production system should be based on a proper pest risk analysis.

Degeneration When a crop is infected with virus its yield will be affected. The rate at which the yield reduction will take place depends on the intensity of the infection the type of virus and the combination of other yield affecting factors that are present. A crop that is already under stress from other factors will suffer more from the virus infection. In general a low infection level will have little effect on the yield but high infection levels can result in yield losses upto 50% or more in case of dangerous viruses like potato virus Y (PVY) or potato leaf roll virus (PLRV). If proper measures are not adopted to control the spread of the viruses the infection level will increase progressively from one generation to next when the potatoes are produced. Gradually or reduction in productivity of the crop is observed in successive generations. This process is called degeneration. The degeneration speed and severity is not the same every where it depends on presence of vectors and sources of infection available. Degeneration rate in warm climate is

higher.

In general the production of the lower seed classes (later generations) is done in the field and follows the same principles every where in the world. Only the number of multiplications and the level of quality maintenance may differ. For the production of basic seed however there are some distinct approaches that can be followed. The conventional system is through clonal selection which fully takes place in the field. Newly developed systems are the rapid multiplication techniques using laboratories and green screen houses.

In the past clonal selection was the only system available for the production of basic seed. Typically true to type and apparently healthy looking plants were selected to start the cycle. The progeny of one plant formed a clone. The clones were kept separate from the others during three to five years of multiplication. Simultaneously in the same year several clones of several varieties were multiplied side by side depending on the expectations of the future seed demand. During the whole process the health and quality characteristics are strictly monitored and in case a single diseased from the system. After two or three multiplications the individual clones of one variety were bulked and constituted as one lot. The thus produced pre basic seed was (or has to be) absolutely true to type and free of all diseases. Presently starting a multiplication cycle absolutely true to type and disease free material must be obtained. This is done by growing a meristem culture of shoot tips of true to type and healthy plants under sterile conditions in a tissue culture laboratory. From the culture small plant lets are raised invitro which are kept in test tubes or small transparent plastic containers. These invitro plantlets can under aseptical conditions be cut into small pieces each consisting of a piece of stem with one node which are again placed in tubes or containers on a growing medium. From the bud present in the node small shoot will develop which will develop into small but complete plantlet. The procedure can be repeated as often as desired. It takes about one month between cuttings and each plantlet can be cut into 5 to 8 pieces. At a desired moment the plantlets can be transplanted in green houses and allowed to grow into normal size plants producing normal tubers. As the plantlets are vulnerable they are normally passed through a hardening process in green or screen houses before entering the open field. Alternatively they can be planted directly in the field under protective nets.

Instead of using plantlets in test tubes nodal cuttings can also be taken from bigger plants. When laboratory space is limited the in vitro plantlets can be transferred from the tubes to pots in green houses. After some time nodal cuttings can be made from the stems of these plants which can be rooted in soil sand and FYM mixture (1 1 1) to be grown into normal plants (either or not via transplanting). With the new shoots growing from the same mother plants the process can be repeated two to three times. Then they are left to grow to maturity. Mini tubers are produced from in vitro plantlets after they have been planted at high density (100 plants per m_) in beds in green or screen houses. The plants remain small and consequently small tubers are produced. Mini tubers of 15 25 mm sizes are preferred. The mini tubers thus produced can be planted directly in the field and enter the seed production chain. When compared to clonal selection the mini tuber production requires high investment in laboratories and green house which makes it more expensive. The advantage however is the fact that the tubers have been less exposed to infections with diseases than the clones that have already been in the field for a number of generations. This may be of particular importance in places where high degeneration rates prevail or a disease of serious nature occurs in the region.

SEED PLOT TECHNIQUE

Potato seed production on scientific lines in India has been started since 1966 through the technique which is known as seed plot technique. The main aim of this technique is to exploit the vector (Aphid Myzos persicae) free period in the Northern plains with adjustment of planting and lifting dates and by adoption of appropriate plant protection management and method of cultivation for disease free seed.

The cultural requirements of the crop grown for seed differ from ware potato production. Different practices followed in seed plot technique are discussed as under

Selection and preparation of field The potato crop should not be repeated in the same field. The planting of potato in chilli brinjal tomato and okra crop rotation is not recommended so that the disease intensity would be lowered down. Adoption hot weather cultivation and 2 3 years crop rotation is recommended to avoid buildup of soil borne pathogens such as black scurf and common scab etc. Minimum isolation distance of 25 metres from the ware crop should be kept.

Field in which potato seed crop is to be grown should be deep ploughed during summer and left as such. This will help in controlling certain pest and diseases and also the weeds.

Seed Seed should be healthy essentially free from the viruses soil borne diseases like bacterial wilt common scab and nematodes etc. genetically pure and of uniform size. Genetical purity is of great importance in potato seed production programme. The identification of potato varieties at their sprouting stage can be possible. A reliable method has been developed using the sprout grown in the light. Another method employed now a days to draw sample from the seed stocks and plant them under long day conditions where flowering is obtained to determine whether the variety is true to the type or not. The minimum size of seed accepted is 28 to 35 mm and maximum size permitted for seed potatoes can be as large as 80 mm but often not more than 55 to 60 mm. Generally 15 stems per m_ should be there small tubers have less sprouts than bigger ones but their weight is also lower. Morrenhof reported that to around 15 00 000 obtain stem per hectare 60 000 tubers equivalent to 1500 kg are required when size of 28 35 is used against 30 000 tubers equivalent to 2700 kg when the size 45 55 is planted under Netherland conditions.

Pre sprouting of seed tubers before planting increase the number of stems per tuber and also hastens quick uniform and full germination. The seed stock of early varieties should be withdrawn from cold storage at least 7 days before planting and that of late varieties 15 days before planting. The number of sprouts from a seed tuber depends on a function of variety physiological age of tuber and the temperature of the chamber in which the seed is kept for sprouting. An ideal temperature for sprouting is 10 12°C.

Thermotherapy Several varieties have been completely cured of PLRV by heat treatment at 35°C for 56 days and at 36°C for 39 days Thirumalchar demonstrated this in the stocks stored in improvised stores under warm conditions at Patna.

Planting

Seed size and spacing Whole potato tubers of about 45 50 g are used for seed crop. Tuber number is a function of plant density which depends on the number of main stems. Proper combination of seed size and spacing is therefore essential to get the number of required stems per ha. About 30 main stems per m yield maximum seed sized tuber. For this there must be 70 000 80 000 plants per ha. In India with careful manipulation of sprouting tuber size spacing and time of planting an average of 4.5 stem per plant can be achieved with seed tubers between 20 25 g when spaced at 50 x 20 cm 50 100 g seed at 60 x 25 cm and 100 g and above at 60 x 30 or 60 x 40 cm. 10 20 g tubers at spacing of 40 x 15 cm seed produced maximum quantity of C grade tubers (>25 g in weight) which are suitable for planting.

Time of planting In hills the planting time is mid April. It may differ because of temperature variation. In plain the planting time ranges from first week of October to 1st week of November depending upon the region. The temperature should be ranged between 8 to 28°C during the crop season.

Fertilization The fertilizer requirement will vary with soil and previous crop taken. In general about 120 150 kg N 80 100 kg P_2O_5 and 100 kg K_2O per ha may be used in seed crop. Heavy application of nitrogen may delay tuberization masking of virus symptoms and delay in maturity.

Irrigation A light irrigation should be given to the crop immediately after planting if pre planting irrigation is

not given. Pre planting irrigation assures the uniform emergence. Second irrigation should be given about one week after planting and subsequent as and when required.

Weed control Full earthing up may be done at planting and pre emergence herbicides are used to control the weeds and avoid spread of contagious viruses. Weed control through cultural method is generally not advised. Because the frequent entry of man and implements are likely to spread contact viruses like. PVX and PVS. For pre emergence weed control herbicides like Pendimethalin Alachlor Metribuzin etc. may be used.

Rouging and Inspection Diseased and off type plants should be pulled out along with mother tuber and newly formed tubers if any as soon as they are identified. This practice should be repeated twice or thrice to avoid the varietal admixture and keep the crop free from viral and phytoplasmal diseases. Inspection of seed crops should be done 3 times at 50 65 and 80 days during growing season and remove all off types and diseased plants showing symptoms of viruses should be removed.

Haulm cutting Haulms destruction is a must to prevent the infection/ transmission of virus infection by aphid (Myzus persicae). The aphid population starts building up in the end of December or 1st weeks of January. At this stage haulms should be removed either manually or by using the chemicals. Paraquate Chloride @ 2.5 lit/ha is most effective for killing of haulms. Singh et al. After removing of haulms the field should be inspected periodically and regrowth if any should be destroyed.

Aphid management This is one of the most important practices of the Seed Plot Technique. The aphid population should be recorded periodically and when it reaches above the threshold 20 aphids per 100 compound leaves dehaulming should be practiced. There should be at least 75 days low aphid period or aphid free period so that an economical yield could be obtained from early bulking varieties. In plains the effective aphid free period is too short. The crop can be escaped from build up of aphids if it is harvested early. In such areas reasonably healthy seed with good yield can be produced with the management of aphid population below threshhold level with the use of systemic insecticides like. Phosphomidon Monocrotophos Dimethoate
etc. (100 125 ml in 100 litres of water). In case of early appearance of aphids spraying of crop should be done in first week of December.

Disease and Pest Management The potato is prone to number of diseases. The seed should be free from seed borne diseases and pest so that the crop is not economically affected in yield and quality. Viral diseases are particularly important in potato seed production programme. The control of fungal bacterial namatodal diseases also determine the value of the seeds potato. Use of granular insecticides such as Thimet 10 G (15 kg/ha) at the time of planting is essential in plains to control the aphids. Spray the crop with Endosulfan 1.5 lit/ha or corboryl 2.5 kg/ha is sprayed if leaf catterpillar damage is noticed. Ridges are treated with chloropyriphos 2.5 lit/ha to control the damage of cut worm. One spray of Rogor or Metasystoc in the first week of December will check the aphid and also other sucking type of pests. One or two protective sprays of Dithane M 45 > 2.5 kg/ha against early and late blights are required. When epidemic of late blight is observed Ridomil Metalaxyl 2.5 kg/ha should be sprayed. Spraying should be done from 3rd week of November at 10 days interval.

Harvesting and storage Harvesting should be done after 15 20 days of haulms cutting so that the skin of tubers gets hardened. Delay in harvest will spoil the quality due to high temperature in March April in the plain s. The harvested tubers should be kept in a cool place for about 15 days for curing. Seed tubers should be graded before transporting to the cold store. The small size tubers should be kept as seed tubers.

Seed treatment After grading the tubers are washed with 1% chlorocin solution followed by rinsing in water and dipping in 3% boric acid for 20 minutes. After treatment the tubers are dried in shade and packed in gunny bags then labled and sealed and kept in cold store.

Favourable Conditions of Growth for Potato

Climate

Potato is a versatile crop and can grow under diverse range of Agro climatic condition. The potato is a crop of temperate climate and thrives well in cool climate. In general relatively cool condition (15.5°C 21.1°C) are most favourable for the growth of plant and tuber formation. In the hot weather of mid summer plant may produce heavy vines but set few tubers.

The potato has a wide range of seasonal adaptability. In the Gangetic plains of Uttar Pradesh sowing time of the crop can be extended from mid. September to almost mid January for about four months an advantage which perhaps no other crop enjoys. In Punjab and Western district of Uttar Pradesh two crops can be raised in succession on the same price of land the first sown in September October and the second in December January. In Southern India where summer temperatures in the plateau region are somewhat milder two crops one in winter and other in summer can be raised. It should be recognised that very few crops can be raised successfully both in Rabi and Kharif season in the same tract. In the Nilgiri Hills three potato crops are raised almost in succession the planting month being April August and January.

In general potato is a summer crop in the hills where it is long day crop and a winter crop in the plains where it is a short day crop. It is possible to cultivate more than one crop in the plains by adjusting the time of sowing. Low temperature high light intensity and short days are conductive for early initiation of tuberization and its subsequent development. It grows best under long day condition. In short day and warmer temperature flowering in potato is restricted and sometimes completely suppressed.

Rainfall

Potato is cultivated as a rainfed as well as irrigated crop. High rainfall and humidity are detrimental to this crop though it requires regular irrigation for the plant growth and tuberization. Soil moisture stress results the lower yield for potato. Potato is sown in the plains when rains are over as it fails with heavy rain. But it needs frequent but light irrigation usually form 6 8 irrigation. The water requirement of this crop is 25 26 hectares centimetre.

Temperature

Temperature exercises a marked influence on plant growth and tuber development. The temperature affects biochemical reactions and though these influences the growth and development in crop plant. Potato can stand temperature ranging from 10°C (50°F) to 26.6°C (80°F) but average is 21.1 C (70°F). The average mean temperature of 15.5°C to 18.3°C (60 65°F) are preferred although prior to tuberization slightly higher temperature give the best growth. According to Mac Gillivary tuberization is best at soil temperature of 17.7°C (64°F). But according to Choudhury tuber production is maximum at 20°C (68°F) and decrease with the rise of temperature. At about 30°C (70°F) tuber production stops totally as at this temperature carbohydrates consumed by respiration exceed those produced by photosynthesis. The work carried out at CPRI Shimla revealed that night temperature of 15°C 20°C (59°F 69°F) are optimum for greater tuber yield in pre tuber initiation phase and 15°C (59°F) in the post tuber initiation phase under short day. With the increase in temperature from 10°C 30°C (50°F 70°F) or 15°C 25°C (59°F 75°F) there was greater extension of growth of plants and accumulation of dry matter in stem. Jones et al. have found a clear influence of soil temperature. 15°C to 18°C (59°F to 64.4°F) being optimal. Higher temperature induces respiration to go up and less carbohydrates is left for the tubers. Heal necrosis may also be caused by higher temperature. High temperature with longer days and an abundant supply of nitrogen favour the growth of all plants except the tuber while the low temperature with intermediate days and deficient nitrogen caused early tuberization. The soil temperature is also important since this determine the rate of respiration of the tuber. A number of worker have obtained increased yield by mulching as it help to reduce the soil

temperature. Irrigations may also reduce the soil temperature. Under cool and short day the plants were small and had a very high ratio of tuber to top. Joshi et. al. studied the effect of night temperature and photoperiods on chlorophyll content dry matter and tuber yield in potato. Plant exposed to long days at 15°C and 25°C showed higher chlorophyll content and dry matter than the plants grown under short days at respective temperature. There was marked decline in chlorophyll dry matter and tuber production at 25°C night temperature under short days as compared to lower temperature.

Table 1. Effect of night temperature and photoperiods on chlorophyll dry matter content and dry weight of tubers

Potato can stand even lower temperature provided frost does not occure. Under higher temperature plants are elongated leaves become wrinkled and plants have sickly appearance. Tuber does not develop under such conditions.

It grows at elevation ranging from sea level to 2743 meters high. In India potato is grown upto 2100 meters high from sea level. Bulk of this crop is mainly grown in the plains. It has been found that potato thrives best under short day conditions coupled with abundant sunshine and cool nights. Cloudy days rains and high humidity are very congenial for spread of fungal and bacterial disease.

Light

Light influences various physiological process of the plant such as chlorophyll synthesis opening and closing of stomata photosynthesis respiration and transpiration. It promotes sprouting in tubers of potato but once it has taken place it inhibits their excessive elongation. The intensity and duration of light is responsible for higher yield and quality of tuber due to increased photosynthesis but tuber must remain covered under the soil to avoid sun scalding. In general conditions that are conductive to production of very large tubers may cause hollow heart in the tuber. Tubers are storage organs and in case of potato starch is chief reserve food which is synthesized in plants from sugar formed during photosynthesis. The amount of sunlight the plant receives determine the rate of photosynthesis to the great extent and directly influences the amount of carbohydrates available for tuber growth.

The tuber formation in potato is a response of the plant to photoperiodic stimulus. Potato has been classified as a short dry (SD) and long day (LD) crop in its tuber initiation response. In the plains of India the crop is taken during short days of winter and under this condition tuber initiation is early the plant is stunted giving bushy appearance bulking is rapid and maturity is advanced. On the other hand under LD conditions prevailing during crop growth in summer in hills tuber initiation is delayed plants are tall and growing season is prolonged. The ratio of tuber to foliage which is an index of efficiency of plants in crop production is greater under SD than under LD condition. The effects of suboptimal number of SD separated by non inductive LD are not additive on tuber initiation in Potato. The foliage exposed to SD that would initiate tuberization is called induced foliage . Light also affects respiration indirectly through temperature. The potato is LD plant in its flower initiation response. It is found that almost all the varieties come to flowering in hills where the potato is cultivated during long days of summer. In photoperiodic reaction it is revealed that red and far red light should be effective.

The yield of potato is poor in India due to its growing in short day period because during this time carbohydrates production is low.

Soil

The potato crop can grow well in all types of soil except alkaline soil and soils with high clay content. Sandy loam loamy soil and sandy soil rich in organic matter are most suitable for potato cultivation. Heavy and wet soils are not suited for potato. The soil should be loose and friable with aeration and good drainage as potato is very sensitive to excess of moisture which causes rotting of tubers. So drainage is most important for successful cultivation of potato. The soil with pH around 5.0 6.5 is considered to be best for potato

cultivation. Slightly acid soils (pH 4.8 5.4) are preferable for potato cultivation especially for areas where scab disease is prevalent. It cannot tolerate alkalinity in the soil since alkali soils create favourable condition for scab disease. Heavy soils are not suitable for the growth and development of tuber. But the heavy soils that are manured heavily with manures such as compost F.Y.M. Oil cakes etc. are found suitable for potato cultivation. Potato grows well even in sandy soils if adequate fertilization is done. Heavy type of soilare difficult to work with and are not well suited for potato cultivation.

Topography

The plains are most suitable for potato cultivation during rabi season. In the hills potato is cultivated on the sloppy land after making terrace.

Cultivation

LAND PREPARATION

The potato needs well pulverized seed bed for tuber production. The soil is brought to a fine tilth by giving 8 10 ploughing followed by planking after each ploughing. The process of planking levels the land breaks the clods loosen and collect the weeds and compresses the soil slightly. The preparation of land is usually begin at 6 8 weeks before the sowing of potato during which 250 quintals of compost or F.Y.M. per hectare are applied to the soil. The soil should be made free from stubbles weeds and clods. Now a days tractors and power tillers are employed for land preparation the latter makes the soil more pulverize free from weeds and clods by minimum number of tillage than that of country plough.

Carbaryl 10 per cent 20 kg. or Texaphene 5 percent or Folidol dust 25.0 37.5 kg or Chlorophyrifos (Pyriban 20% EC)

1 litre per hectare should be applied with last preparatory tillage.

PREPARATORY TILLAGE

Tillage operations that are carried out to prepare the field for raising crop from the harvest of a crop to the sowing of the next crop are known as preparatory tillage. It is divided into primary and secondary tillage operation.

Primary tillage or ploughing

The tillage operation that is done after the harvest of crop to bring the land under cultivation is known as primary tillage. Ploughing is the opening of the compact soil with the help of different ploughs. Primary tillage is done mainly to open the hard soil and to separate the top soil from lower layers and to uprooting of weeds also. Potato is a crop whose growing season is short and whose planting time is restricted. Speedy agricultural operations are a basic need to ensure success.

There are several implements used for primary or preliminary tillage as follows

Country Plough. It is an indigenous plough and is one of the most common implements used by Indian farmers. It is drawn with a pair of bullocks. It is used both for tilling the land and harvesting of potato. The country plough works to a depth of 10 15 cm. and opens out a furrow of 12.5 to 17.5 cm. The plough can work up about 0.14 hectare per day in the initial ploughing and subsequently the efficiency increases to about 0.20 hectare a day.

Mould board plough. It is most suitable for primary tillage of almost all types of soil. It cuts square furrow and the soil is inverted completely depending on the curvature given to the mould board plough and thus help in burying the weeds. The mould board plough ploughs to a depth of 15 cm having width from 15 to 35 cm. It covers 0.20 0.26 hectares of land in a working day of eight hours.

Bose plough. It is a modified form of mould board plough. It is made of wood except the share which is made of steel or iron. The structure and function of this plough is almost similar to mould board plough. This plough is gaining popularity among the farmers. Most of the farmers of our country are using this plough.

Disc plough. It is also used for ploughing which have little resemblance to common mould board plough. It is clod breaking implements which is invariably used for initial ploughing in hard soil. It can cover about two hectares a day.

Spade. Spade is most common implements used for various agricultural operations like bunding channeling ridging and harvesting of potato. It is used for breaking and preparing of the soil when the land size is small. A man can dig about 0.08 hectare in a day of eight hours.

Tractor. It is most important tools for mechanization of various farm operations and it has become a vital part of modern agriculture. Four wheeled tractor having average horse power of 30 to 35 can be used for ploughing harrowing sowing harvesting transport and belt work (i.e. cutting of chaff lifting of water etc.). The Tractor is wonderful piece of invention for the agriculture.

Power tiller. The power tiller is generally used for plough
ing harrowing puddling and pumping of water. It makes the soil pulverized very well and hurried the weeds completely. The tilling capacity of a power tiller is about 0.25 acres per hours.

Secondary tillage

The tillage operations that are performed on the soil after primary tillage to bring a good soil tilth are known as secondary tillage. Secondary tillage consist of lighter or finer operation which is done to clean the soil break the clods and incorporate the manures and fertilizers.

There are some implements used for secondary tillage as follows

Ladder or Plank. It is an age old implement used for secondary tillage. Planking is done to crush the hard clods level the soil surface and to compact the soil lightly. It is pulled by a pair of bullock or tractor.

Harrow. It is commonly used for secondary tillage and is drawn by a tractor. Harrows are used for making the soil loose and friable. It can cover 1.0 hectares of the land in a working day of 8 hours.

Cultivator. It is one of the most useful implements used for secondary tillage of potato field. It may also be used for primary tillage cultivation and weeding purposes soon after the emergence of the plant. It can cover 1.0 to 1.5 hectares of land in a working day of 8 hours.

Besides this Spade Khurpi Nirani etc. are also used for secondary tillage.

AFTER TILLAGE

The tillage operations that are done in the standing crop after planting and prior to harvesting of the crop plants are called after tillage. This is also known inter cultivation or post planting cultivation. It includes harrowing hoeing weeding earthing up drilling or side dressing of fertilizer etc. Spade Nirani Harrow Wheel hoe etc. are used for inter cultivation.

PLANTING OF POTATO

Sowing Time

The potato crop is grown in different periods in different parts of India depending on the ecological conditions. (Vide Table 1)

Selection of Seeds

Seed is the base on which the foundation of potato farming has to be laid. In fact in no other crop is the value of good seed so important as in the potato. With assured good seed over 50 percent of the problem of production of the growers can be overcome.

Potato is an asexually propagated crop and it is propagated from tubers which are commonly spoken of as seed. Pure and healthy seed is the basic requirement for a good crop. Seed is one of the major inputs in potato production accounting for more than 50 percent of total cost of cultivation. If the seed is low quality no other factors like good culture manuring and plant protection measure will be of any help in securing profitable yield. Tubers showing any surface borne diseases like scabs wart nematode infection or effect of rot caused by fungi and bacteria should be sorted out and destroyed.

Seed tubers are the costliest item in the total cost of production and it also affects the yield of the crop. Seed is major input in potato cultivation accounting for 45 50 per cent of total cost of cultivation. The following points must be taken into account at the time of selection of tubers for seed.

Seed tubers must be uniform in shape and size.

Seed tubers must be free from any surface borne disease like scabs wart nematode infection or effect of rot caused by fungi and bacteria as they carries a number of pathogenic disease such as late blight charcoal rot brown rot black scurf etc. and bacterial disease such as ring rot (C.O. Pseudomonas solanacearum) and also insect attack. Tuber moth which infects potatoes in the country storage often damages the buds decreasing the seed value of the tuber. Mealy bug is another tuber insects in the country storage affecting the quality of seed.

Seed tubers must be 2.5 3.8 cm in size and 50 60 gm in weight. Small size tubers produce virus infected plants.

The seed tubers should be in their right stage of sprouting so that it germinates quickly and establishes itself into a vigorus plant and the sprouts should be about one cm. long at the time of planting as over sprouted seed give rise to plants with poor vigour and low yield. The seed tubers should be kept in cool place for about three week in the eastern plains and one week in the North Western plains for sprouting.

The seed tubers should not be shriveled. Because seed tubers which have shriveled in storage loose much of their vitality. The use of such seed or over sprouted seed give rise to plants with poor vigour and low yields.

The seed tubers should be true to type.

Certified seed tubers should be preferred.

Source of seed tubers for commercial use

There are three sources of seed tubers for commercial use as follows

Seed stored in country cellers. It is old and primitive method of storing seed potatoes. The varieties such as Kufri Safed Phulwa and Satha with good keeping quality can be stored in country cellars. The varieties like Darjeeling Red Round and Kufri Red can also be stored in country celler with proper care and management. The potatoes that are stored in country cellar need desprouting once or twice during storage to avoid their shrinkage. It does not withstand cutting operation and has to be strictly avoided. The whole tubers are planted in the field. The seed storing in the country cellars are fast losing importance with the popularization of seed preserved in the cold storage.

Seed stored in the cold storage. It is most useful and economical method of storing seeds in large quantities for autumn planting in the plains particularly when early crops are sought to be raised. The seed potatoes should be removed at least by the beginning of November from the cold storage as storage for long period (about 8 9 months) affects the seed value of the tubers adversely and such seed tubers develop into weak plant with several thin stem which mature early and yield poor crop of small sized tubers. The seed potatoes after they are removed from cold storage should be dried and carefully sorted and should be kept at least one week in cool and shady place for sprouting. It is preferable to plant whole tubers as the cold stored seed do not withstand cutting operations successfully. However where cutting of large sized seed tubers become necessary and unavoidable it is best to suberise the cut surface in cool place before planting in the field. The cold stored seed cannot withstand transport over long distance in the plains during September October. For this it is better to use such seeds locally within the juridiction of the cold storage. The seed tubers need to be trans-ported in the distance place should be dried and sorted carefully in the shade of the cold storage and then transported.

Seed produced in the hill areas. Potato is cultivated in the summer season in the hill areas. Here the harvesting is done in the month of October. These potatoes are used as seed in the plains. But this seed

tuber cannot be used immediately after harvest as they are partially dormant. They are profitably be used as seed tuber in a place where planting is done late i.e. between November and January. They can withstand rough handling and can be transported over long distance in loose bulk or in bags in which respiratory activity warms up the stock during transit which help to force the tuber to sprout. If the stocks are still unsprouted a short period of storage in a warm place before planting is desirable. It ensures quick and better germination of seed potato.

The seed produced in the hills is invariably used as cut seed. This is highly desirable practice for the following reason.

Hill produce usually consists of large sized tubers it is uneconomic to sow large sized tubers cutting helps to considerably lower the seed rate per hectare.

Hill seed is often in a semidormant state cutting of tubers and planting then immediately after in the moist soil helps to overcome the dormancy and results in better germination.

DORMANCY OF SEED POTATOES

Potato tubers are living entities with high rate of metabolism and they do not keep well under prolonged storage unless special precautions are taken. Potatoes are susceptible to three main types of deterioration in storage Shrinkage rot and Sprouting.

As stated early the time taken from harvest to the initiation of sprouting is termed dormancy. Immediately after harvest tubers have a rest period or dormant period during which they will not sprout even through placed under suitable condition. So dormancy has been defined as that condition of potato tubers in which they fail to sprout under environmental condition that are otherwise suitable for sprouting.

The problem of dormancy is of a great significance under Indian condition of culture particularly when seed from the hills is to be used as seed soon after harvest. The period of dormancy varies from variety to variety and is influenced by several external factors. After tuber formation the buds on the potato tubers remain dormant for a period of time the duration of which is largely a varietal character although it can be modified to some extent by factors of storage environment particularly temperature.

Dormant or even semidormant tubers will not germinate readily in the ground their emergence is considerably delayed and often erratic and the crops will be uneven. On the basis of the duration of dormancy as calculated from the time of harvest to the first appearance of sprouts under condition otherwise favourable for sprouting commercial varieties can be broadly divided in the following three groups.

Fungal Diseases and their Management

LATE BLIGHT

Symptoms

Late blight is the most dreaded disease limiting potato production in the subtropics. Although severity of this disease is moderate in subtropics as compared to temperate climates lack of appropriate management technology in this region results in heavy crop losses. The disease appears first as water soaked irregular pale green lesions mostly near tips and margins of leaves. These lesions rapidly grow into large brown to purplish black necrotic spots. During morning hours a white mildew which consist of sporangia and spores of the pathogen can be seen on lower surface of infected leaves especially around the edges of the necrotic lesions (Fig. 1). Light to dark brown lesions appear on stems or petioles that elongate and encircle the stems. The affected stems or petioles become week at these locations and may collapse. Under disease favorable conditions entire crop gives blackened blighted appearance and may be killed within a week. The infected tubers are initially hard dry and firm but may be invaded by other pathogens mainly bacteria and turn to soft rot.

Distribution and losses

The disease severity is not uniform throughout the subtropical region. For example in India it is most severe in temperate highlands followed by tropical highlands and subtropical plains. Even in the subtropical plains the disease is generally more regular and severe in north eastern plains of Bihar Assam and Orissa as compared to western plains. These variations in disease severity are primarily due to the differences in weather conditions. In hilly regions losses may go as high as 80 90 percent in susceptible potato varieties not protected by fungicides. Losses are generally low in plains where disease does not occur every year. However in certain years these may go up to 25 per cent.

Pathogen

Late blight is caused by Phytophthora infestans (Mont.) de Bary. It belongs to order Peranosporales of class Oomycetes The fungus is coenocytic which produces lemon shaped detachable papilliate sporangia on sympodially branched sporangiophores of indeterminate growth. The sporangiophores exhibit a characteristic swelling at junction where sporangia are attached with the sporangiophores. The fungus is hetrothallic and requires two mating types viz. A1 and A2 for sexual reproduction. The fungus is believed to have originated in Mexico and migrated to the rest of the world. It caused the great historic potato famine in Ireland during 1845 46.

Variability The fungus is very elastic and new pathogenic races of the fungus appear in field which can overcome resistance of disease resistant cultivars. Ever since discovery of major genes in Solanum demissum and their use in management of this disease more and more newer races of P. infestans have appeared throughout the world. In India only simple races (0 1 4) used to occur until 1965 but complex races started appearing in late sixties with the introduction of late blight resistant cultivars such as Kufri Jyoti Kufri Khasigaro and Kufri Muthu etc. and by end of 1980 eight to nine gene complex races became quite prevalent particularly in hilly regions.

New races of the pathogen could arise through mutation somatic hybridization adaptive parasitism or sexual reproduction. Sexual reproduction prior to 1980 s was mainly restricted to Mexico but recently it has been found operative in many European and Asian countries including India.

Survivability Phytophthora infestans mainly survives through infected seed tubers kept in cold stores in the plains and country stores in hilly regions. Under temperate conditions the fungus can survive in refuse pile in infested vines and tubers. Volunteer plants can also serve as primary source of the pathogen. The pathogen can also survive as oospores which are produced sexually through mating of Al and A2 strains.

Genetics and cytogenetics Sporangium of P. infestans is multinucleate. Both migration of nuclei from hyphae and division within the sporangium initially give rise to multinucleate condition. Degeneration of nuclei coupled with nuclear division occurs in detached sporangia before formation of zoospores. P.infestans in contrast to most other fungi resembles higher organisms in being diploid in the vegetative phase with meiosis occurring before gamete formation. The pathogen can occur as diploid triploid or tetraploid. Polyploidy in P.infestans could be one of the reasons for variability arising within the fungus.

Epidemiology

Appearance of late blight and its subsequent build up and spread depends on several factors. These include sources of inoculum plant protection support provided through fungicide sprays deployment of host resistance in field and weather conditions.

Sources of inoculum-infected seed tubers left in soil and refuge piles in the temperate regions and the tubers cold stored in subtropical regions serve as primary source of the disease. The fungus may also survive as oospores in soil but the extent of their contribution to primary inoculum is not clear. Similarly role of potato and tomato stalk and infected true potato seed in the perpetuation of the disease is not certain.

Environment and disease-Appearance of late blight depends on inoculum load host resistance and

weather conditions. Weather conditions play a decisive role in the appearance and build up of late blight. At nearly 100 percent relative humidity sporangia of the pathogen appear within 8 hours at temperature range of 18 to22°C. The sporangia are prone to desiccation but can remain viable for several hours at moderate humidity while attached to sporangiophores or after they are deposited on leaf surfaces. Optimum temperature for indirect germination through zoospores is 12°C. It may take only 30 minutes to produce zoospores at this temperature. The zoospores are disseminated by splashing rain drops and cause rapid development of disease in field.

Figure 1. Late blight caused by Phytophthora infection on potato leaves

Zoospores produce germ tubes and appresoria in the presence of free water and penetrate the host tissue within two to two and half hour at 10 to 25°C. Once the penetration has occurred subsequent development of the disease is most rapid at 17 to 25°C. optimum at 21°C when lesion with fresh sporangia appear within 3 to 5 days. Rainfall and soil temperature below 18°C result in higher tuber infection.

Factors such as day length and light intensity are known to influence resistance of potato cultivars. Expression of race non specific resistance is better under long day conditions. Host nutrition and virus infection in plants may also affect their reaction to late blight.

Several models to forecast late blight have been developed but the most successful and widely used models were Blightcast developed by Krause et al. and SYMPHYT developed by Bruhn and Fry. Computer aided decision support systems. Different methods and weather criteria may be required for forecasting potato blight for different regions. Based on local weather parameters a computerized forecast for late blight named as JHULSACAST has been developed for western subtropical plains of India.

Disease spread and build up Build up and spread of late blight has mainly been studied in relation to focus of infection. Blight development around infection focus primarily depends on the dispersal of P. infestans spores which is primarily restricted to short distance although long distance dispersal has also been reported. Early infection mainly occurs in lower leaves which later spread to all parts of the plant. The disease develops more in the wind direction and the incidence is inversely proportional to the distance from the disease source. Primary infection focus is mainly limited to an area about 10 meters of the source. Secondary infection foci develop around the primary source.

Management

Effective management of late blight would entail reduction of both foliar and tuber infection. This can be achieved by employing chemicals crop husbandry methods and host resistance in an integrated manner.

Chemical-Both contact and systemic fungicides are important in the management of late blight. Earlier inorganic molecules such as copper salts and Bordeaux mixture were used to manage the disease. Later discovery of dithiocarbamates replaced copper salts and were put to widest use. Recently a new group of fungicides viz. phenylamides especially metalaxyl a systemic fungicide have been proved to be the most potent fungicides ever evolved. Within a few years of its development this has become a major fungicide used in the control of late blight the world over. But isolates of P.infestans resistant to metalaxyl have appeared both in India and other countries. To prevent development of resistance in the pathogen metalaxyl can best be used in combination with contact fungicides such as mancozeb. Another fungicide Cymoxanil in mixture with the contact fungicides can be used to manage metalaxyl resistant isolates of the pathogen. Optimum use of any fungicide can be made following disease forecasting systems. Heavy dependence on fungicides could pose threat to environment and human population. Scientific community is now devising ways and means to reduce the use of fungicides. Use of naturally occurring biocontrol agents is considered a safe option in place of fungicides. Antagonism to P. infeslans by some naturally occurring microorganisms such as Trichoderma viride Penicillium virdicatum Chetomium brasilense Acremonium strictum Myrohecium varrucaria Penicillium avrantiogriseum Epiccocum pvtrpuranscens. Stahcybotrys

coccodes. Pseudomonas syringae Fusarium graminearum and Pythium ultimum have been reported. Biocontrol agents have been found effective against late blight disease under controlled conditions such as laboratory and glasshouse but less effective in field. An integrated use of biocontrol agents with low dose of fungicides could be the next best strategy.

Cultural practices Cultural methods aim at eliminating or reducing the initial inoculum load in seed tuber and other sources. Care should be taken to avoid tuber infection by high ridging covering the tubers minimizing irrigation after the blight has set in and by cutting the infected haulms. The tubers should be harvested after proper skin curing and diseased tubers should be sorted out before storage. Elimination of refuse piles in hills could also help to minimize disease inoculum. It has been estimated that the onset of epidemic can be delayed by 3 to 6 weeks if all primary infection from early potato can be eliminated.

EARLY AND PHOMA BLIGHT

Symptoms

The early blight caused by Alternaria solani (Ell & Mart.). Jones & Grout starts appearing on the potato crop just before the initiation of tuberization. The disease continues to develop till death of the plants. Initially the symptoms occur on the lower and older leaves in the form of small (1 2 mm) circular to oval brown spots (Fig. 2). These lesions have the tendency to become large and angular at later stage. Mature lesions on foliage look dry and papery and often have the concentric rings looking like bulls eye. The rings are more prominent in large blotchy spots and give them a target board effect. The spots are often dry and brittle but some times under conditions of heavy dew or rain become wet and dark brown appearing somewhat like small lesions of late blight. However these are distinguished from late blight by the absence of white mildew growth on the under surface of the spots. The spots are mostly 3 to 5 mm in diameter but in some cases may be up to 10 mm. The spots may enlarge and coalesce to form large necrotic areas. Ultimately the whole leaf dries up and hangs along the stem. The spots may also develop on the stem at a late stage of growth of the plant.

The affected tubers show dark brown lesions on the surface. These lesions are slightly sunken and are circular or irregular in outline measuring up to 2 cm in diameter. The tissues underneath the surface of the spot show a brown and corky dry rot. This rot may be observed up to a depth of 6 mm and does not develop further into the tuber flesh as may be observed in late blight affected tubers. Tuber infection is rare in India.

Leaf spots caused by Phoma exigua Desm. are larger 1 to 2.5 cm in diameter with broad alternate light and dark concentric zones. Affected tubers have grey to greenish black depressed lesions on the surface upto 3 cm wide.

Leaf spots caused by Phoma sorghina Doerema Doren and van Kest are characterized by pinhead size spots which may be oval circular or irregular not exceeding 4 mm in diameter. Infected tubers show dark grey large lesions (up to 1.7 cm).

Distribution

The incidence and severity of early blight and leaf spots is generally high in the crop receiving imbalanced doses of NPK particularly low nitrogen. Early blight occurs in all the potato growing areas. Disease appears in a severe form in the sub mountainous regions. Depending upon the severity phoma leaf spots may cause significant yield losses. It has been reported to cause losses up to 20 per cent in Kharif crop in Ranchi and adjoining plateau region.

Epidemiology

The incidence of early blight is mostly influenced by moisture temperature variety of potato age and vigour of the plant. Optimum conditions for the development of the disease in a severe form require high temperature alternating with moist periods and a poor vigour of the plant.

Early blight was observed to be severe when the humidity was high early in the season followed by high temperature. Conidia of A. solani were found to infect the crop even after being exposed to freezing temperatures on the surface of the soil or buried to a depth of 5 to 20cm. The conidia can germinate and the mycelium can grow in culture at temperatures ranging from 1° to 45°C with an optimum of 26° to 28°C. The development of the disease in the field is severe at day temperatures of 25° to 32°C. The laboratory studies showed that incubation temperature of 26ºC was optimum for the development of infection in inoculated detached leaves.

All the pathogens viz. A. solani P. exigua and P. sorghina can infect tubers hence capable of surviving during storage. These pathogens can also survive in soil and plant debris particularly in temperate climate. The infected tubers form the primary source of inocula for both early blight and leaf spots. In general these diseases are favoured by moderate temperature (17 25°C) and high humidity around 75 per cent. Intermittent dry and wet weather is more conducive for early blight.

During crop season infection initially appears on the lower leaves near the ground level and results in the infection of young immature tubers if not covered by the soil. The affected tubers when used as seed serve as potential source for disease in the subsequent season.

Low Input Technology for Potato Production

Since independence increasing emphasis has been given to agricultural development. The inputs necessary to increase productivity namely seeds fertilizers irrigation fuel etc. were made available at subsidized rates to encourage their use for maximizing the crop productivity. This intensive crop production strategy was called the Green Revolution technology. The intensive use of inputs is now creating problems like declining soil fertility soil erosion environmental pollution due to agricultural chemicals chemical residues in foods pest outbreaks and inequality in distribution of benefits of agriculture. Therefore there is now an increasing emphasis the world over towards low input agriculture.

Figure 1. Break up of the operational cost of cultivation in potato

INPUT INTENSIVENESS OF POTATO CULTIVATION

Potato is one of the most input intensive crops. Compared to rice and wheat potato cultivation is 2 3 times costlier. For any further increase in the area under the crop and its better utilization there is a need to make it less expensive. About 35 40% of the cost is for seed followed by labour (human bullock and mechanical together). Fertilizer and manure and irrigation are the other main monetary inputs in potato production (Fig. 1). These costs are incurred when all the cultural operations and inputs are given at the optimum level and are discussed below.

Seed

The seed input requirement ranges from 25 40 q/ha. In the Indo Gangetic plains the seed used in the autumn season is after cold storage. Therefore there is an added cost of storage of seed potatoes from February/March to September/October. As potatoes are bulky the transport from the cold stores to the fields involves considerable cost. Moreover after removing the seed tubers from the cold stores they have to be kept in shade for about 10 15 days for chitting of the eyes culling rotted tubers etc. These operations involve labour and money adding to the cost while the cost of seed handling is generally very low in other crops.

Cultural operations

Potato requires more labour (both mechanical and human) as compared to other crops. In this crop land preparation planting weeding earthing up and harvesting operations are the major field operations involving considerable energy and cost. Besides land preparation is more intense for potato since a fine tilth is required to prepare a ridge for easy penetration of root better development of the stolons and enlargement

of the tubers.

Where potato fields are large planting has to be done mechanically using a tractor drawn semi or fully automatic planter. This is a labour/energy intensive operation since the seed quantity is large. When planting is done manually high labour/energy is required for planting and ridging. The seeds are dibbled manually into the ridges using hand tools. When the crop is about 25 30 days old an intercultural implement like tripthali is run in the field followed by earthing up.

For harvesting the ridges are opened up to expose the tubers using a digger or ridger or manually using a khurpa. As compared to the other crops in potato at least one tillering + planking ridging earthing up and harvesting wherever it is done mechanically are the extra mechanical operations adding considerably to the cost of cultivation and energy input.

Post harvest operations in potato also involve considerable cost and energy. The produce (about 25 40 tons/ha) has to be heaped in shade for skin suberization. The produce has to be sorted for removing cut cracked/damaged and diseased tubers before grading and packing requiring considerable labour. Cutting down/minimizing any of the cultural operations directly results in reduced cost of potato cultivation.

Manures and fertilizers

Potato crop requires high fertilizer input. The recommendation for N P_2O_5 and K_2O in the northern plains ranged from 180 240 80 100 and 100 150 kg/ha respectively. The efficiency of utilization of the applied fertilizer is low in potato due to frequent irrigations during early part of the crop shallow root system short growing season etc. Normally irrigation is applied at an interval of 8 10 days initially while later on the interval increases to 12 15 days. The frequent irrigations at the initial stages of crop growth when the root system is not fully developed leaches out a greater proportion of the nutrients out of the root zone. This problem is aggravated by the shallow root system which is normally assumed to be about 60 cm only. The short growing period is another factor which increases the requirement of fertiliser since more fertilizer is added at the time of planting so as to hasten the crop growth and ensure high interception of the incident radiation.

Weed management

Potato requires weed free environment for optimum yield. Since potato tubers are underground presence of weeds at the time of harvest makes harvesting difficult. Frequent irrigations in the plains and rains in the hills and high nutrient input encourage luxuriant growth of weeds thus increasing the cost incurred on weeding operations.

TOWARDS LOW INPUT TECHNOLOGY FOR POTATO PRODUCTION

With the realization of the consequences of high input cultivation steps are being taken to reduce the inputs. Saving can be made in labour seed tillage fertilizer and irrigation inputs in potato crop perse as well as in the potato based cropping system.

Tillage

Studies have shown that there is a possibility of practicing zero tillage/minimum tillage practices even in the case of potato. Results of experiments at Gwalior showed that one harrowing followed by one planking did not affect tuber yield in fields which had green manure crop of synhemp buried in the kharif season. Similarly in some situations the second earthing up can be done away with when the full size ridge is made right at planting and where the ridges do not get eroded due to irrigation. Weeds should be either negligible in these situations or have to be controlled through herbicides. Saving in land preparation could also be effected in wheat following potato since the soil tilth is greatly improved at the time of harvesting of potato. Efforts have been made to save mechanical energy through use of low cost implements for reducing the labour/energy requirement. Some of the low cost implements being developed are peg type inter cultivator rotary peg type inter cultivator rotating blade type inter cultivator and cup type potato planter.

Seed

To reduce the seed input cost many alternative seed production strategies have been developed including true potato seed propagation through stem cuttings mini tubers etc. However these technologies have not yet reached the stage of large scale adoption. Hence these technologies cannot be evaluated for their effect on the economics of potato production.

Use of small seed is another option to reduce the seed input cost. The use of small seeds with an adjustment in the planting geometry reduces the seed requirement. The use of small seeds has been found to economise the seed requirement by about 50%. The availability of large quantities of small seed is a problem. To overcome this problem use of cut seed tubers has been studied. The results suggest that in ware crop where seed borne diseases as well as rotting of seed due to high temperature is not a problem cut seed can be used. Treatment of the seed with fungicides (2% solution of mancozeb) is recommended after cutting. Large size tubers can also be effectively planted by increasing the plant spacing.

Fertilizers

Growing varieties giving high yield at low fertilizer input can effect reduction in fertilizer input cost. A technique has been developed to determine the fertilizer requirement fora target yield. The technique consists of fitting the regression equation and determining the a b and c coefficients of the regression equation.

Apart from using nutrient efficient varieties saving in fertilizer input could also be effected through judicious choice of source of nutrient and method of application. In case of nitrogen urea is the cheapest source but it affects the growing sprouts. Therefore other sources like ammonium sulphate calcium ammonium nitrate etc. are recommended for potato but these are costlier than urea. Studies on economic and efficient use of urea have shown that application of urea one day before planting mitigates the injurious effect. Similarly combinations of different methods of application have also been tried for making safe use of urea for potato. At Shillong application of 80 Kg N/ha through urea as soil application top dressing and foliar application at tuber initiation in 2 1 1 ratio was as effective as 120 Kg N/ha thus economising about 40 Kg N/ha. Soaking of seed tubers in 3% urea for 1 hour has also been found to save almost 10 Kg N/ha as well as give 26 q/ha more tuber yield. In the case of P soaking of seed tubers in 1.5% single super phosphate+ 0.5% urea solution along with a suitable fungicide for 4 hours effected considerable saving in P fertilisers. In addition biofertilizers e.g. Azotobacter and phosphorous solubilizing bacteria have also been found effective in reducing N and P requirement of the crop respectively.

Development of cropping systems that utilise the residual nutrients efficiently can also reduce the fertilizer input. This aspect has been studied extensively in potato based cropping systems. Since potato is a shallow rooted short duration crop with high nutrient input requirement it leaves considerable residues. These residues are effectively utilised by crops like wheat maize etc. grown in sequence following potato thus economising nutrient requirement of the system as a whole. The studies have shown that wheat following potato needs only half N and no P and K the requirement of which is met out of the residues left by potato.

In the case of potato sunflower and potato onion sequences the N requirement of sunflower and onion is largely met out of the residues after potato. Thus there is scope for effecting saving in fertiliser input of potato. However there is a still greater scope for saving in fertiliser input if seen from the cropping system perspective and can be fully exploited by judicious choice of sequences based on location season etc.

Irrigation

Considerable saving in water could be effected if efficient methods of irrigation like sprinkler or drip irrigation systems are adopted. These options being costly cannot be advocated for low input situations. However a more scientific scheduling technique can effect saving in water with minimum loss. Irrigating the crop at critical soil moisture deficit of 25 mm on medium textured soils reduces the water requirement as

well as losses at Jalandhar. Alternate furrow irrigation has also been found to economise water input. Almost 25 35% water saving has been found but yield decrease to the extent of about 10% has also been observed. Where labour is cheap and easily available mulching can also be practiced. Paddy straw mulch has been found to save about 150 mm water. Generally mulching can easily save 1 2 irrigations.

Weed control

Many of the cultural operations are complimentary to each other. Weed control is one such operation which is benefited by many other cultural operations. Hot weather cultivation recommended for control of soil borne pathogens also mitigates the problem of weeds. Similarly mulching practiced for water economy reduces the weeds. As regards weed control perse economy can be achieved on system basis due to the complimentarity of weed control in potato affecting the other crops in sequence. Studies showed that weed control in potato through metribuzin 0.7 kg/ha and oxyfluorfen 0.2 kg/ha as pre emergence herbicides mitigated weed problem in the succeeding wheat crop. In potato blackgram sequence weed control in potato through metribuzin 0.7 kg/ha minimised the problem of weeds in black gram. Similarly in intercropping situations weed control in potato + maize could be effected through use of metribuzin 0.5 kg/ha thus there is considerable saving in input for weed control in the inter crop system than when both the crops are grown as sole crops.

Pests and diseases control

Late blight is the most serious disease affecting the crop in the northern Gangetic plains with the best option being growing resistant varieties. However where it is not feasible forecasting of the disease can help reduce fungicide input. Presently prophylactic sprays are given and if the disease does not appear considerable loss of money and chemicals occur. As regards most of the other pests and diseases use of healthy seed and hot weather cultivation and adoption of appropriate crop sequences minimizes the problem in most places in the ware crop.

Cultural practices developed to maximize potato production are highly input intensive. However there is a considerable scope to reduce the inputs on a single crop basis and much more possibility on cropping systems basis. So far the input technologies have been developed without considering the overall effect on input intensiveness. Therefore a combination of practices has to be evaluated and developed for each situation since many of the technologies are complimentary to each other. This would enable potato production not only with fewer resources but also on a wider non traditional area.

Micro NUTRIENT REQUIREMENTS of Potato

Micro nutrients which include zinc iron manganese copper molybdenum boron and chlorine play a specific role in the growth and development of a plant. Even though these elements are needed in only minute quantities many soils do not supply them in sufficient quantity for healthy growth and optimum yield of potato.

Application of only NPK fertilizers for growing high yielding potato varieties with increased nutrient demands the decreasing availability of farmyard manure and intensive arable agriculture have combined to increase the demands made on the soil in terms of its ability to supply micro nutrients to plants. It is becoming evident that without the use of some of the micro nutrients it is not possible to get the maximum benefit of other inputs.

EFFECT OF MICRO NUTRIENTS ON GROWTH AND YIELD OF POTATO

Starch constitutes about 75% of the dry weight of potato tubers. The amount of starch accumulated is determined by the rate of photosynthesis translocation of photosynthates from leaves to tubers and their subsequent conversion to starch. The photosynthetic rate has been shown to increase by 72 and 80% in the presence of 10 ppm of zinc and manganese respectively in Hoagland s solution.

Supplementing zinc has been shown to increase the incorporation of 14C from the labeled sucrose glucose and fructose into starch.

The increase in tuber yield with micro nutrient application can occur with an increase in number of tubers and size of tubers or both. Zinc iron boron and molybdenum have been reported to increase the tuber number of medium and large grades at the cost of small ones i.e. the total tuber number was not affected.

DIAGNOSIS OF MICRO NUTRIENT DEFICIENCIES IN SOILS AND PLANTS

Diagnosis is the first step for precise monitoring and efficient correction of micro nutrient disorders in potato plants and soils. Several approaches have been used to diagnose the magnitude of micro nutrient deficiencies in potato plants and soils. They are discussed hereafter.

Visual diagnosis

Signs of stress will appear whenever any one of the micro nutrients becomes severely deficient or fall below the marginal deficiency stage of development.

Each element develops its own characteristic deficiency symptoms. Visual diagnosis of symptoms is possible as soon as the symptoms have appeared. The symptoms can not be easily classified later on because they get modified by other environmental factors.

Deficiency symptoms

Zinc Zinc deficiency in potato often known as fern leaf or little leaf appears on young developing leaves. Deficient plants show severe stunting and bronzing or yellowing of the foliage usually around the leaf margins starting from the tips (Fig 1). Youngest leaves are cupped upwards and rolled to such an extent that the terminal growth resembles that of ferns. Leaves of affected plants are smaller and their upper inter nodes are shorter.

Iron Its deficiency appears initially as yellowing of top young leaves. With time the leaves become light yellow to nearly white. During the deficiency blade tips remain green fora longer time. Netted green veination is seen when traces of iron are absorbed and translocated along the veins for chlorophyll formation. Green veinalion is actually a sign of iron recovery.

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

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

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

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

Plant analysis

Unfortunately by the time micro nutrient deficiency symptoms appear significant crop losses have already occurred. The critical nutrient concentration is a convenient reference point for assessing the nutrient status of a crop. The critical concentration is taken at the point where growth of the plants is 5 or 10% below the

maximum point. The safe level is the nutrient concentration maintained appreciably above the critical deficiency concentration for optimum potato production (Table 1). But care has to be exercised also to maintain the nutrient level in the plant below the toxicity range. The toxicity limit of copper is observed to be 34 ppm in plant in acidic hill soil of Shimla region.

Plant analysis for total concentration of nutrients is generally recommended. However leaf analysis for total iron content often fails to explain iron chlorosis in plants. Iron in ferrous form has been found more useful to detect iron deficiency.

Soil analysis

Soil analysis has the major advantage over other diagnostic techniques as it evaluates the micro nutrient supplying capacity of a soil prior to planting of potato crop. Several chemical extractants have been used for estimating the plant available micro nutrient contents in different soils. The critical deficiency limits of DTPA. EDTA and ammonium acetate (pH 4.6) extractable zinc below which economic response of potato to Zn application can be expected in acidic brown hill soils of Shimla region are 0.55 1.70 and 1.50 ppm respectively.

Whereas the critical deficiency limits of DTPA extractable Zn Fe and Cu in alluvial soils of Jalandhar are 0.75 6.6 and 0.32 ppm respectively.

MICRO NUTRIENT DEFICIENCY IN POTATO GROWING AREAS

Soil is the reservoir for supply of all the essential micronutrients required for the normal growth of potato crop. Thus information about the extent of micro nutrient deficient potato growing areas is vital. Micro nutrients status of soil in potato growing areas indicated that zinc is the most deficient micro nutrient in potato growing soils followed by iron copper and manganese. Out of 121 field experiments conducted in alluvial soil of Jalandhar (Punjab) potato responded to Zn in 57% to Fe in 40% and to Cu in 38% fields with a mean response of 21 21 and 24 q/ha respectively (Table 2).Table 2. Response of potato to Zn. Fe and Cu in different fields at Jalandhar.

RESPONSE OF POTATO TO MICRO NUTRIENTS

Response of potato to micro nutrients differs with soil group. Zinc is the most deficient micro nutrient in almost all potato growing soils. Alluvial soils are more responsive to iron manganese boron and copper as compared to other soils. The response of potato to applied micro nutrients depends on the magnitude of the deficiency in the soil. Responses of potato are strikingly higher on micro nutrient deficient soils than any other soils.

Factors affecting response of potato to micro nutrients

Several factors influence the magnitude of response to the applied micro nutrients. The most important among these are potato cultivars soil types and their nutrient status soil environment climate cultural practices and nutrient interactions. Cultivar Marked differences exist in potato varieties regarding their sensitivity to micro nutrients. Cultivation of crop varieties less susceptible to a particular nutrient stress can assist in economizing on the cost of alleviation of its deficiency. A fairly wide differential response of potato cultivars to Zn Fe Mn and B has been demonstrated under field conditions (Table 3).

Root and shoot parameters of cultivars Identification of root and shoot parameters responsible for better micro nutrient uptake efficiency can help to use the information to have micro nutrient efficient varieties. An evaluation of zinc uptake efficiency of three potato cultivars grown in the same soil in pots showed that zinc application significantly increased total dry matter accumulation (shoot+Tuber) of cv. Kufri Chandramukhi by 41% and that of cv. Kufri Jyoti by 23% at soil solution concentration of 0.03 ppin zinc but Zn application did not affect dry matter accumulation (DMA) of cv. Kufri Badshah. This indicated That Kufri Chandramukhi had least Zn efficiency followed by Kufri Jyoti and Kufri Badshah. The reason for low Zn uptake efficiency of Kufri Chandramukhi was its lower root DMA ratio (3.6) than Kufri Badsliah (8.2) and Kufri Jyoti (7.1)

because the zinc influx (Zn uptake rate per unit root length) was similar in all the cultivars in the absence of Zn application.

MICRO NUTRIENTS AND QUALITY OF POTATO TUBERS

Zinc copper manganese boron and molybdenum have been shown to increase ascorbic acid content of tubers. Zinc fertilization reduced the content of tyrosine orthodihydroxy and total phenols in tubers. The potato used for processing should contain minimum quantities of tyrosine and phenolic compounds as they are implicated in enzymic discoloration which occurs in raw peeled potatoes due to oxidation of tyrosine and chlorogenic acid formation of ferric dihydric phenolic complexes after cooking in processed products. Molybdenum and boron application increased starch content of tubers. Chloride reduced dry matter content in potato tubers. It resulted in an inhibition of the activity of the hydrolytic enzymes and hence in feeble translocation of starch.

AMELIORATION OF MICRO NUTRIENT DEFICIENCIES

Once the deficiency of a micro nutrient is detected it becomes imperative to find the best fertilizer material and techniques to ameliorate the same at least for the future cropping in the same soil.

Methods of micro nutrient application

There are three main approaches to tackle micro nutrient disorders in potato.

First approach consists of the application of a micro nutrient carrier to the soil where large quantity of a fertilizer has to be applied to compensate the high fixation capacity or quick reversion of the nutrient elements to unavailable forms. However its effect lasts for a few years depending upon the type of the soil and cropping system.

Second approach consists of foliar application of micro nutrients to each crop while the third approach is of treating mother seed tubers with micro nutrient compounds. Foliar spray during dry spell should be avoided between 11 a.m. and 3 p.m. to prevent scorching of leaves. The optimum dose of different micro nutrients is presented in Table 4.

Table 4. Doses of micronutrient application for correction of their deficiency in potato

Time of application

Time of application will be governed by micro nutrient content of seed tubers the growth stage at which particular micro nutrient is required and the severity of deficiency in the soil. Generally the micro nutrient content of seed tubers is low and most of them are absorbed during the early growth thus it favours early fertilization with micro nutrients. Experiments carried out at Shimla revealed that spray application of Zn was superior to soil application and also seed treatment in a soil that had marginal available zinc. But in the highly deficient soil seed treatment with zinc salts proved to be the best. Therefore the delayed fertilization with zinc will be less effective in case the deficiency is severe.

Organic Farming

Modern agriculture undoubtedly has increased production and labour efficiency. But concerns have been raised time and again over its adverse effects on soil productivity and environment. These are soil erosion depletion of organic matter in soil low water availability salinization fertilizer and pesticide contamination of food and water bodies and erosion of bio diversity. Dependence of modern agriculture on use of fossil based inputs such as chemical fertilizers and pesticides/herbicides as well as farm machinery are held responsible for the adverse effects. As a result there is a resurgence of interest in organic farming globally which holds sustainability of natural resources and environment supreme along with natural taste and nutritional quality of the produce. Thus organic farming for agricultural production favours maximum use of organic materials and discourages use of synthetic agro inputs to ensure conservation of natural resources and healthy environment. Organic farming is still in its infancy in India and there is not much work done in

this field on potato. However work has begun on this important field hence basics of organic farming are given in this chapter.

CONCEPT DEFINITION AND COMPONENTS

Until well into the twentieth century organic farming was the worldwide way of the life. It still is in vogue in many of the poorer and/or remote regions of the world where farmers cannot afford the technological inputs of modern agriculture. Slightly lower yield (5 15 percent) in organic farming than modern farming is an accepted fact. However the net return on investment is usually higher because of low inputs and when environmental costs are taken into account the organic farming is far superior on a long term basis. The profitability of organic farming depends on the higher prices that its products command in the market place. Organic farming is not based exclusively on short term economics but also considers ecological concepts. Organic farming combines traditional techniques and stress conservation with modern technologies.

The concept of organic farming excludes the use of synthetic fertilizers pesticides and plant growth regulators. While it includes improved seed including genetically engineered crop strains minimum tillage practices manuring crops through organic materials (crop residues animal excreta nitrogen fixing legumes and on and off farm organic wastes) and use of rock phosphate and gypsum. It permits integrated pest management (IPM) that relies heavily on biological control principles and use of bio pesticides. Disease control through use of sulphur dust extracts of toxic plants antibiotics derived from fermentation etc. is allowed under organic farming. Weed control is effected through crop rotations and manual weeding. It relies on wind and solar energy instead of purchased energy. Use of biologically produced plant growth regulators is also permitted. It emphasizes minimum use of any purchased inputs that too from outside the farm. The operative principle components of organic fanning are as follows

Organize the production of crops and livestock and management of farm resources so that they harmonies rather than conflict with natural systems.

Use and development of appropriate technologies based upon an understanding of biological systems.

Maintain soil fertility for optimum production through renewable resources.

Use crop diversification to optimize production.

Aim for optimum nutritional value of staple food.

Use decentralized structures for processing distribution and marketing of products.

Strive for equitable relationships between those that work and live on the land.

Create a system which is aesthetically pleasing for those working in this system and for those viewing it from the outside e.g.. It should enhance rather than scare the landscape of which it forms a part.

Minimize the leaching of nutrients through rotation with deep rooted crops.

The avoidance of mould board ploughing in favour of chisel ploughing.

Apply nutrients into the rotation onto a sod crop if possible to maximize uptake.

The seasonal use of cover crops in and around major cash crops.

Value of Organic Amendments and Soil Conditioners

The value of organic amendments is assessed by the amount of potentially available plant nutrients they contain. Usually this is done in terms of their macro nutrient (N.P. and K) content. However organic materials contain secondary and micro nutrients that contribute significantly to increased crop yields soil fertility and physical condition. Soil s physical condition is improved through increased water infiltration water holding capacity aeration and permeability soil aggregation rooting depth decreased soil crusting bulk density run off and erosion. Different organic amendments used along with their values are presented in the following section

Bulky organic manurers Well decomposed farmyard manure (FYM) and compost made from animal excreta and litter are bulky in nature and supply small amounts of plant nutrients are classified as bulky

organic manures. They are applied 15 30 t/ha.

The average nutrient content of different bulky manures is given in Table 1.

Table 1. Average nutrient content of bulky organic manures

SUSTAINABLE INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management (INM) is the maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from fertilizers organic manures green manures bio fertilizer non conventional sources and crop residues. Integrated nutrient management aims at maximization of the use efficiency and minimization of the avoidable losses of nutrients from all the sources such that triple objective of maximization of crop yields sustenance of soil water and air quality and improvement of socio economic conditions of farming community is accomplished. It recommends conjoint application of chemical fertilizer organic manures and bio fertilizer in addition to inclusion of legumes in cropping systems and incorporation of on and off farm generated crop residues to constitute an efficient integrated nutrient management strategy. Most important INM components are discussed briefly hereunder

Chemical fertilizers. Chemical fertilizers have played a major role in enhancing the food production. But the average consumption figure of 86.8 kg NPK/ha in India represents only 25% of the recommended rates. In a state like Arunachal Pradesh where it is as low as 1.9 kg/ha there is a scope of enhancing the use of NPK on the agricultural lands. The sustainable agriculture means application of yield maximizing but environmentally safe fertilizer dosages by resorting to more splits in sandy soils especially for higher N rates by using slow release N fertilizer materials.

Organic manures They are valuable by products of farming or allied industries and derived from plant and animal sources. Bulky and concentrated organic manures have been discussed in an earlier section. Depending upon availability they can substitute up to 50% mineral fertilizer and 100% Pand K at appropriate dosage to potato crop. In the dry sandy soils during limited water availability organics play major beneficial role in improving soil structure conserving soil moisture through enhanced aggregation and moderating the extremities in soil temperature. The benefit of this approach can be utilized in early crop of potato when due to high soil temperature the tuber yields are normally very low.

Bio fertilizers. In INM bio fertilizer are used only to supplement nutrients in combination with chemical fertilizers and organic manures. Various bio fertilizer have been discussed in an earlier section.

Green manuring. The green manuring has already been discussed earlier. Role of green manuring in INM is to supplement nutrients in combination with chemical fertilizers and to improve physical condition of the soil. Green manuring usually does not help save or reduce N fertilizer needs of potato yet for fixed yield targets some saving in nitrogen is possible because tuber yield level is raised by green manuring. Green manuring helps achieve 30 50% higher produce of tubers of uniform shape and size and superior quality.

Biological and Serological Diagnosis of Potato Viruses

An early and accurate diagnosis of the viruses is essential for effective management of the viral diseases in potato seed production. Control of plant virus diseases relies primarily on preventing the establishment development and disposal of the causal viruses. Plant viruses are generally identified by the visual symptoms induced in the host and/or other indicator plants particle morphology mode of transmission serological properties and nucleic acid sequences.

The number of viruses and allied pathogens in any given environment are limited on any crop. Virus disease symptoms may be checked biologically on a set of indicator plants (Table 1) by mechanical sap

and or aphid/graft inoculations. Each sample (potato) leaf/tuber must be tested separately. For bioassay leaf samples must be obtained from two positions i.e. one from top and second from the middle. Ideally two unrelated tests must be done for each sample.

Table 1. Plant species reaction to important potato viruses and viraids. L local symptoms (L) haphazard symptom S. systemic symptoms

There are two types of indicator hosts viz systemic (Fig. la) and local lesion hosts. The latter are effective because they are highly sensitive quick in response and show clear reactions such as chlorotic or necrotic spots. Careful selection of test plants is important because not all strains or ecotypes of any test plant may be equally susceptible and responsive. Unfortunately not many viruses can be routinely detected by using such test plants. There is also a great deal of variation(s) in their reaction to the virus their isolates or strains viz. Gomphrena globosa does not give local lesions for XHB strain of PVX C. quinoa reacts systemically to PVS strain or depending on external factors such as inoculation method load of inoculum conditions for growing test plants. Providing moderate temperature (18 24° C). high humidity (>80%) and constant light (