ANNUAL

REPORT

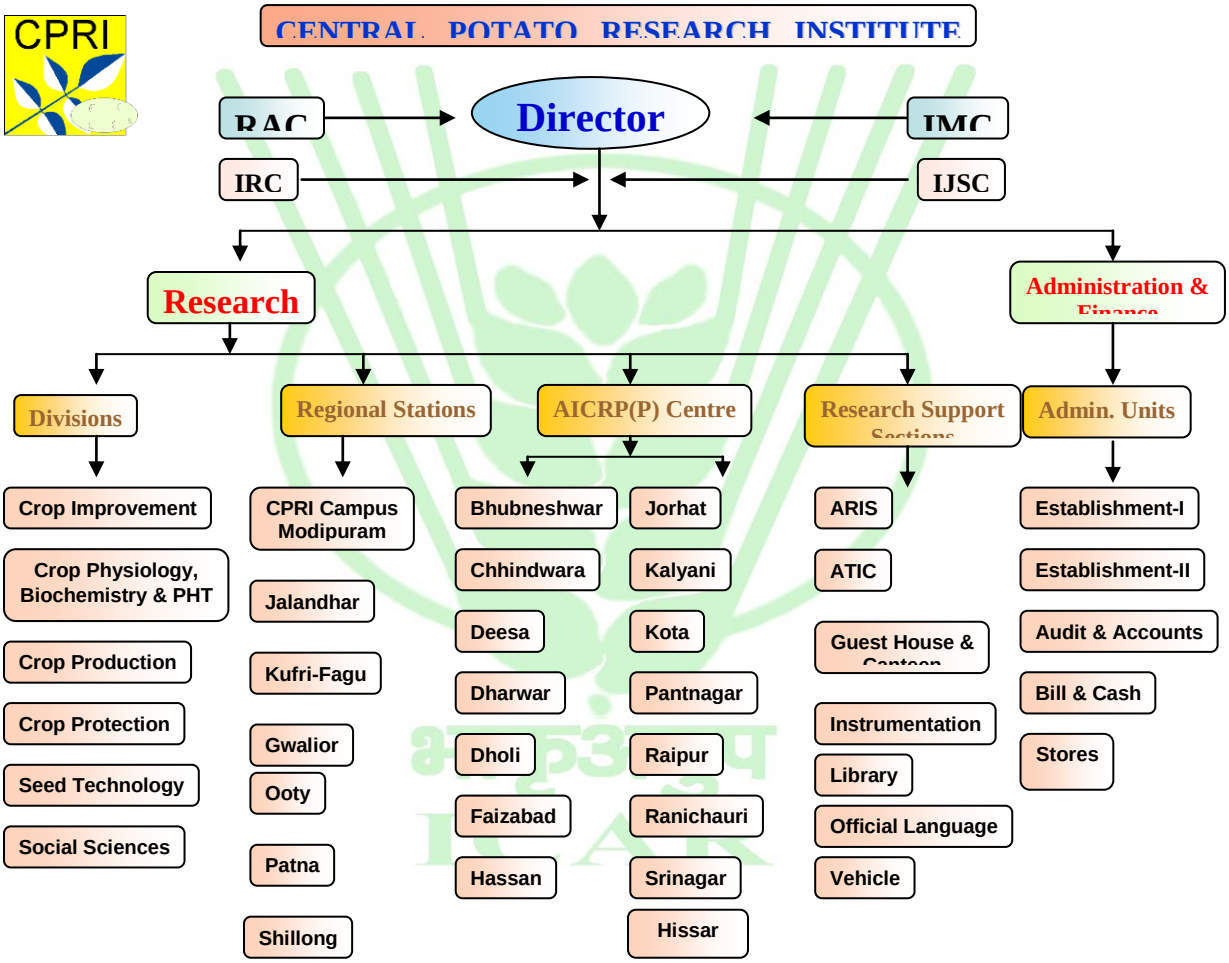
2009-10

INTRODUCTION

Potato research in India formally began on April, 1935 with the opening of a Potato Breeding Station at Shimla and two seed production farms at Bhowali (Kumaon hills, Uttarakhand) and Kufri (Shimla hills, Himachal Pradesh) as a part of the Indian (then Imperial) Agricultural Research Institute, Delhi. In 1945, a scheme for the establishment of Central Potato Research Institute was drawn up under the guidance of the then Agricultural Advisor to the Government of India, Sir Herbert Steward. Dr. S. Ramanujam, who was then working as an Economic Botanist at IARI, was appointed as an Officer on Special Duty for implementing the scheme in 1946. The institute was established in August 1949 at Patna and started functioning from an old single-storey, barrack-type building provided by the Government of Bihar. Three small units under the IARI looking after potato, namely Potato breeding Station at Shimla, Seed Certification Station at Kufri, and Potato Multiplication Station at Bhowali were merged with the newly created CPRI. The headquarter was shifted to Shimla, Himachal Pradesh in 1956 in order to facilitate hybridization work and better maintenance of seed health. The Institute was transferred to the Indian Council of Agricultural Research (ICAR) in April 1966. Presently, it has 7 regional research stations in different potato growing areas of the country. These are located in Kufri-Fagu (HP), Modipuram (UP), Jalandhar (Punjab), Gwalior (MP), Patna (Bihar), Shillong (Meghalaya), and Ootacamund (Tamil Nadu).

The Mission

Carry out research, education and extension on potato in collaboration with national and international partners for enhancing productivity and profitability, achieving sustainable food and nutritional security, and alleviating rural poverty.



Mandate:

The Central Potato Research Institute (CPRI) is a nonprofit scientific institution under the Indian Council of Agricultural Research, working exclusively on potato. The institute has played a key role in popularizing potato cultivation and utilization under sub-tropical agroecosystem. We believe that potato can play an important role in food and nutritional security of India, while helping the rural poor to rise out of poverty. The institute focuses all its energy to make that belief becomes a reality.

- To undertake basic and strategic research for developing technologies to enhance productivity and utilization of potato.
- To produce disease-free basic seed of notified varieties developed by the Institute.
- To act as a national repository of scientific information relevant to potato.
- To provide leadership and co-ordinate network research with state agricultural universities for generating location and variety specific technologies and for solving area-specific problems of potato production.
- To collaborate with national and international agencies in achieving the above objectives.
- To act as a centre of training in research methodologies and technology for upgrading scientific manpower in modern technologies for potato production.
- To provide consultancy in potato research and development.

Work of the Institute is being carried out by the six Divisions; Crop Improvement; Plant Protection; Crop Production; Crop Physiology, Biochemistry & Post Harvest Technology; Seed Technology; and Social Sciences under 20 well defined research programmes. In addition to regular research programme, 22 externally funded research projects sponsored by the ICAR, CIP, ABSP-II (USAID), AP Cess Fund, DBT, NABARD (RIF), & Mini Mission-1 are also under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

Achievements of the Institute

Research highlights during the year

- The national repository of potato germplasm was strengthened and now it has more than 3900 accessions.
- Registered three elite genetic stocks namely SS1725-22, SS2040 (frost tolerance) and JX 90 (early/late blight resistance)
- Released advance hybrid JX-576 as Kufri Gaurav for North-western plains. The variety possess higher N,P and K efficiency, thereby enabling lesser use of N,P,K fertilizer and restoration of soil health.
- Released the processing hybrid MP/01-916 as Kufri Chipsona-4 for Karnataka, West Bengal and Madhya Pradesh.
- Developed transgenic lines of Kufri Chipsona-1 with invertase RNAi gene construct possessing excellent cold chipping attributes.
- Thematic maps prepared for the areas climatically suitable for growing *kharif* potato in India and growing seed crop in the NE states.
- Potato acreage and production were estimated through remote sensing GIS and crop modeling in the states of Punjab, UP, Bihar and West Bengal.
- In long term manurial/fertilizer experiment system productivity was higher in maize-potato-onion (54.5 t/ha) followed by rice-potato-wheat.
- New prototype of aeroponics for faster multiplication of potato mini tuber production was designed, developed and tested successfully.

- *Phytophthora infestans* population 1a mitochondrial haplotype is quickly replacing the 1b type in Karnataka, Himachal Pradesh, Uttar Pradesh and Uttarakhand.
- Potato hybrid LBY-15 and LBY-17 possessing combined resistance to late blight and PVY were selected for introduction into AICRP for multilocation trials.
- Dipstick assay was standardized for detection of five potato viruses viz. PVX, PVA, PVS, PVM and PVY.
- Kufri Pushkar was found highly resistant to russet scab and pitted type common scab; soil application of stable bleaching powder @ 3 q/ha was most effective in managing russet scab.
- Thiacloprid 240 SC was found effective for managing *Myzus persicae*, *Aphis gossipii* and white flies.
- Spray of neem and *ratna jayot* extracts in cow urine @ 10% caused 88 and 83% mortality of glasshouse whitefly.
- The promising hybrid OS/93-D-204 possessing resistance to both the species of potato cyst nematode and resistant to late blight was recommended for the release in AICRP meeting.
- A simple method for estimation for reducing sugar in potato in the field using Benedict's reagent was developed by the Institute.
- Dipping of potato slices in magnesium chloride (0.5%) and calcium chloride (0.5%) for 10 minutes resulted in 3.7% reduction in oil content of chips.
- Developed and improved heap storage technology for short-term storage of table and processing potatoes with the use of CIPC; residues of CIPC in the peels of potato tubers (2-7ppm) were far below the permissible limits.
- During the year 2009-10 a total of 33466 q nucleus and breeder seed was produced by the Institute of which 26566 q was breeder seed available for the supply. Out of which 23526 q has been supplied to various agencies and 2927 q kept in cold store for further supply during the crop season.
- A survey conducted in Gujarat and West Bengal revealed a significant increase in the potato yield where the farmers had used new fungicides such

as cymoxanil, dimethomorph and metalaxyl based combination with mancozeb than the use of mancozeb alone.

- A study of economics of potato based cropping system in Muzaffarpur district of Bihar revealed that seed accounted 30% share of total cost followed by fertilizer (22.5%), machine labour (17.5%), human labour (16.1%) and irrigation (3.4%).

Facilities

The Institute created state-of-the-art laboratories for conducting basic and strategic research in the field of biotechnology, genetics and plant breeding, plant protection, soil science and agronomy, plant physiology, biochemistry, and post harvest technology. The CPRI is the first Institute, among plant science research Institutes of India, to introduce ELISA (1984) and ISEM (1987) for plant virus diagnosis. The virus diagnosis laboratory is now equipped with automated ELISA system, PCR and NASH facilities. Because of its unique record in the field of virus diagnosis, this laboratory has been notified by the Government of India as 'Accredited Test Laboratory' for testing and certification of tissue culture raised potato microplants and minitubers.

The biotechnology laboratory of the Institute, created in 1992, presently houses all the facilities for transgenic research, DNA fingerprinting, molecular breeding, micropropagation and cryo-conservation. A new laboratory has recently been created for conducting basic research on cell biology and somatic cell genetics. The radio-tracer laboratory of the institute was created in 1996 for carrying out basic research on nutrient dynamics in soil and plant. This laboratory is also helping in molecular diagnosis of plant pathogens and other molecular biology related works. The institute has a well-equipped Fungal Pathology Laboratory that has world-class facility for basic and applied research on late blight pathogen. Besides, the institute also has laboratories for Plant Physiology and Post Harvest Technology works.

The institute has 521 ha farm lands distributed over 15 units for conducting field experiments and undertaking breeders seed production. CPRI Library is the second largest potato library in the world. Besides, the Institute has well-equipped ARIS cell, ATIC, museum, auditorium, conference hall, committee room at the Hqrs. and similar facilities have been provided at the regional stations. The Institute is fully equipped to organize training programmes with AV aids, hostel, etc. A separate administrative building has been constructed with modern office settings and other facilities. In addition, a new pathology laboratory and two additional rooms for library have been made functional.

EXECUTIVE SUMMARY

CROP IMPROVEMENT

The National repository of potato germplasm was strengthened and now it has more than 3900 accessions of potato germplasm. This collection was maintained in tuber, *in-vitro* as well as seed form at three locations. New accessions were converted into tuber form for adding to field gene bank, evaluation and use by the breeders. By meristem tip culture 58 accessions were made virus-free. A large number of accessions were evaluated for various biotic and abiotic characters, the results were documented and three elite genetic stocks namely SS1725-22, SS2040 (frost tolerant) and JX90 (resistance to early and late blight) were registered with the National Bureau of Plant Genetic Resources.

Under the programme breeding potato cultivars for Indo-gangetic plains, more than 300 new cross combinations were made to generate segregating progenies for clonal selection. Based on consistent performance over the years, hybrids MS/4-2261, 2002P14, 2002P26 and 2001P67 were identified as promising and may be promoted for multi-location trials under AICRP (Potato). An indigenous potato clone K-22 already in cultivation in some areas was evaluated and found to be promising for intensive cropping system as it has very early foliage maturity combined with early tuber bulking. Further tests will be done to assess its performance for important agronomic characters.

Efforts were continued to develop varieties suitable for processing into chips and French fries preferably with early maturity. More than 1 lakh seeds were produced by hybridization and seedlings raised and 869 seedlings were selected. An advance hybrid MP/01-916 was found promising based on its performance at six locations as it had high yield as well as good processing quality.

For supplying recommended TPS population 92-PT-27 to farmers, more than 5 kg of TPS was produced. The recurrent breeding was continued for improving early bulking and hardiness of seedling transplant crop. The segregating progenies were screened for these characters and some early bulking clones were selected for use as parents. Twenty bi-parental crosses were made among the parents previously selected for these traits and 43 bi-parental crosses were made for selecting early bulking populations. TPS populations performing better than the previously recommended population 92-PT-27 have been identified, which will be further evaluated for confirmation.

Transgenic lines of Kufri Chipsona-1 with invertase RNAi gene construct were found to have excellent cold-chipping attributes. A patent application for Indian patent for the process of development of RNAi cold-chipping potato transgenics has been filed. As partner of Potato Genome Sequencing Consortium (PGSC) 460 Mbp potato genome sequence data was generated and that was assembled into contigs. A total of 877 large contigs were generated which covered around 2.4 Mbp sequence of potato chromosome 2 in which the average contig size was 2,696 bases and the largest contig was of 46,321 bases. The hybrid nature of the putative somatic hybrids of *S. tuberosum* + *S. pinnatisectum* and *S tuberosum* + *S. etuberosum* was confirmed by molecular and phenotypic markers.

CROP PRODUCTION

Resource management strategies were developed for major potato based cropping

systems. At Ooty higher potato equivalent yield (PEY) was recorded in potato+French bean inter-cropping in summer season. Inter-cropping of potato cultivar Kufri Giriraj with broad beans in 1:1 combination produced the higher potato equivalent yield, however, in case of advance stage hybrid OS/93-D-204 population ratio of 2:1 gave the maximum yield. At Shimla, French bean required only 75% of recommended N in potato+French bean inter-cropping system. The PEY was higher in garlic-late potato sequence by 19% over garlic-potato relay system. At Patna, PEY, economic return and benefit : cost ratio were higher in potato+rabi maize inter-cropping system At Gwalior greengram-potato sequence was more economical than bajra-potato sequence.

Studies on GIS based delineation of sites suitable for kharif potato cultivation in India were taken up. The possible areas which are climatically suitable for raising the potato crop in the kharif season were mapped. The genetic coefficients of Kufri Giriraj and Kufri Swarna have been finalized and the daily weather database of different locations in the Nilgiris has been developed. GIS based data analysis also identified suitable areas in eastern plains for disease free seed production. Studies were also undertaken to estimate the growing period which would be available for growing potato under different combinations of maximum and minimum temperature scenarios viz. <35˚; <18˚& >2˚; <35˚; <21˚& >2˚ and <35˚; <23˚ &>2˚, respectively. Thematic maps depicting the possible growing period under the three scenarios were developed.

GIS data helped in identifying 14 zones viz. 1.1A13Eh1, 1.2A13Et2, 2.1M9Eh1, 2.2L12Eh1, 2.3M9Et2, 2.4L12Et2, 4.1N8Dd3, 4.2P14Dd3, 5.1L4Dd3, 6.4K4Cd5, 8.1H6Dd3, 9.1N8Dm_Cd4, 10.2K4Cd5 and 10.3I6Cd5 with pH between 8-9 while three zones viz. 5.3L7Dm4, 13.1O8Cd_Cm6 and 18.2S7Dm4 had pH more than 9. It emphasized the need for developing varieties with tolerance to higher soil pH.

A preliminary version of the DSS for the N recommendation module has been developed and is being tested. A database of potential productivity linked with spatial attributes of each of the ten potato varieties viz Kufri Ashoka, Kufri Chandramukhi, Kufri Pukhraj, Kufri Jawahar, Kufri Jyoti, Kufri Bahar, Kufri Lalima, Kufri Badshah, Kufri Sindhuri and Kufri Sutlej was created. Thematic mapping of these yield data is under progress.

Potato acreage and production were estimated through remote sensing, GIS and crop modeling in the states of Punjab, Uttar Pradesh, Bihar and West Bengal. Winter potato acreage in these four states was 1045.7 thousand hectares and total potato production was 23213.9 thousand tones.

Hybrid JX 576 possesses high tolerance to nutrients (N, P and K) stress and was more N, P and K efficient than Kufri Pukhraj, Kufri Pushkar, Kufri Badshah and Kufri Jyoti. This hybrid was more N efficient than Kufri Jyoti and Kufri Pukhraj at Patna. The hybrid JX 576 also showed higher water use efficiency of 164 kg tubers/mm water in comparison to 139, 123 and 104 kg tubers/mm water of cvs. Kufri Pukhraj, Kufri Badshah and Kufri Jyoti, respectively at Jalandhar. At Ooty, the hybrid OS/93-D-204 was most P efficient followed by cvs., Kufri Himalani, Kufri Girdhari, Kufri Giriraj and Kufri Jyoti.

Bio-fertilizers studies at Shimla revealed that 25% of recommended N and P from chemical fertilizers can be saved by using efficient strains of *Azotobacter* and phosphorus solubilzers, respectively.

In long term manurial/fertilizer experiment at Modipuram, system productivity was higher in maize–potato–onion (54.5 t/ha) followed by rice–potato–wheat (50.9 t/ha). The lowest PEY was recorded in sesamum-potato–green gram system (29.6 t/ha). The system productivity, tuber size and number of tubers in inorganic treatments were higher than organic treatments. However in rice, green gram and sesamum, yields were at par, from

organic and inorganic sources of plant nutrients. Application of secondary nutrients increased the yield of rice, potato and maize, while there was no effect in wheat, onion, green gram and sesamum. The incorporation of residue of preceding crop was not found effective in enhancing the crop yields.

Unlike previous seven years, the organic raised crop, on same site, remained green till maturity. The tuber yield increased by 47.2 and 53.3% in Kufri Anand and Kufri Chipsona-1, respectively compared to 2008-09. Similarly unlike in the past, the application of nutrients through fertilizers did not give better yield than vermicompost (organic manure) and in case of Kufri Chipsona-3, it was 2.03 t/ha (5%) less than organic yield. The application of biofertilizer (B_5) with inorganic fertilizers, reduced the tuber yield, while its application with vermicompost increased the tuber yield by 1.57, 1.47 and 1.53 t/ha in Kufri Surya, Kufri Pukhraj and Kufri Bahar, respectively.

Fabrication work of the manually operated multipurpose toolbar with four different attachments, was carried out. It consists mainly of an ergonomically designed handle, a pneumatic wheel and a tool mounting assembly. Attachments fabricated for use with this manually operated push type multipurpose toolbar are single row three-tined inter-cultivator, v-shaped blade weeder attachment, improved soil crust breaking attachment and load carrier attachment. A manually operated push type of wheel hoe consisting mainly of an iron wheel and three numbers of sweep tines, have been improved in its weeding mechanism.

A low cost power operated potato peeling machine was designed, fabricated and evaluated. It consisted of main supporting frame, peeling drum, water supply and drain system and the power supply and transmission system. It is a batch type peeler that makes use of the rough surface of the perforations created on the inner side of the rotating drum for peeling of tubers. The provision has also been made for continuous removal of peels. The peeling efficiency of the tubers has been found as 82%, with peeling loss of 3%. The design of a potato slicer was also prepared.

A new prototype of aeroponics for conducting experiments on potato mini tuber production was designed, developed and tested. This system consists of a growth chamber, nozzles, nutrient solution tank, high pressure pump, filter, electrical and electronic components and other accessories. Another model of aeroponics for 30 plants was also developed to demonstrate technology in technology shows. A high capacity mechanized seed potato treatment system was designed, developed and tested. For mechanized seed treatment, special pallets have been designed and fabricated.

PLANT PROTECTION

Late blight incidence in the entire Indo-Gangetic plains was insignificant during 2009-10 resulting in a bumper harvest. However, there was a marked increase in metalaxyl resistant population of *Phytophthora infestans* during 2009 in the state of Rajasthan and West Bengal. Complex physiological races comprising 9-11 r genes were detected in the states of Rajasthan, West Bengal, Punjab, and Bihar. A_2 mating type was not detected in Rajasthan, Punjab, Uttarakhand, Karnataka and Bihar states while it was 100% in HP hills. Population with Ia mitochondrial haplotype, that was first reported in 2002, is quickly replacing the Ib type in Karnataka, Himachal Pradesh, Uttar Pradesh and Uttarakhand. The JHULCAST model successfully forecasted late blight appearance in North-west Indo-Gangetic plains. Amongst four fungicides namely, sectin (fenamidone 10% + mancozeb 50%), curzate (cymoxanil 8% + mancozeb 64 %), ridomil (metalaxyl

8% + mancozeb 64 %), and mancozeb (72 %WP) evaluated curzate and sectin proved equally effective (11.66 % DI) as compared to control (95% DI).

For development of late blight resistant cultivars, 375 early generation (F_1C_1-F_1C_4) clones were evaluated and 60 promosing clones were selected. In advance stage generations, 13 hybrids were evaluated and 10 promosing hybrids were selected. The meiotic tetraploid VMT 5-1 yielded significantly higher than the best control Kufri Himalini. The hybrids LBY-15 and LBY-17 possessing combined resistance to late blight and PVY were selected for introduction into AICRP (P) for multi-location trials.

Dipstick assay was standardized for the detection of five potato viruses viz., PVX, PVA, PVS, PVM, PVY. The coat protein genes of PALCV and PVX were amplified, cloned in expression vectors and transformed in *E. coli* for over-expression and extraction. A total of 188 mericlones of 91 germplasm accessions were checked by IEM and at least one mericlone each of 51 accessions were found free from PVX, 52 from PVS, 17 from PVM, 11 from PVY, and 8 from both PVX and PVY. Kufri Badshah and Kufri Pukhraj were transformed with the replicase gene of potato apical leaf curl virus. Forty six positive lines of Kufri Badshah and 22 of Kufri Pukhraj have been identified. Similarly, the early variety Kufri Pukhraj has been transformed with the CP gene of PVY and 29 transgene-positive lines have been identified.

Kufri Pushkar and Kufri Anand were highly resistant to russet scab, whereas Kufri Sindhuri, Kufri Sherpa and Kufri Lalima were highly susceptible. Kufri Pushkar was also resistant to pitted type of common scab. Soil application of stable bleaching powder @ 3q/ha was most effective in managing russet scab. None of the three biocontrol agents received from NBAII, Bangalore viz. *T. viride* (PDBC- TV-23, *T. harzianum* (PDBC- TH-10), *T. virens* (PDBC- TVS-10) were found effective against black scurf. *Bacillus subtilis* (BS KD-4, KD-7), *Pseudomonas fluorescens* (KD-4, ND-4B) were not effective against common scab in two field trials. Storage of potato varieties in heaps after harvest in February revealed very low rotting up to mid-June which increased rapidly after July 1 and reached the maximum by mid-July. A survey conducted in Indore and Ujjain districts revealed presence of 0 to 60% incidence of bacterial wilt in 15 out of 22 fields in eight villages of the region. The disease was less where certified seed has been used. All the varieties grown in the region were susceptible to the disease.

At Modipuram, *Myzus persicae* Sulzer was recorded as early as 12th November 2009 and its population build up started in mid December; in Gwalior, it was recorded in 3rd week of December and crossed the critical level by 1st week of January, 2010. Highest population of thrips (42 thrips/plant) was recorded during 4th week of September, 2009 and population declined in the month of November-December. *Thrips palmi* was the predominant species of thrips at Gwalior. Thiacloprid 240SC was effective in managing *Myzus persicae, Aphis gossypii,* as well as whiteflies. Spray of neem and ratna jayot extracts in cow urine @ 10% caused 87.97 and 82.98% mortality of glasshouse white fly (*Trialeurodes vapororium* (Westhood) after 14 days of spray. The seed kernels of *ritha* (soap nut) @ 1.5% w/w was most effective in minimizing the tuber damage by potato tuber moth after three months of storage at Shimla. A bio-intensive management schedule for white grub consisting of mass collection of beetles and killing them in kerosenized water, mulching the potato ridges with garlic, bana, stinging nettles, and eucalyptus leaves and inclusion of *Heterorhabditis indica* (EPN) resulted in the least infestation at harvest.

One thousand four hundred and eighteen clones were evaluated for resistance to golden nematode and 357 were selected. Fifty five advance stage hybrids were evaluated in four replicated trials along with Kufri Girdhari and Kufri Swarna and 32 were selected on the basis of agronomic traits and resistance to potato cyst nematodes and late blight.

The advance generation hybrid OS/01-516 possessing resistance to both the species of potato cyst nematodes together with field resistance to late blight out-yielded the best control K. Girdhari. The promising hybrid OS/93-D-204 has been recommended for release during 27th Group Meeting of Potato Workers of All India Coordinated Research Project (Potato).

Application of carbofuran and phorate @ 2 kg a.i /ha reduced the multiplication of PCN and improved the potato yield. Neem cake blended with *T. viride* recorded significantly higher yield and lower PCN multiplication among the various organic amendments evaluated against PCN and was comparable with carbofuran. Significant bio-suppression of PCN coupled with enhanced potato yield was achieved by the application of the bio-control agent *Pseudomonas fluorescens* @10 kg/ha. Potato+broadbean intercropping in 1:1 ratio reduced PCN population by 10% in susceptible variety Kufri Giriraj Effect of various soil management strategies on PCN dynamics revealed lower PCN population in monocropping of advance hybrid OS/93-D-204 (reduction of PCN by 22%) closely followed by the recommended practice of potato + French beans intercropping.

CROP PHYSIOLOGY, BIOCHEMISTRY & POST HARVEST TECHNOLOGY

A simple method for the estimation of reducing sugars in potatoes in the field using Benedict's reagent was developed. Influence of pressure cooking and microwave cooking on the three antioxidants viz. phenols, ascorbic acid and carotenes was studied in five varieties and the contents of antioxidants were higher in microwave cooked potatoes. An attempt was made to prepare extruded product using a blend of potato (20%) and cassava (80%) flours. Potato flakes was prepared from seven potato varieties and a maxium flake yield of (20.1%) was obtained in Kufri Frysona. Potato *lachha* was prepared from nine potato cultivars and highest *lachha* yield of 37.2% was obtained from Kufri Himsona. French fries were prepared from five processing varieties, recovery was higher (44.8%) in Kufri Chipsona-1, the texture of fries was firmer (1530 g force) in Kufri Frysona. Dipping of potato slices in magnesium chloride (0.5%) and calcium chloride (0.5%) for 10 minutes resulted in 3.7% reduction in oil content of chips. Acrylamide content was determined in 41 Indian potato varieties and it ranged from 40 µg /kg chips (Kufri Chipsona-2) to 3799 µg/kg chips (Kufri Kanchan). Starch was extracted from potatoes after 90 days of storage in heap, 2-4 ^{o}C and 10-12 ^{o}C, and starch recovery was maximum (11.75%) in potatoes stored at 10-12 ^{o}C.

Potatoes of three processing cultivars stored in improved heaps for 90 days were evaluated by ITC, Ltd at their laboratory in Roorkee. Undesirable colour and total potato defects were nil in cvs. Kufri Chipsona-1 and Kufri Chipsona-3 and less than 5.0% in Kufri Lauvkar and the potatoes were graded as highly acceptable for processing. Efforts were made for transfer of technology on improved heap storage technology through on- farm trainings and demonstrations, live phone-in programme on Doordarshan and reports/news items in the local news papers. Even low concentration of CIPC significantly reduced sprouting up to 80 days in two potato cultivars *viz.* Kufri Pushkar and Kufri Surya generally suitable for export. Treated potatoes of cv. Kufri

Surya with low reducing sugar contents were suitable for processing into chips. CIPC residues in peels of potato tubers (2-7 ppm) were far below the permissible limits. Storability of Kufri Himsona and Kufri Chipsona-3 was very good under heap and pit storage with lower total losses as compared to Kufri Chipsona-1. Reducing sugar content in the three processing cultivars remained ≤100mg/100g fresh weight and the chip colour was highly acceptable up to mid June. CIPC treated heap stored potatoes recorded less peeling loss, more recovery and lower oil content of chips, lower reducing sugar and sucrose contents and produced chips of highly acceptable colour with more crispness as compared to untreated potatoes up to 90 days. Rotting was reduced in CIPC treated tubers stored in heaps with clove oil @ 3ml/100 tubers, followed by tubers placed along with Naphthalene balls wrapped in paper @ 10g/100 tubers and Neem powder @ 20g/100 tubers. Total losses in advanced processing hybrids, MP/04-578, MP/03-626, MP/2K-516 and MP/98-172 were at par with the control cultivars. Changes in biochemical parameters and chipping quality during storage at 10-12^{o}C with CIPC showed varying patterns in different varieties. Out of nine processing varieties/hybrids stored at 10-12^{o}C, Lady Rosetta and Kufri Frysona made chips of superior texture. Higher accumulation of reducing sugars and sucrose led to total deterioration in the processing quality of Chipsona cultivars after 9 months of storage at 12^{o}C. Reconditioning of tubers at 20ºC resulted in reduction of sugar content in potatoes which however did not result in improving the chip colour.

SEED TECHNOLOGY

During the year 2009-10 indexing of 28733 tubers of 24 varieties was done at Modipuram, Jalandhar, Gwalior, Patna, Kufri and Shimla. A total production of 33466.41 quintal nucleus and breeder seed was achieved in an area of 143.20 hectare in different stages and generations. A total of 26566.36 quintal seed was available for supply during 2009-10 which includes surplus nucleus seed of 1555.50 quintal. Out of which 23525.98 quintal seed was supplied to various agencies and about 2926.89 quintal was kept in cold store for the further supply during the crop season. At CPRS, Ooty, an area of 8.90 hectare was planted and 824.77 quintal quality seed was produced. Out of which, 533.73 quintal was supplied to various agencies. At CPRS, Shillong an area of 5.47 hectare was planted and 375.37 quintal quality seed was produced. Out of which, 155.74 quintal was supplied to various agencies.

A total of 39,163 *in vitro* plantlets of 20 varieties and 54,631 micro/ mini/buffer stock tubers of 18 varieties were produced at CPRI, Shimla and supplied to different stations of CPRI. A total of 7,915 *in vitro* plantlets of 18 varieties were used for planting at CPRI, Shimla and 13,108 *in vitro* plantlets were kept for further multiplication. About 8,225 *in vitro* plantlets of 12 varieties were transferred to liquid media for microtuber production. In addition to this, 47,237 *in vitro* plantlets and 9767 microtubers of eight varieties were also produced at tissue culture laboratory CPRIC, Modipuram.

A total of 4,10,573 minitubers and 5, 10,242 tubers were produced from microplants (3,62,095 from 73,456), microtubers (48,478 from 24,278) and recycling of < 3 g (5, 10,242 from 1,20,015) mini tubers at Modipuram, Jalandhar, Gwalior, Patna, Kufri, Ooty and Shillong.

Overall health status of seed crop at Modipuram, Jalandhar, Gwalior, Patna and Kufri recorded during tuber indexing was 96.2, 80.2, 98.6, 94.2 and 95.1 percent, stage-I was 94.5, 95.2, 99.0, 98.3 and 94.13 percent, stage-II was 93.8, 97.2, 98.7, 100.0 and 97.0 percent respectively. Health status recorded in G-0 on the above centers was cent-percent whereas in G-1 on the above centers was 99.8, 100.0, 99.2, 100.0 and 99.1 percent respectively.

Study on effect of antibiotics on *in vitro* bacterial contaminant and morphology of Kufri Jyoti revealed that for obtaining optimal growth without any bacterial contamination we can incorporate carbenicillin 75 mg l^{-1} and cefotaxime 150 mg l^{-1} into the culture media. Study on effect of CCC on potato seed production and prolonging the shelf life of potato indicated that soaking of tubers in 100 ppm CCC reduces the weight loss during storage to the tune of 1.2 to 3.8 % than control.

SOCIAL SCIENCES

Survey was conducted at farmers field in the state of Gujarat and West Bengal to assess economic impact of new late blight control molecules vis-à-vis the Mancozeb. In the state of West Bengal farmers using new late blight control molecules harvested 31% higher potato yield than the farmers who used comparable number of Mancozeb (only) sprays. While the farmers using new molecules got 71% higher yield as compared to those who applied 2 or less number of sprays of Mancozeb only. Similarly in Gujarat new late blight control molecules yielded about 22% and 44% higher as compared to those who applied Mancozeb only and $\leq$ 2 sprays of Mancozeb respectively. Average yield on farms where late blight chemicals were applied was 37.21% higher in West Bengal and 20.30% higher in Gujarat. To compare the economics of potato based cropping system a survey was conducted in Muzaffarpur district of Bihar. The cost of seed contributed around 30% share in total cost followed by fertilizer (22.49%), machine labour (17.52%), human labour (16.12%) and irrigation (3.40%). The BC ratio was 1.21, indicating that production system is traditionally input based and there was a need for intervention by extension system. Overall farmers had a net profit of Rs.11,594./= from potato cultivation. The technological gaps for selected potato technologies was assessed at Shimla and Patna. The survey indicated that there was 40% gap in Shimla and 64.28% in Patna with respect to cultural operations, late blight management, pest management, healthy seed potato production and nutrient management. However, the lowest gap was found in integrated pest management (56.5%) in Patna. Assessment of selected potato technologies revealed that an average yield of 225 per hectare from

demonstration plot as against 198q/ha obtained from farmers own practice at Shimla. At Patna in Bihar demonstrations on adoption of improved varieties like Kufri Kanchan, K. Ashoka and K. Pushkar resulted in increased yield (16.66% to 24.66%) as compared to local varieties. Maximum increase in yield was recorded for Kufri Ashoka (24.66%) followed by Kufri Kanchan (21.87%). Potato varieties Kufri Ashoka was found most remunerative with a net return of Rs.43,500/=. Overall knowledge of the participants improved by 21% during 8 days Model Training Course on "*Techniques for improved quality seed potatoes production"* . However, gain in knowledge was in general aspects related to potato cultivation (52%) followed by plant breeding, biotechnology and entomology (26%), PHT and Crop Physiology (25%).

RESEARCH ACHIEVEMENTS 2009-10

Most of the Institutes research programmes are of multidisciplinary nature and have been identified as per mandate set by the Council and priorities identified in the Research Advisory Committee (RAC) and Institute Research Council (IRC) meetings held every year. At present, potato research is being carried out under the following 20 programmes. For convenience - research achievements under these programmes during 2009-010 are presented under different disciplines.

RESEARCH PROGRAMMES YEAR 2009- 10

Research Programmes & Institute Code No.	**Programme Leader and Co-Investigator**
Potato genetic resources P1-2004/1-IPR-F30/0210	Dr. Jai Gopal **Co-Investigator:** Drs. Vinod Kumar, SK Luthra, Raj Kumar, Vinay Bhardwaj, ID Garg, PH Singh, AK Somani, Ashiv Mehta, RS Marwaha, TA Joseph, Shambhu Kumar, Rajpal Singh, Kamlesh Malik, AK Srivastava and Uma Maheshwari.
Development of varieties and technology for potato processing P1-2004/3-IPR-F30/0210	Dr. SV Singh **Co-Investigator:** Drs. SK Pandey, RS Marwaha, Dinesh Kumar, Parveen Kumar and Vinay Bhardwaj.
Breeding potato cultivars for Indo Gangetic plains P1-2004/5-IPR-F30/0210	Dr. SK Luthra **Co-Investigator:** Drs. Raj Kumar, VK Gupta, BP Singh, Shambhu Kumar and Eradasappa E.
Biotechnology in potato improvement P1-2004/6-IPR-F30/0210	Dr. D. Pattanayak **Co-Investigator:** Drs. VU Patil, SK Chakrabarti, SK Pandey, RS Marwaha, Raj Kumar and Dr. Dinesh Kumar

TPS technology for potato production P1-2004/11-IPR-F30/0210	Dr. Shambhu Kumar **Co-Investigator:** Drs. SV Singh, AK Srivastava, Devender Kumar and Eradasappa E.
Cell Biology and somatic cell genetics for potato imporovement PI-2004/22-1 PR-F-30/0210	Dr. Jagdiesh Kumar and Dr. SK Pandey
Develop sustainable potato based cropping systems P1-2004/7-IPR-F27/0210	Dr. SS Lal **Co-Investigator:** Drs. JP Singh, PM Govindakrishnan, VS Kushwah, RK Arora, Praveen Kumar, Name Singh, SK Singh, VK Dua, SP Singh, Sanay Rawal, Manoj Kumar, K Manorama, Shashi Rawat, MK Jatav and Islam Ahmed.
Integrated nutrient and water management in potato P1-2004/9-IPR-F25/0210	Dr. SP Trehan **Co-Investigator:** Drs. NC Upadhyay, MC Sood, Name Singh, Manoj Kumar, K Manorama, MK Jatav, Sanjay Rawal and Raj Kumar
Studies on long term manurial/fertilizer application and organic farming in potato production P1-2004/20-IPR-F25/0210	Dr. NC Upadhayay **Co-Investigator:** Drs. OP Singh, MC Sood and MA Khan.
Mechanization of potato cultivation P1-2004/10-IPR-N20/0210	Er. Manjit Singh **Co-Investigator:** Ers. Sunil Gulati and Sukhwinder Singh.
Management of late blight in potato P1-2004/2-IPR-H20/0210	Dr. BP Singh **Co-Investigator:** Drs. PH Singh, RK Arora, SK Chakrabarti, M Narayan Bhat, SK Kaushik, Sanjeev Sharma, Shashi Rawat, AK Srivastava, TA Joseph, D. Pattanayak, Mehi Lal
Diagnostics and detection of pathogens in potato P1-2004/12-IPR-H20/0210	Dr. ID Garg (up to May, 2009; Dr. S.K. Chakrabarti (from June, 2009 onwards) **Co-Investigator:** Dr. Jeevalatha, Dr. JK Tiwari
Integrated disease management in potato P1-2004/13-IPR-H20/0210	Dr. RK Arora **Co-Investigator:** Drs. AK Somani, Rajpal Singh, Vinay Sagar.
Integrated pest management in potato P1-2004/14-IPR-H10/0210	Dr. VK Chandla **(up to Feb. 2010); Dr. Kamalesh Malik (March, 2010 onwards)Co-Investigator:** Drs. S Ramani, Gulab Ram, Anuj Bhatnagar and Brajesh Singh
Management of potato cyst nematodes P1-2004/15-IPR-H10/0210	Dr. TA Joseph **Co-Investigator:** Drs. Uma Maheshwari and K Manorama.
Physiological response of potato plants to heat stress P1-2004/4-IPR-F60/0210	Dr. JS Minhas **Co-Investigator:** Drs. Devendra Kumar, Kamlesh Malik, Sanjay Rawal and VK Gupta.
Storage behaviour and processing	Dr. Ashiv Mehta **Co-Investigator:** Drs. R Ezekiel, RS

quality of potatoes P1-2004/16-IPR-F60/0210	Marwaha, SV Singh, RK Arora, Brajesh Singh and Dinesh Kumar.
Diversified utilization of potatoes P1-2004/17-IPR-Q10/0210	Dr. R Ezekiel **Co-Investigator:** Drs. RS Marwaha, Dinesh Kumar and Brajesh Singh.
Development and production of nucleus and breeder seed of potato P1-2004/18-IPR-F00/0210	Dr. PH Singh **Co-Investigator:** Drs. BP Singh, VS Kushwah, RK Arora, RP Rai, AK Somani, Gulab Ram, Rajpal Singh, Vinay Singh, Ashwani Sharma, SP Singh, Vinod Kumar, R Muthu Raj, SK Singh, Dhruv Kumar, Anuj Bhatnagar, G Ravichandran, EP Venkatasalam, Dr. Murlidhar, Jagannath, P Jassal and Brij Mohan.
Impact of potato technologies developed by the Institute P1-2004/19-IPR-COO/0210	Dr. NK Pandey **Co-Investigator:** Drs. Rambir, RK Rana, Anil Kumar and Barsati Lal.

DIVISION OF CROP IMPROVEMENT

Potato Genetic Resources

The CPRI is the designated National Repository of potato germplasm and is the holder of the biggest potato gene bank in South Asia. Potato collections are evaluated for all important biotic and abiotic factors including adaptability and quality traits. The information generated is documented both in electronic and printed form and made available to the breeders, and the breeders' choice material is also supplied to them for developing improved cultivars.The results of the programme has been described below :

Collection, conservation, evaluation and documentation of potato germplasm.

Collection

The National repository of potato germplasm collection was futher strengthened at CPRI. During the year under report, 20 accessions from CIP, Lima Peru, 49 from USA, 11 from China, 2 from Canada and 9 from Bangladesh were added to cultivated germplasm collection. The present germplasm collection at CPRI consists of more than 3,900 accessions of cultivated and wild species acquired from 30 countries (Table 1).

Table 1. Potato germplasm holding at CPRI, Shimla

Material	No. of accessions				No. of donor countries
	Tuber	*In-vitro*	True seed	Total	
a) Tuberosum (Cultivars / parental lines) *Indian*					
Cultivars bred at CPRI	44	44		44	
Advanced hybrids	86	17	-	86	
Indigenous varieties	51	22	-	51	
Indigenous samples	97	43		97	
Exotic	1445	1550	-	1750	30
b) Andigena	770	-	-	770	5
c) Wild/ semi-cultivated sps.	110 (38 species)	-	972 (104 species)	1082 (118 species)	5
Total germplasm				3920	

Conservation

One thousand three hundred twenty seven Tuberosum accessions, 770 Andigena accessions and 69 indigenous samples were maintained in fields at Jalandhar. Nearly 1250 Tuberosum accessions, 90 indigenous samples and 15 VDS lines were maintained

in fields at Kufri. Seven hundred fifty one Andigena accessions were maintained in fields at Patna. Ten dihaploids of Indian commercial varieties were maintained in glasshouses at Shimla. Four hundred and forty five clones of 121 accessions of 37 wild species were maintained in tuber form in glasshouses/polyhouse at Shimla and 104 clones in fields at Modipuram. With a view to evaluate different wild species in the tuber form , 59 clones were obtained from 29 accessions of 9 species by converting them into tuber form from TPS form at Shimla. A total of 4,062 true seeds of 24 clones of 15 accessions pertaining to 13 wild species were produced through sib-mating/selfing at Shimla. Sixteen elite clones of 9 *Solanum* species were conserved in the *in-vitro* form. Nearly 1700 Tuberosum accessions were maintained in *in-vitro* form. Minitubers of 74 accessions were produced from in-vitro repository and added to the germplasm collection maintained under field conditions at Kufri. Fifty eight accessions including Kufri Swarna, Kufri Megha, Kufri Frysona and JX-576 were made free from all viruses through meristem tip culture (Fig.1)

Figure 1: A mericlone of potato

Evaluation

A large number of accessions were evaluated for various biotic and abiotic stresses and also for adaptability and physcio-biochemical qualities. Promising accessions identified in these evaluations are listed in Table 2.

Table 2. Evaluation of potato germplasm

Character	Location	No. of accessions evaluated	Promising accessions
Adapatabilti y	Kufri Replicated Row trial	 30 158	 None CP nos. 1485, 3644, 3776, 3790 and 3841
	Jalandhar Spring	 100	 CP nos. 3255, 3258, 3424 and 3443
	Modipuram Autumn	102	CP nos. 3050, 3095, 3099, 3127, 3142, 3163,

	(Early) Autumn (Main)	 191	3165, 3167, 3175 and 3185 CP nos.3125, 3127, 3146, 3150, 3165, 3184, 3187, 3208, 3252, 3414, 3421, 3434, 3451and 3461
Late blight Foliage	 Kufri (Field) Shillong (Field)	 214 35	 19-HR; 22-R; 21-MR 3-R (CP Nos. 1722, 2132 and 2163)
	Shimla(Lab)	95	2-R(CP nos. 1922 and 3421), 40-MR
Tuber	Shimla(Lab)	95	2-MR (CP nos. 3467 and 3574)
Stem necrosis	Gwalior	29	1-HR(CP 3786); 2-R (CP Nos. 3870 and 3871); 5-MR (confirmed for 4 years)
Viruses PVX & PVY PALCV	 Shimla Modipuram	 110 (1st time) 34 (2nd time) 100	 14 accessions were resistant to both PVX and PVY) 8 accessions were resistant to both PVX and PVY 14 accessions were found infected with PALCV
Leaf hopper and Mites	Modipuram	202 30 (Stem necrosis resistant lines)	19 accessions were resistant to leaf hopper. As many as 60 accessions showed less than 5 % mite damage. Six accessions namely CP Nos. 3264, 3281, 3364, 3426, 3430 and 3446 were resistant to both hopper burn and mite damage.
Cyst nematodes	Ooty	114	9 accessions (CP nos.3102, 3395, 3409, 3431, 3435, 3442, 3594, 3641 and 3760) were resistant to both the species
Keeping quality	Jalandhar	66	10- best keepers ;17-good keepers and 17-average keepers. (CP nos. 2060, 2067 2077, 2082, 2096, 2125, 2141, 2142, 2160 and 2172 were rated as best keepers)
Chipping	Jalandhar	61	Six accessions viz. CP Nos. 2066, 2069, 2101, 2110, 2132 and 2134 were found to be suitable for chipping.
Vitamin C	Jalandhar	72	CP Nos. 2145, 2150, 2158, 3791, 3852, 3854

			and 3900 were promising.

HR- highly resistant, R- resistant, MR- moderately resistant

Flower characters

Observations were recorded on flower characters namely flower colour, flowering intensity and pollen fertility on 43 andegina accessions flowered of the 194 accessions planted at Kufri.

Combining ability for late blight resistance

A set of 16 x 4 crosses was completed for studying the combining ability of parents in order to identify good parents for breeding programme.

Core collection

In order to develop a core collection of Andigena germplasm maintained at CPRI, data were recorded on 21 characters including foliage, tuber, sprout and floral characters for 740 accessions. The data was analyzed using Power Core (v.1.0) developed by NIAB, Korea. A core collection comprising of 78 accessions representing total diversity was constituted.

Documentation

Computer databases were updated by incorporating the evaluation data for various accessions. Databases of availability of various accessions at different conservation sites were also updated.

Germplasm registration

Following germplasm lines have been registered with NBPGR, New Delhi as elite genetic stocks.

1. SS 1725-22: *Solanum spegazzinii*- a diploid source of high frost tolerance in potato (Registration No. INGR09121)
2. SS 2040: *Solanum tuberosum* ssp *andigena,* a tetraploid source of high frost tolerance in potato (Registration No. INGR09120).
3. JX 90: an advance stage hybrid having combined resistance to late blight and early blight (Registration No. INGR09069).

Improvement of Andigena

For improvement of andigena population crosses among unrelated improved Andigena hybrids were attempted. In total 8,272 true seeds were obtained from 9 crosses. Seedling were raised and at harvest depending upon the availability, 8-30 tubers representing different genotypes were randomly retained from different cross combinations for further use in hybridization.

In first and second clonal generations, clones from andigena hybrids x andigena hybrids and backcrosses of andigena hybrids, were evaluated. In first clonal generation, based on tuber characters 195 clones were selected out of 1880 clones evaluated in observational rows. In second clonal generation, 12 clones were selected out of 92 clones evaluated. The yield range of the selected clones was 550 to 700 g/plant as compared to 510 g/plant of Kufri Pushkar.

None of the hybrids out yielded the control Kufri Pushkar at 80 days in preliminary yield trial (5 hyrbids) and confirmatory yield trial (2 hybrids).

Evaluation and documentation of wild and semi-cultivated potato

Screening for Late blight resistance

In order to diversify the sources of resistance to late blight in potato breeding programmes, two hundred sixty five (265) clones of 35 wild species were screened for late blight resistance under natural epiphytotic conditions. Sixty clones were resistant (AUDPC <100) and 21 were moderately resistant (AUDPC =101-300). Since late blight had appeared late in the season, the resistance of identified clones will be confirmed in the next crop season.

Screening for bacterial wilt

Sixty seven clones of wild species were evaluated at Bhowali in field however none of them was found tolerant to bacterial wilt.

Documentation

The information pertaining to wild species on various aspects like late blight screening, tuber availability in summers and winters, new accessions added, TPS produced through sib mating or selfing etc., was added to the germplasm database.

Breeding potato cultivars for Indo-Gangetic plains

The programme aims at developing short duration (65-80 days) early bulking, high yielding varieites with good keeping quality and late blight resistance for incorporation in intensive cropping systems in Sub-tropical plains. The major work done during last one year is reported below:

Release of Kufri Gaurav

The hybrid JX 576 was released by the Institute for cultivation in North Western plains as variety Kufri Gaurav (Figure). It is medium maturing variety performs well under nutrient stress conditions and is moderately resistant to late blight.

(Photograph to be included of Kufri Gaurav)

Hybridization and seedling raising

A total of 7, 17, 809 true potato seeds were obtained from the 325 successful crosses.

About 1, 31, 136 seedlings were raised in field from sowing of 3, 43, 575 true potato seeds. At harvest 12, 565 promising clones were selected. Selections were made based on tuber characters such as shape, skin colour, eye depth and devoid of tuber abnormalities.

Evaluation in nitial clonal generation

In initial clonal generation (F_1C_1, F_1C_2 and F_1C_3), 18,715 clones were evaluated at 65/75/80 days crop duration and 1722 promising clones were selected for further based on tuber characters.

Replicated yield trials

Jalandhar

Early (September) planting condition: None of the six advance stage hybrids were performed better than K. Surya, K. Pukhraj and K. Ashoka at 60 and 75 days harvest.

Normal (October) planting conditions: Of the 24 advance stage hybrids evaluated in four preliminary yield trials at 65 days, two promising hybrids namely J.4-40 and J.4-109 were selected as these out-yielded the controls. Three advance stage hybrids namly J.2-14, J.2-97 and J.3-121 were selected out of 13 hybrids evaluated in two confirmatory yield trial as these out-yielded the control at 65 days.

Modipuram

Preliminary yield trials: Nineteen advance stage hybrids were evaluated along with K. Bahar, K Sadabahar and K. Pukhraj at 80 DAP. Advance stage hybrids namly MS/6-547, MS/6-819, MS/6-1423, MS/6-1523, MS/6-1895 and MS6/-2680 were selected based on high yield and desirable tuber characters.

Confirmatory yield trial: Six advance stage hybrids were evaluated along with controls K Bahar, K. Sadabahar and K. Pukhraj at 80 DAP. On the basis of tuber yield and tuber characters advance stage hybrids MS/5-284 and MS/5-1543 were selected.

Final yield trial: Three advance stage hybrids were evaluated along with controls K. Bahar, K. Sadabahar and K. Pukhraj at 80 DAP. Hybrid MS/4-2261 produced significantly high total and marketable tuber yield as compared to the best control K. Pukhraj.

Patna

Preliminary yield trials: Fourteen advance stage hybrids were evaluated along with controls K. Arun, K. Pukhraj and K. Khyati at 75 DAP. Six hybrids namely 2005P42, 2005P75, 2005P50, 2005P76, 2005P17 and 2005P24 and 2005P73 were selected based on high tuber yield and desirable tuber characters.

Confirmatory yield trials: Seven hybrids were evaluated along with controls K. Arun, K. Pukhraj and K. Khyati at 75 DAP. Advance stage hyrids namely 2004P5, 2004P18 2003P2 and 2003P21 were selected on the basis of tuber yield, tuber characteristics and disease resistance.

Final yield trial: Three hybrids were evaluated along with controls K. Arun, K. Pukhraj and K. Khyati at 75 DAP. The hybrids 2002P14 and 2002P26 out performed than control K.Arun and K. Khyati, respectively, for marketable and total tuber yield.

Evaluation of cultures for baby potatoes

Modipuram: Cultivars K. Himsona and Lal Sheel (an indigenous cultivar from Bangladesh) were evaluated at 65 and 80 DAP. The produce with tuber weight between 5-20 g was considered as baby potatoes. K. Himsona produced 67 q/ha and 70 q/ha baby potatoes at 65 and 80 day crop durations, respectively; whereas Lal Sheel produced 19 q/ha and 84 q/ha baby potatoes at 65 and 80 day crops duration, respectively.

Patna*:* Five genotypes namely Lal Sheel, Phulwa White, Red Flesh, Hellora and PRT-3B/19 were evaluated at 75 and 90 DAP. Phulwa White gave the highest average no. of tubers per plant; total tuber yield per m^2 and tuber yield per plant at 75 DAP. At 90 DAP; Lal Sheel gave the highest average no. of tubers per plant while Phulwa White gave highest tuber yield per plant. Highest total tuber yield per m^2 was found in Hellora and Phulwa White.

Evaluation of Indigenous varieties

Two indigenous varieties namely G-4 and K-22 were evaluated along with K Khyati, K Sadabahar and K Surya at 65 and 80 days crop duration at Modiupram, Kalyani and Patna.

Modipuram : At 65 days, indigenous variety K-22 (371 q/ha) produced significant high total and marketable tuber yield than K. Khyati (226 q/ha) and K. Surya (245 q/ha) though it was at par with the best control K. Sadabahar (254 q/ha). At 80 days crop duration, K-22 (273q/ha) remained at par with K Surya (282q/ha) though it yield performance was lower than the best control K. Sadabahar (349 q/ha) and K Khyati (324 q/ha).

Kalyani : The indigenous variety K-22 (202 & 280 q/ha) produced at par tuber yield with best control Kufri Khyati (224 & 307 q/ha) at 65 and 80 DAP.

Patna : K-22 yielded at par with control variety K. Khyati at 65 days crop duration but at 80 days it gave higher marketable as well as total tuber yield than K. Khyati.

Indigenous variety K-22 showed early foliage senescence than the controls and also had early bulking over the location. Thus K-22 can be an apt choice for incorporation as sandwich crop in intensive cropping sequences.

Introduction of hybrids in AICRP (Potato)

Based on consistently good performance over years one hybrid from Modipuram and three hybrids from Patna are proposed for inclusion in All India Coordinated Researcdh Project on Potato (AICRP-POTATO).

Modipuram: Based on superior performance, the hybrid MS/4-2261 over 3 years is being proposed for inclusion in AICRP (Table 3). The hybrid produced significantly high total and marketable tuber yield than best control Kufri Pukhraj. The hybrid possesses 15.41% dry matter with good keeping quality and is field resistant to late blight at Modipuram conditions. Also, unlike Kufri Pukhraj this hybrid does not develop tuber skin

colour on exposure to sunlight. It has yellow, oval tubers with shallow eyes and light yellow flesh.

Figure 2: MS/ 4-2261- Flowers, Leaf and Tubers.

Table. 3. Culture propsed to be initiated in AICRP-POTATO from the project " Development of late blight resistance medium maturing varities" (Location – Modipuram)

Genotype	Tuber yield q/ha							
	2007-2008		2008-2009		2009-2010		Average	
	Total	Total	Marketable	Total	Marketable	Total	Marketable	Total
	75 DAP	90 DAP	80 DAP	80 DAP	80 DAP	80 DAP	80 DAP	80 DAP
MS/4-2261*	276.1	385.5	344.01	367.71	421.08	452.18	382.45	409.94
K. Bahar	247.2	287.5	223.25	238.16	333.41	361.92	278.33	300.04
K. Pukhraj	269.2	353.4	317.50	340.28	385.10	414.22	351.13	377.25
K Sadabahar	-	-	290.80	300.87	358.87	371.52	324.84	336.20
C.D. (0.05)	26.3	27.8	4.92	4.84	29.10	25.43		

Yellow, Oval, Shallow eyes, Light yellow flesh.

Patna: The hybrids 2002P14 and 2002P26 are being proposed for introduction in AICRP (P) trials (Table-4). Besides these, another advance stage hybrid 2001P67 combining early foliage maturity with high yield was also identified for introduction into AICRP (Fig 3). It possesses attractive white, round-oval tubers with fleet eyes (Table-5).

Table-4. Culture propsed to be initiated in AICRP-POTATO from the project "Breeding improved potato varieities for Eastern Plains" (Location – Patna)

	Yield q/ha at 75 days during the year					
Genotype	2006-07	2007-08	2008-09	2009-10	Average	Dry Matter%

2002P-14	315.00	295.10	274.58	214.12	274.70	18.2
2002P-26	330.00	324.86	290.56	246.18	297.90	16.1
K. Arun	287.00	262.22	242.06	189.47	245.19	19.2
K. Pukhraj	312.00	239.76	--	248.84	266.87	16.0
K. Khyati	--	265.03	258.06	208.45	243.85	14.8
CD (0.05)	33.50	28.65	5.40	16.41	--	4.0
2001P-67	318.86	291.11	266.38	265.20	284.64	19.1
K. Khyati	--	332.12	241.16	208.45	260.58	---
K. Pukhraj	330.83	327.53	--	248.84	302.40	15.2
K. Arun	237.82	280.35	239.34	189.47	236.75	19.0
CD (0.05)	17.00	31.92	25.09	16.41	---	----

2002P-14: Red, Round, Medium deep eyes, Light Yellow flesh, medium dormancy, moderately resistant to late blight.
2002P-26: White,Round, fleet eyes-crown end deep, Light Yellow flesh, Medium dormancy, moderately resistant to late blight
2001P-67 White Oval Fleet eyes White Medium dormancy, moderately resistant to late blight

Fig. 3 Tuber photographs of 2002P-14, 2002P-26 and 2001P-67

Evaluation of advance hybrid JX576 in On-farm trial: The advance hybrid JX576 was evaluated at Pantnagar, Hissar, Jalandhar and Modipuram during 2009-2010 and it outyileded the contro Kufri Pushkar at all the locations. On an average it produced 8% higher marketable and total tuber yield than the control Kufri Pushkar. About 95% yield of JX575 is marketable (Table 5).

Table5. Performance (t/ha) of advance hybrid JX 576 (Kufri Gaurav) and at 90 days in On-Farm trials under All India Coordinated Research Project on Potato.

Genotype	Pantnagar (Uttranchal)	Hisar (Haryana)	Jalandhar (Punjab)	Modipuram (U.P.)	Mean

	Total	Marketable	Total	Marketable	Total	Marketable	Total	Marketable	Total	Marketable
JX 576	46.9	46.3	36.9	35.4	47.5	44.7	36.5	33.4	42.0	40.0
Kufri Pushkar	44.4	43.7	35.4	33.8	44.9	42.2	30.5	27.9	38.8	36.9

Development of Varieties and Technology for Processing

The objectives of this programme are development of early maturing cultivars for chips and French fry making, fine tuning of agro-technology for processing potatoes and understanding the sugar metabolism in potato tuber under sub-tropical climates. Central Potato Research Institute has developed four indigenous chipping and one French fry making variety. But still there is urgent need for the development of varieties with early maturity and suitable for warmer regions of the country.

Release of Kufri Chipsona- 4

The processing hybrid MP/01-916 has been released at the Institute level by the CPRI as variety Kufri Chipsona – 4 (Figure __). The variety is early maturing and late blight resistant suitable for warmer region of the Country. It has high tuber dry matter and low reducing sugars and is suitable for processing into chips.

Tuber & chips of Kufri Chipsona -4

Hybridization and seedling raising

A total of 1,09,411 true seeds of 83 crosses were produced at Kufri and seedlings were raised at Modipuram. In all, 869 clones were selected on the basis of tuber characters.

Early Clonal generations

In total 2, 161 clones of F_1C_1 and F_1C_2 generation were evaluated and 130 clones were selected on the basis of tuber characters an chip colour. In F_1C_3, 15 genotypes were evaluated on the basis of tuber yield, chip colour and dry matter and 10 genotypes were selected.

Advance Clonal generations

In F_1C_4, on the basis of tuber yield and quality characters three cultures namely MP/05-5, MP/05-41 and MP/05-180 were selected out of 5 tested at 75 and 90 days. In F_1C_5 two cultures namely MP/4-578 and MP/4-816 were evaluated at 75 and 90 days and both were selected based on tuber yield and quality parameters.

The hybrids namely MP/02-32 and MP/03-626 were evaluated at 75 and 90 and on the basis of yield and quality characters both the hybrids were retained. In another trial, three processing hybrids namely MP/01-916, MP/01-1142 and MP/02-204 were evaluated at 75 and 90 days and based on superior performance hybrids MP/01-916 and MP/01-1142 were retained.

Multilocational trials

Hybrid MP/01-916 suitable for chips was evaluated at Indore (MP), Hooglee, Vardhwan (WB), Bagespura, Madenuar, Chikmanglor(Karnataka) at 90 days. It had superior or at par performance with controls (Table 6 & 7). The processing quality parameters of MP/01-916 at Indore indicated its suitability for processing. In the industrial testing by Pepsico India Holdings Private Limited at Bardwan (West Bengal), Madenaur and Chikmanglor (Karnataka) produced best quality chips.

Table 6. Total and processing grade tuber (t/ha) of MP/01-916 in Karnataka, West Bengal & Madhya Pradesh during 2008-10

Hybrid/ Variety	Karnataka				Mean	West Bengal		Mean	Indore (MP)	Over all Mean
	Hassan	Medenur	Bagesh-pura	Chick-manalur		Bardw-man	Hoogaly			
Total tuber yield (t/ha)										
MP/01-916	**30.1**	**16.4**	**16.9**	**27.8**	**22.8**	**41.2**	**36.2**	**38.7**	**32.0**	**31.2**
Atlantic	27.2	12.4	7.4	29.2	19.1	35.1	28.7	32.0	20.8	24.0
Kufri Surya	33.1	15.3	11.6	35.3	23.8	39.7*	27.5	33.6*	--	28.7
Processing grade yield (t/ha)										
MP/01-916	**26.6**	**13.2**	**14.0**	**24.1**	**19.5**	**33.2**	**26.0**	**29.6**	**25.1**	**24.7**
Atlantic	25.2	10.2	6.7	27.1	17.3	30.0	23.5	26.8	17.3	20.5

Kufri Surya	31.4	12.3	9.6	32.3	21.4	38.7*	22.3	30.5	--	26.0

*** evaluated for one year only.**

Table 7. Processing quality of hybrid MP/01-916 in Karnataka, West Bengal & Madhya Pradesh

Hybrid/ Variety	Karnataka				Mean	West Bengal		Mean	Indore (MP)	Over all Mean
	Hassan	Medenur	Bagesh-pura	Chick-manalur		Bardw-man	Hoogaly			
Chip Colour Score										
MP/01-916	**1.7**	**2.6**	**-**	**2.4**	**2.2**	**2.0**	**-**	**2.0**	**1.7**	**2.0**
Atlantic	1.9	2.4	-	2.0	2.1	1.1	-	1.1	1.4	1.5
Kufri Surya	4.1	2.2	-	2.5	2.9	-	-	-	-	2.9
Dry Matter (%)										
MP/01-916	**22.4**	**22.7**	**-**	**23.9**	**23.0**	**24.5**	**-**	**24.5**	**20.0**	**22.5**
Atlantic	22.1	25.6	-	20.6	22.8	23.0	-	23.0	22.0	22.6
Kufri Surya	21.1	18.4	-	21.0	20.2	-	-	-	-	20.2

Yield, processing and nutritional qualities of varieties / hybrids at Jalandhar (Punjab):

Twelve potato varieties / hybrids were evaluated for yield and processing quality at 100 days.

Hybrid MP/01-916 gave maximum tuber yield (57.36 t/ha), which was at par with high yielding table potato cultivar (Kufri Pukhraj) (57.02 t/ha). Among the processing cultivars, Lady Rosetta, MP/01-916 and Kufri Himsona gave significantly higher chip grade tuber yield while French fry grade tuber yield was highest in Kufri Surya.

All processing varieties could make acceptable colour chips. In processing varieties dry matter content in potatoes ranged between 18.8 (Kufri Chipsona-1) to 23.4 (Kufri Frysona and Kufri Chipsona-2). Chip yield was maximum in Lady Rosetta (30.7%), followed by Kufri Himsona (30.4%) and Kufri Frysona (30.4%). Chips of MP/01-916 showed maximum crispness (71.0 peaks). Tubers of MP/01-916 also contained

maximum Vitamin-C content (13.33 mg/100 g fresh weight). Tubers of Kufri Chipsona-1 contained minimum reducing sugars (21.9 mg/100 g fresh weight) while sucrose contents were minimum in Lady Rosetta. Maximum contents of free amino acids were found in Kennbec and of phenols in Kufri Surya (61.7 mg/100 g fresh weight). Among Indian Potato genotypes, hybrid MP/01-916 was found promosing based on processing grade yield, chip colour, dry matter and chip yield.

Optimizing in-row spacing and plant density for higher processing grade tuber production in cvs. Kufri Chipsona-3 and Kufri Himsona

In Kufri Chipsona-3 maximum total and processing grade tuber yield were recorded when 65,800 plants/ha were planted at 67.5 × 22.5 cm, crop geometry, but it did not differ significantly with other in-row spacing treatments. In Kufri Himsona, maximum total, processing grade and net tuber yield were recorded when 49,400 plants/ha were planted at 67.5 × 30 cm, crop geometry, but it did not differ significantly with other treatments. Processing quality traits like chip colour and specific gravity did not differ significantly with in-row spacing/plant density treatments.

Optimizing fertilizer and in-row spacing requirements of hybrid MP/01-916 for chipping

The results indicated that fertilizer dose already recommended for the processing varieities i.e 270 kg N, 80 kg P_2O_5 and 150 kg K_2O per hectare is also optimum for processing hybrid MP/01-916. At this dose 84.3 % processing grade yield was obtained (Table 12) Processing and total tuber yield decreased with increase in row spacing from 15 to 25 cm, though it was not significant. Crop geometry of 67.5 × 20 cm seems to be optimum for tuber yield and processing characters (Table 12).

Table 12: Effect of fertilizer and in-row spacing treatments on potato hybrid MP/01-916

Fertility levels N : P_2O_5: K_2O (kg/ha)	Total tuber yield (q/ha)	Processing-grade yield (q/ha)	Processing grade (%)	Tuber dry matter content (%)	Specific gravity	Chip color
F_1 =180 – 80 --100	292.8	231.5	79.0	22.1	1.081	2.77
F_2 =225 – 80 – 125	308.2	257.8	83.5	22.5	1.079	3.52
F_3 =270 – 80 – 150	316.1	266.3	84.3	21.6	1.079	2.89
$LSD_{0.05}$	22.6	29.4	4.42	NS	NS	0.66
In-row spacing (cm)						
15	320.4	265.2	82.5	21.1	1.079	2.99
20	305.6	251.4	82.2	21.7	1.080	3.11

25	291.2	238.9	82.1	22.4	1.080	3.08
$LSD_{0.05}$	NS	NS	NS	1.18	NS	NS

TPS technology for potato production

TPS is an acronym for True Potato Seed, which is the product of sexual reproduction. This programme intends to develop a technology wherein instead a seed tuber, TPS is used for raising a commercial crop. For the success of this technology it is imperative that seedlings grown from TPS are hardy and have an early tuber bulking. This programme thus has two components, one is on breeding for early and hardy TPS population and the second aims at physiological studies aimed at developing techniques for improving seedling establishment. The project-wise report for these components is given below.

Development of early bulking and hardy TPS population.

TPS Production

During the year, a total of 6.7 Kgs TPS of 63 crosses (1.4 kgs) including recommended population 92PT-27 and naturally flowering parental line TPS/D-150 was produced at Patna.

Recurrent breeding for early bulking

Twenty five early bulking genotypes were selected from the seedlings of 16 crosses. These will be evaluated for flowering characters and intermated for the next cycle of recurrent selection for early bulking. Thirteen early bulking clones were also selected from the F_1C_1 generation of 7 crosses. A new set of 20 bi-parental crosses were made among selected parents to select for early bulking genotypes from the segregating population for recurrent breeding. Another 43 biparental crosses were made for their evaluation and selection of early bulking TPS populations.

Seedling Transplant crop:

Thirty five TPS populations along with control 92PT-27 were evaluated as transplanted crop (Table 13, Fig. 4) at Patna. Sixteen populations viz., PWW 903, PWW 908, PWW 914, PWW 912, PWW 942, PWW 905, PWW 906, PWW 913, PWW 939, 2009KPT-29, PRR 902, PRR 903, PRR 906, PRR 925, PRW 904 gave higher yield than the control 92PT-27 at 90 days. Yield of TPS/D-150 (Selfed/OP) was at par with the control. Population PRR 902 gave the highest percentage of red tubers

Table 13. Performance of selected populations as transplanted crop at 90 days at Patna

Trial No.	No. of Populations tested	Red tuber %	Selected Populations	Yield (q/ha)	
				MTY	TTY
1.	8	--	PWW 903	224.6	293.0
		--	PWW 908	224.8	292.4
		--	PWW 914	225.0	270.9
		--	PWW 912	231.7	290.0
		--	PWW 942	237.8	297.6
		--	92PT-27	188.1	251.1
			CD(0.05)	11.5	13.6
2.	11	--	PWW 905	141.5	245.6
		--	PWW 906	161.1	247.4
		--	PWW 913	165.2	245.6
		--	PWW 939	169.3	278.9
		--	92PT-27	146.7	226.7
			CD(0.05)	14.3	15.0
3.	12	--	2009KPT-14	142.6	205.2
		--	2009KPT-29	171.5	254.4
		--	D-150	135.6	194.1
		--	92PT-27	150.4	211.9
			CD(0.05)	20.8	17.2
4.	10	74.5	PRR 902	244.4	278.1
		41.7	PRR 903	216.3	244.8
		49.2	PRR 906	215.6	246.7
		20.4	PRR 925	248.9	287.4
		22.3	PRW 904	220.4	254.8
		--	92PT-27	197.0	230.4
			CD(0.05)	12.9	14.3

Fifty five TPS populations were evaluated at Shillong and based on seedling survival, late blight incidence and tuber yield TPS populations namely HPS/35-54, HPS/43-D-150, HPS/44-54, HPS/67-MST-1, MF II/MST 71 and PT/08-83 performed well. (Table 14).

Table 14. Performance of selected TPS populations at Shillong

TPS Population	Survival (%)	AUDPC	Yield (q/ha)
HPS/35-54	82.5	203.92	60.61
HPS/43 – D-150	84.5	209.88	51.11
HPS/44-54	60.5	213.88	50.64
HPS-67/MST-1	61	277.58	46.11
MF II / MST 71	66.5	132.19	45.04

PT/08-83	66.5	302.75	45.22
SE	8.63	46.43	5.51
CD (0.05)	24.72	133.05	15.78

Figure 4: Harvest of seedling crop

Seedling tuber crop

Among the 12 white skinned populations, PT/08-83, PT/08-104, PT/08-109 and TPS/D-150 (OP/Selfed) yielded higher than the control 92PT-27 at 75 days. However, population PT/08-94 yielded at par with K. Kanchan among four red skin populations. (Table 15).

Table 15. Performance of selected TPS population using seedling tubers at Patna

No. of Populations tested	Selected Populations	Yield (q/ha)	
		MTY	TTY
12	PT/08-83	122.2	128.7
	PT/08-104	111.1	123.4
	PT/08-109	100.0	106.9
	D-150	88.0	98.6
	92PT-27	72.2	75.7
	CD(0.05)	15.4	18.7
4	PT/08-18	54.6	68.1
	PT/08-94	110.6	131.0
	PT/08-95	66.2	81.0
	PT/08-118	53.2	66.2
	K.Kanchan	109.7	126.9
	CD(0.05)	11.2	19.5

Development of techniques for seedling establishment and vigour

Seed priming through chemicals

The treatment with GA 1500 ppm was most effective in initiating germination in the TPS families (C-3 and 92pt-27). The other chemicals tested (K NO_3 and KH_2PO_4) were ineffective in breaking the dormancy.

Biotechnology in Crop improvement

This programme has two components. One is to develop potato transgenics for reduction of cold-induced sweetening and bacterial wilt resistance, and the other is on sequencing of potato chromosome 2 as partner of Potato Genome Sequencing Consortium (PGSC). The progress made during the year is as given below.

Development of potato transgenics for quality improvement

Cold-induced sweetening is an unwanted physiological process that makes potato unfit for processing due to accumulation of high amount of reducing sugars. Reduction of cold-induced sweetening in potato has been attempted by RNAi-mediated silencing of expressing of gene encoding potato vacuolar invertase, a key enzyme in the pathway involved in synthesis of reducing sugars, through introduction of gene construct containing inverted repeat cDNA fragment of potato vacuolar invertase gene (*INV*) intervened by potato granule bound starch synthase (GBSS) intron (*iIR-INV*). The T-DNA region of the RNAi vector cassette used for potato transformation, pBI121::CaMV35S:: *iIR-INV*, is shown in Fig. 5.

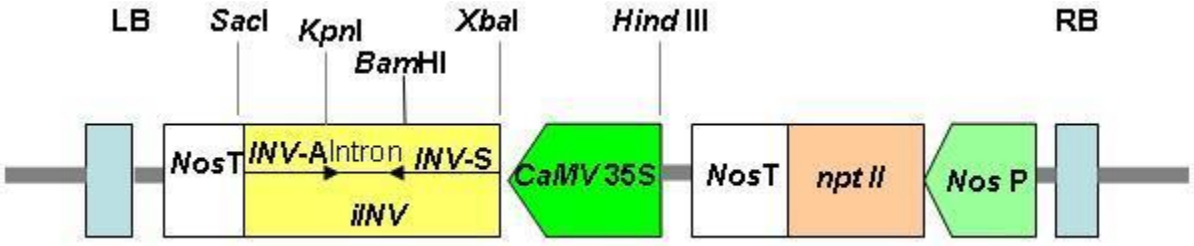


Figure 5: Map of T-DNA region of pBI121::CaMV 35S:: *iIR-INV* vector cassette

The gene construct was introduced into Kufri Chipsona-1 through *Agrobacterium* mediated transformation and after RT-PCR screening of 100 putative transgenic lines, 45 were found positive for NPTII expression. Based on glasshouse trials at Shimla, 15 promising transgenic lines were identified and tested under glasshouse

conditions at Jalandhar as main winter crop. Freshly harvested produce was cold stored at 2-3 °C. Three transgenic lines (K.ChipINV RNAi-2214, -2013, -2311) produced acceptable chip colour (Fig. 6) after 45 days of cold storage when evaluated directly after cold storage, and six transgenic lines (K.ChipINV RNAi-2214, -2013, -2311, -2123, -2262, -2213) produced acceptable chip colour after 21 days of reconditioning at 20 °C as evidenced by visible colour score (chip colour score up to 3 is highly acceptable in a scale of 1-10). Only one transgenic line (K.ChipINV RNAi-2214) produced acceptable chip colour directly after cold storage for 90 days. The Southern analysis revealed that KChipInvRNAi-2214 carried single copy of the transgene, while other five lines had two or three copies of the transgene.

Figure 6: Cold-chipping performance of vacuolar invertase RNAi transgenic lines of Kufri Chipsona-1. Visual chip colour score is mentioned at the bottom of each line.

Development of potato transgenics for disease and pest resistance

Bacterial wilt is an important disease problem for potato production worldwide. Since no durable source of resistance to this disease is known, attempt has been made in

imparting resistance through transgenics by introduction of an antimicrobial peptide gene, bovine enteric β-defensin (*EBD*).

Indian potato cultivar, Kufri Surya, was transformed with the EBD gene to develop transgenic potato resistant to bacterial wilt. A total of 1000 intermodal stem explants of Kufri Surya were co cultivated with *EBD* gene for *Agrobacterium*-mediated genetic transformation and about 35 putative transformants were obtained. PCR with EBD gene specific primers was performed on genomic DNA template isolated from putative transformants for confirmation of transgenicity, and six lines were found positive (Fig.7)

Figure 7: PCR screening of Kufri Surya *EBD* putative transformants for transgenicity. Lanes: M, molecular ladder of 100bp; NC, negative control; 1-10, transformants; PC, positive control.

Structural and functional genomics of potato

The institute is contributing to sequencing of potato chromosome 2 as partner of potato genome sequencing consortium. The BAC library of RH89-039-16 in pIndigoBAC5 vector with 78,336 *E. coli* clones had been obtained from The Netherlands. BAC DNA from 70 BAC clones was isolated using QIAGEN Large construct kit. Short gun sequencing of 35 BAC clones was done using 454 GS FLX Titanium. A single run generated 460 Mbp sequence data that was assembled into contigs using the GS Assembler software. A total of 877 large contigs were generated which covered around 2.4 Mbp sequence of potato chromosome 2. The average contig size was 2,696 bases and the largest contig was of 46,321 bases. The 96.60% bases were above Q 40, which shows their good quality and accuracy in sequencing.

Two sets of specific primers were designed from RH (*S. tuberosum*) and DM (*S. phureja*) BAC end sequences to study the extent of homology in various *S. tuberosum* sub species. The objective of the study was to find out relative usefulness of DM and RH sequence data in designing trait-specific markers in future molecular breeding work. The primers were designed from the BAC end sequence libraries that were picked randomly and leaving approximately 200 bases from the

start so as to ensure selection of insert sequence from potato genome only. Ten sets of primers from each DM and RH were designed and used for screening around 20 different potato genotypes including 4 tetraploid varieties and 16 species. The presence and absence of PCR products amplified by the primers are presented in Table 16. It is evident that all the PCR primers designed on the basis of RH (*S. tuberosum*) BAC sequence amplified genome region of all the four tetraploid varieties. On the contrary, one primer set (DM7) designed on the basis of DM sequence failed to amplify genomic region of two tetraploid varieties indicating sequence divergence in that region. In general, primers designed on the basis of DM (*S. phureja*) sequence amplified genomic regions of majority of the species studied. While primers designed on the basis of RH (*S. tuberosum*) sequence failed to amplify in many wild species.

Table 16: PCR amplification of genomic DNA from 20 potato genotypes using primers designed on the basis of DM and RH sequence data.

Primers/ Genotype	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
DM1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
DM5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM7	-	-	-	-	+	-	-	+	-	+	+	+	+	-	+	+	-	+	+	+
DM8	+	+	+	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
DM9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
DM10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
RH1	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+
RH2	-	-	+	+	-	+	+	+	+	+	-	+	+	-	-	-	-	+	-	+
RH3	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
RH4	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
RH5	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
RH6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
RH7	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
RH8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
RH9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
RH10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+

Note: 1. *S. sparsipilum* (SS 1724-2), 2. *S. spegazzinii* (SS 1725-84), 3. *S. albicans* (SS 1763-18), 4. *S. brevicaule* (SS 1794-7), 5. *S. demissum* (SS 1850-4), 6. *S. andigena* (JEX/A-785), 7. Atlantic, 8. Kufri Chipsona 3, 9. Kufri Pukhraj, 10. Phulwa, 11. *S. chacoense, 12.* K Badshah, 13. MP/97-1008, 14. *S. sleumeri, 15. S. bulbocastanum, 16. S. cardiophyllum, 17. S. alandiae, 18. S. mona, 19. S. jamsii, 20. S. andigena* (JEX/A-1038). Presence of band is indicated by '+' and absence of band is indicated by '-'.

Cell Biology and somatic cell genetics for potato improvement

This programme aims at transferring useful gene from IEBN wild species to cultivated background through somatic fusions as conventional crosses are not successful in these cases. Major achievements in the programme during the year 2009-10 are described below :

Characterization of interspecific potato somatic hybrids

Interspecific potato somatic hybrids (14 of C-13 + *S. pinnatisectum*, 40 of C-13 + *S. etuberosum*, 24 of C-13 + *S. bulbocastanum* and 110 of C-13 + *S. commersonii*) were characterized for confirmation of their hybridity through molecular, cellular and phenotypic assessment.

RAPD fingerprinting analysis using random 15 decamer primers namely OPAC-06, OPAC-09, OPAC-13, OPAC-14, OPAQ-02, OPAQ-14, OPAQ-15, OPAQ-16, OAPQ-20, OPAT-03, OPAT-06, OPAT-09, OPD-03, OPG-09 and OPK-06 (OPERON) was done. Presence of the 'species-specific diagnostic bands' i.e. unique bands from parental genotype in the somatic hybrids, were looked for in the somatic hybrids fingerprints and accordingly individual clone was confirmed as somatic hybrid or not. Twelve somatic hybrids of C-13 + *S. pinnatisectum* (No. 1 to 10, 12 and 13) showed 'species-specific diagnostic bands' which confirmed the hybridity by possessing both parental components as revealed by all the RAPD primers. (Fig.8). However clone no. 11 & 14 were not somatic hybrids. Correspondingly, 21 somatic hybrids of C-13 + *S. etuberosum* (No. 1-1 to 1-5, 2-1 to 2-4, 2-6 to 2-8, 6-1 to 6-3, 8, 10 to 12, 17-1 and 17-2) were also confirmed as true somatic hybrids by the 15 RAPD primers. While somatic hybrids No. 3-1, 3-2, 4-1, 4-2, 5, 7, 9, 13, 14-1, 14-2, 15, 16, 19-1, 19-3, 19-7, 20-2, 20-5, 20-7 and 20-8 were not true somatic hybrids as they showed wild parental components only and might be homokaryon of either of the parents (Fig. 9a & 9b).

Flow Cytometry analysis

Flow cytometry analysis corroborated with the results of RAPD analysis for the confirmation of tetraploid nature the somatic hybrids. Based on the flow cytometry analysis, somatic hybrids C-13 + *S. pinnatisectum* (No. 1 to 10, 12 and 13) (Fig. 10), and C-13 + *S. etuberosum* (No. 1-1 to 1-5, 2-1 to 2-4, 2-6 to 2-8, 6-1 to 6-3, 8, 10 to 12, 17-1 and 17-2) (Fig. 11) were confirmed as tetraploid potato.

Phenotypic assessment

Out of 14 somatic hybrids of C-13 + *S. pinnatisectum*, 12 hybrids (No. 1 to 10, 12 and 13) showed intermediate morphology of their corresponding parents. The leaf shape of somatic hybrids was ovate lanceolate type to that of ovate and narrow lanceolate type in parents C-13 and *S. pinnatisectum*, respectively. The tubers of these somatic hybrids were with dark purple black skin color and round tuber shape in contrast to brown skin color and oblong tuber shape of C-13; and brown-purple skin color and round tuber shape of *S. pinnatisectum.* The corolla size of somatic hybrids was larger (3.87 cm) than that of C-13 (2.38 cm) and *S. pinnatisectum* (3.14 cm). Flowers of somatic hybrids and *S. pinnatisectum* were white with purple shade while C-13 had small and white flowers with yellow tinge (Fig. 12).

In the somatic hybrids of C-13 (+) *S. etuberosum*, 21 hybrids (No. 1-1 to 1-5, 2-1 to 2-4, 2-6 to 2-8, 6-1 to 6-3, 8, 10 to 12, 17-1 and 17-2) displayed intermediate morphology of their parents. Leaf shape of the somatic hybrids was ovate lanceolate type with weak margin in contrast to ovate lanceolate type and strong margin of C-13; and ovate type and weak margins of *S. etuberosum*. Intermediate type leaf structure was appeared in the somatic hybrids in contrary to close type in both the parents. The corolla size of somatic hybrids was medium (3.56 cm) to that small size of C-13 (2.38 cm) and *S. etuberosum* (2.84 cm). Flowers of somatic hybrids were white with purple shade while C-13 had white with yellow striped. All the somatic hybrids including parents were late maturing type (> 120 days) (Fig. 13). There was no tuber formation in the parent *S. etuberosum* and somatic hybrids as well. Thus phenotypic assessment of somatic hybrids concurs with the findings of RAPD and FC analysis.

Evaluation for late blight resistance

Late blight resistance of the somatic hybrids of C-13 (+) *S. pinnatisectum* was carried out in the field grown crop at Shimla. Somatic hybrids and parent *S. pinnatisectum* did not show late blight (*Phytophthora infestans*) symptoms on the foliage (RAUDPC values: 0.00) while in the parent C-13 few symptoms of *P. infestans* were visualized (RAUDPC value: 0.07). Whereas, late blight symptoms were severe in the experimental plot of Kufri Jyoti, a highly susceptible variety (RAUDPC value: 0.47) Therefore, somatic hybrids and their parents could be characterized as highly resistant potato clones.

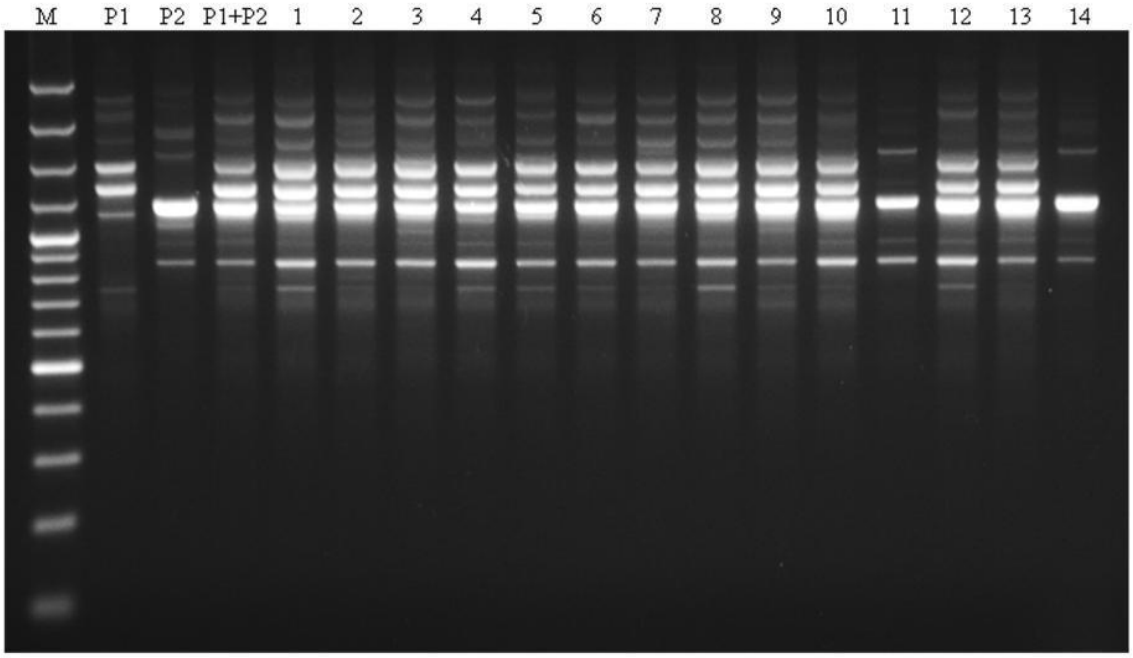


Figure 8: RAPD profiles generated by primer OPAQ-2 on 1.6% agrose gel. M=100 bp ladder, P_1 (Parent 1) =C-13, P_2 (Parent 2) = *S. pinnatisectum*, P_1+P_2 = Pooled parental Dna,

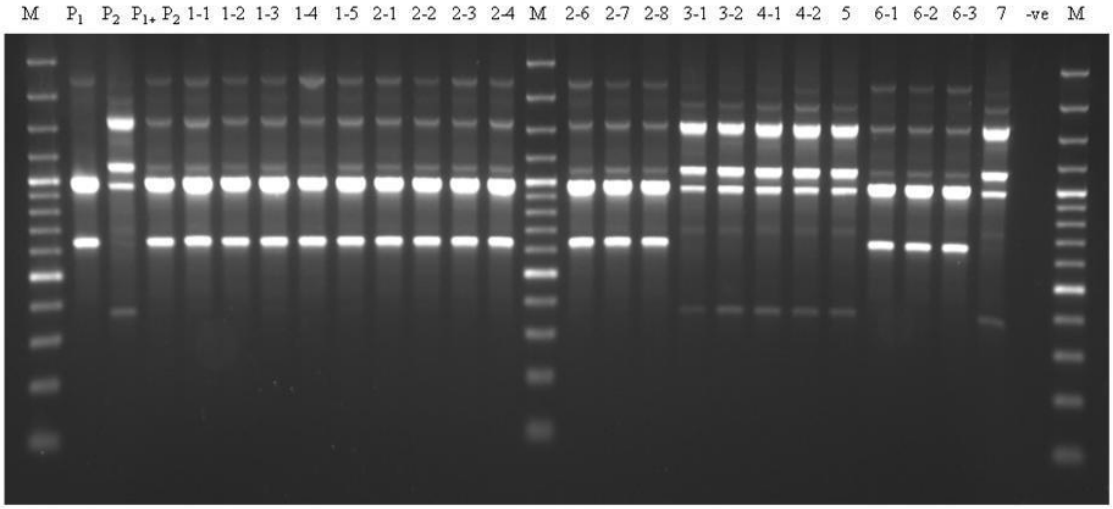


Figure 9a: DNA fingerprint profile (RAPD) of somatic hybrid clones of C-13 and *S. etuberosum* using primer OPAC-13. M = 100 bp ladder, P_1 (Parent 1) = C-13, P_2 (Parent 2) = *S. etuberosum*, P_1+P_2 = combined parental DNA and –ve (negative control) = distilled water.

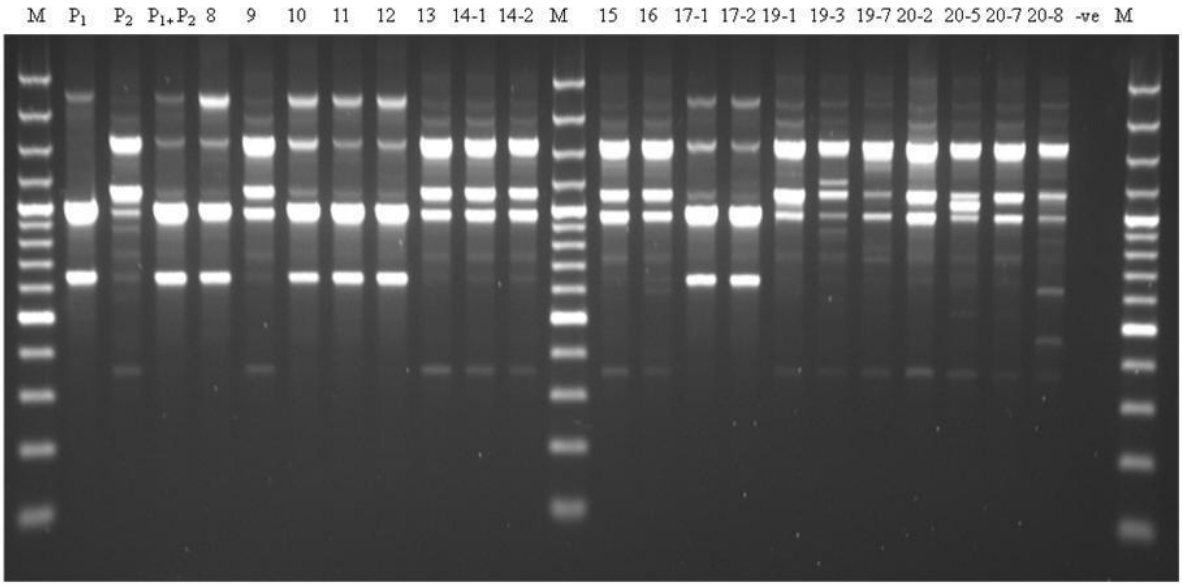


Figure 9b: DNA fingerprint profile (RAPD) of somatic hybrid clones of C-13 and *S. etuberosum* using primer OPAC-13. M = 100 bp ladder, P_1 (Parent 1) = C-13, P_2 (Parent 2) = *S. etuberosum*, P_1+P_2 = combined parental DNA and –ve (negative control) = distilled water.

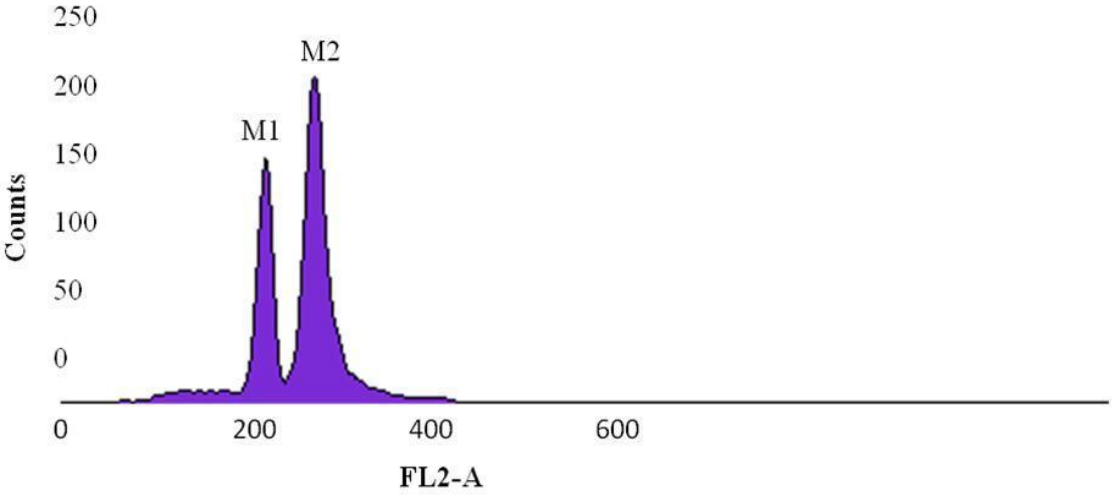


Figure 10: histogram of fluorescence intensities associated with nuclear DNA of somatic hybrid (di) haploid C-13 and *S. pinnatisectum*. Peak M1: internal standard (CRBC), M2: somatic hybrid clone.

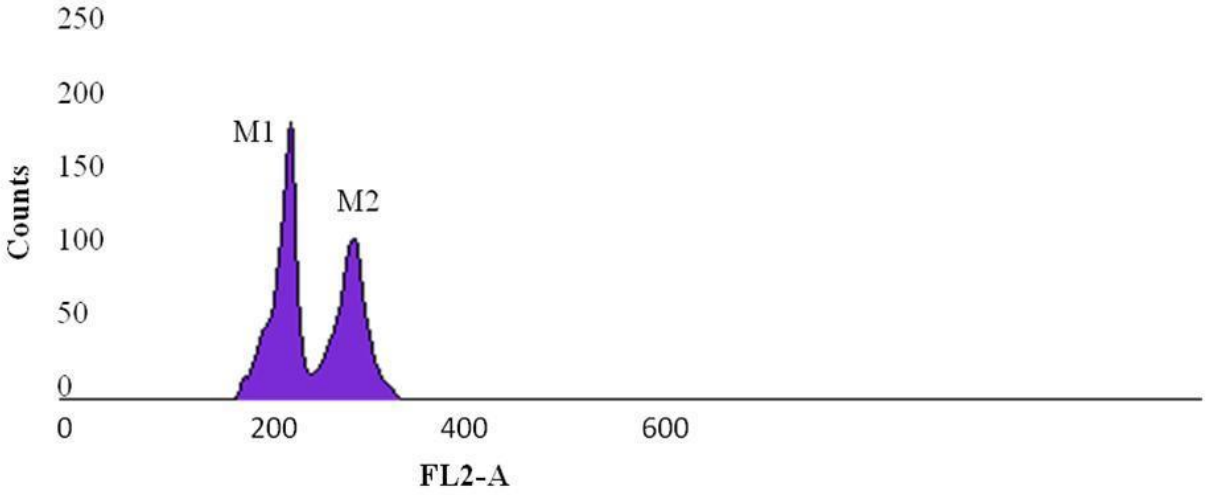


Figure 11: Histogram of fluorescence intensities associated with nuclear DNA of somatic hybrid (di) haploid C-13 and *S. etuberosum*. Peak M1: internal standard (CRBC), M2: somatic hybrid clone.

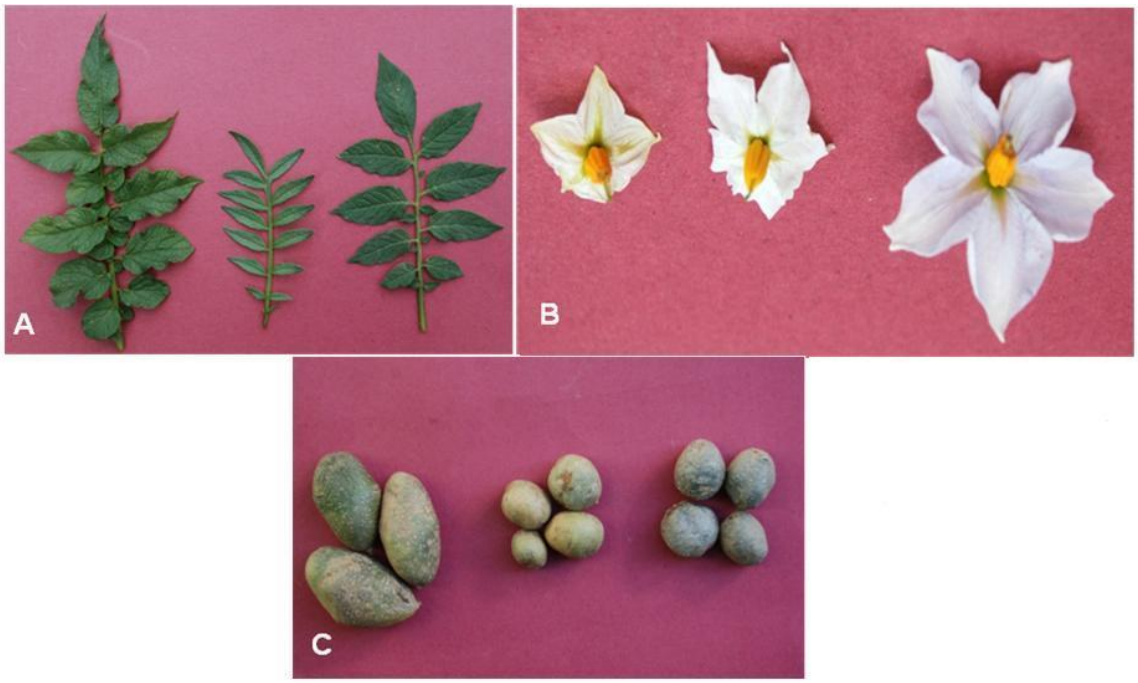


Figure 12: Leaves (A), Flower (B) and Tubers(C) of parents dihaploid C-13 and IEBN wild species *S. pinnatisectum* and somatic hybrid, respectively.

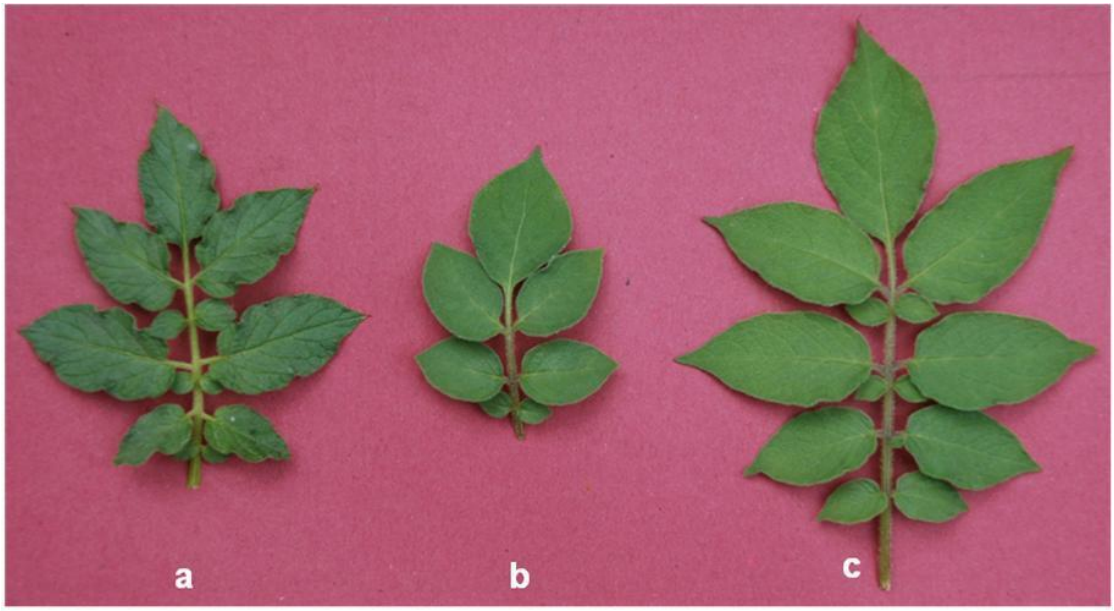


Figure 13: Leaf of parents *S. tuberosum* dihaploid C-13(a), *S. etuberosum* (b) and somatic hybrid C-13+ *S. etuberosum* (c).

DIVISION OF CROP PRODUCTION

Potato Based Cropping Systems

The task of increasing food production is becoming more challenging day by day due to shrinking of cultivable land caused by rapidly increasing urbanization and degradation of land resources. Increasing food production per unit area and time is the only option to meet the growing food demand of the increasing population of our country. Potato crop produces higher food per unit area and time to offer excellent opportunity for this. It is also a high value cash crop and thus enhances profitability of the system. Keeping this in view the programme aims to identify/develop potato based crop sequences and intercropping systems for major potato growing areas of the country and develop resource management strategies through the use of decision support tools.

Resource management in potato based cropping systems

Yield stability of potato under varying soil management strategies in the southern hills

Management practices that improve soil quality can enhance potato yield stability by reducing the impact of adverse growing conditions. There are several technologies available for successful production of potato, some among them are being practiced by the farmers and others are not due to various reasons. In order to evaluate few of our most important technologies in comparison to the farmers' practice, a study was initiated with potato *cv*. Kufri Giriraj and an advance stage hybrid OS/93-D-204. Results revealed that in general the performance of advance stage hybrid OS/93-D-204 was better than Kufri Giriraj. Potato equivalent yield (PEY) of the system as a whole was maximized from the

recommended improved practices in the potato + French beans intercropping in summer season followed by growing of cabbage in the autumn season.

The potato cyst nematode (PCN) population differed significantly between different treatments both after harvest of summer as well as autumn crops. In case of Kufri Giriraj, growing of potato as mono crop resulted in significant increase in PCN population both after summer as well as autumn season crops. The increase was 28 per cent in the current year over the previous year. In case of advance stage hybrid OS/93-D-204, mono cropping of potato recorded the lowest PCN population (194 per 100 g soil) reduction of 22% and it was closely followed by the recommended practice of growing potato + French beans intercropping followed by cabbage in autumn season. Application of FYM (20 t/ha) to potato crop in summer recorded higher PCN population of 251 per 100 g soil.

Introducing new crops in potato as intercrops in the southern hills

In Nilgiri hills legumes may prove beneficial as intercrop with potato due to its atmospheric nitrogen fixing capacity and also help in non proliferation of potato cyst nematodes (PCN) as it is a non-host for the PCN. Soybean was not found suitable for intercropping with potato under Nilgiri conditions. Hence, the trial was repeated with Broadbean using five different treatments and potato crop was tried with two varieties namely Kufri Giriraj and an advance stage hybrid OS/93-D-204. No significant difference in yield was observed between different treatments of sole and intercropping combinations with Broadbean. However, the yields obtained with the advance stage

hybrid OS/93-D-204 were higher in comparison with that of Kufri Giriraj both under sole and intercrop stands. Varietal differences were noticed with reference to PEY of intercrop combinations. Kufri Giriraj intercropped with Broadbeans in 1:1 combination it produced tuber yield almost equivalent to that of sole potato. In the case of advance stage hybrid OS/93-D-204, 2:1 population ratio produced the maximum PEY. The PCN population also showed differential response with respect to potato varieties. In Kufri Giriraj monocropping of potato resulted in 47 per cent increase in PCN population over its initial level with in a period of two years. Growing Broadbeans as intercrop at 1:1 ratio reduced PCN population by 10 percent over a period of two years. In case of the hybrid, (OS/93-D-204) growing of potato alone was more effective than intercropping with Broadbeans. However, the yield advantage in terms of PEY was more when it was intercropped with Broadbeans at a population proportion of 2:1.

Effect of varying levels of nitrogen in potato+maize intercropping system in the north western hills.

At Shimla combinations of 3 levels of N (0, 50 and 100% of recommended) to potato and maize in 1:1 intercropping system were evaluated during the third year of field experimentation. The sole crop treatments of potato and maize with 0 and 100% N were also included for comparison. Results indicated that in pure crop stands, yields of both maize and potato crops increased significantly when recommended doses of N were applied, over no N. In intercropping situations, potato yield with 100% N was significantly higher over no N. Maize yield with 100% N was significantly higher over no N when the intercropped potato received either 50 or 100% N. The highest land equivalent ratio (LER) of 1.17 was obtained when both the crops in intercropping situation received full recommended doses of N.

Nitrogen requirement of French bean in potato+French bean intercropping in the north western hills

During third year of field experimentation at Shimla, the treatments comprised of 5 levels of N to French bean (0, 25, 50, 75 and 100% of recommended) were evaluated in potato+French bean (1:1) intercropping. Potato was raised with 100% recommended dose of N in intercropping. Pure crop treatments of potato and French bean with 0 and 100% N were also included for comparison. Highest French bean pod yield was obtained when it received 75% N, which was at par with 50 or 100% N and significantly higher over 0 or 25% N, showing thereby that French bean required only 75% N in potato+French bean (1:1) intercropping. All the intercropping treatments gave an LER of more than unity thus showing that the intercropping of potato + French bean was always beneficial irrespective of N dose to French bean.

Resource management in garlic–potato sequence

A field experiment was initiated at Shimla during last year with the objective of finding suitable crop geometry of garlic and potato in garlic–potato sequence. There were in all seven treatments in which population density of garlic ranged from 40 to 100%. The highest yield of garlic (52.44 q/ha) was obtained in garlic–late potato sequence, which was significantly higher over other treatments. However, the potato yield was highest in garlic–potato relay sequence. The data on potato equivalent yield (PEY) showed that it was higher (308.87 q/ha) in garlic–late potato sequence *i.e.* 18.8% higher over second best treatment garlic–potato relay system (259.9 q/ha).

Spatial intensification of potato through intercropping of maize in north Indo-Gangetic plains

Intercropping of potato and maize is very popular and economical in potato growing areas of north Bihar district. However, the sowing time of winter potato or winter maize depends to a large extent on the harvesting of preceding rice crop and receding of water in low lying areas. The crop geometry of the intercropping system needs special attention

so as to explore the possibility of designing suitable, appropriate and conducive pattern of planting of potato and sowing of maize to take higher yield and economic returns.

Intercropping of maize in potato was highly remunerative (Table-1). Benefit cost ration was also in favor of potato+maize intercropping system. There was no significant difference due to method of maize sowing on net return and benefit cost ratio. However, row spacing of 67.5 cm gave higher benefit:cost ratio (1.64) as compared to 60 cm row spacing (1.55).

The potato equivalent yield was significantly higher in the intercropping system irrespective of date and method of maize sowing than the respective sole component crop stand. The highest total PEY was recorded when intercrop was sown simultaneously with potato planting. There was no significant variation with respect to method of maize sowing.

There was no significant effect of method of maize sowing on the yield and potato equivalent yield of maize. However, row spacing did influence significantly the yield and yield attributes of maize. Potato+maize sown at 67.5 cm spaced row produced more grain yield of maize as compared to row spacing of 60 cm (Table 1).

Synthesis of potato legume intercropping in north western Indo-Gangetic plains

In a field experiment at Modipuram, potato varieties *viz.* Kufri Surya and Kufri Pukhraj were planted in furrow irrigated raised bed method on 1st November, 2008. The legumes namely gram (Sadbhawna), lentil (GS-121), peas (Auricle), *methi* (Deshi), French bean & Bakla were sown in between two rows of potatoes in bed planting on the same day. The potato yield was not affected adversely with the incorporation of legumes in between two rows. The yield of Kufri Pukhraj varied from 258-282 q/ha with 6.20-7.80 lakh tubers/ha, while the yield of Kufri Surya remained 142-165 q/ha with 6.73-7.72 lakh tubers per hectare. The additional yield of legumes (*Methi* green foliage 138 to 141 q/ha + seed yield, green peas 167-175 q/ha, French bean green pods 17-19 q/ha, lentil grains 13-14 q/ha and *Bakla* green pods 21-25 q/ha worked as insurance crops.

Table 1. Effect of planting geometry of potato+ maize intercropping on yield and economics at Patna

Treatments	Potato yield	Inter crop yield (q/ha)		Total potato equivalent yield (q/ha)	Net return (Rs/ha)	Return per rupee investment
		Maize grains yield	Potato equivalent yield			
Inter cropping pattern						
Sole potato	312.9	-	-	312.9	75168	1.50
Sole maize D_1	-	76.50	153.0	153.0	38500	1.38
Sole maize D_2	-	68.60	137.2	137.2	33880	1.30
Sole maize D_3	-	54.40	108.8	108.8	26320	1.20
Potato+ maize sown on potato ridge on one side, D_1	274.5	67.40	134.8	409.3	103820	1.60
Potato+ maize sown on potato ridge on one side, D_2	283.6	61.60	123.2	406.8	102620	1.58
Potato+ maize sown on potato ridge on one side, D_3	296.7	54.80	109.6	406.3	100820	1.52
Potato+ maize sown in the furrow of potato ridge D_1	270.5	69.80	139.6	410.1	104140	1.60
Potato+ maize sown in the furrow of potato ridge D_2	286.5	63.70	127.4	413.9	105460	1.62
Potato+ maize sown in the furrow of potato ridge D_3	293.4	56.80	113.6	407.0	101100	1.52
CD(P=0.05)	16.4	4.32	4.1	18.4	-	-
Row Spacing						
60 cm	281.4	60.15	120.3	401.7	100630	1.55
67.5 cm	287.0	64.55	129.1	416.1	106290	1.64
CD (P=0.05)	NS	4.10	4.3	NS	-	-

D1=Maize sown on the same day as potato planting, D2= Maize sown 10 days after potato planting and D3= Maize sown after earthing up of potato.

Agro-techniques for potato+sugarcane intercropping system in north western plains

A field experiment has been initiated in 2009-10 with the objective to develop agro-techniques for potato+sugarcane inter-cropping system. The trial has differential NPK doses for sugarcane in association with potato. The results revealed that the marketable tuber number varied significantly in first year (247.5- 386.4 thousand/ha), however total and small tuber number remained statistically at par. Marketable (15.0-32.7 t/ha) and total (18.4-37.0 t/ha) yield varied significantly, whereas small size tuber yields were at par.

Low input technology for potato based cropping system in north central plains

In a field experiment at Gwalior *Bajra*, *til*, green gram and fallow were included and sown/kept in *kharif* and wheat, mustard, potato and fallow were planted/sown/kept in *rabi* season. Recommended cultural practices were adopted for other crops and low input package for potato crop. Highest cost of cultivation was recorded with *bajra*-potato sequence (Rs 53,800/ha) as compared to other cropping systems. Maximum gross return of Rs 97,140/ha was recorded with green gram–potato sequence. Highest net return of Rs 49,140/ha was obtained with green gram–potato sequence followed by *bajra*-potato sequence (Rs 37,052/ha). Benefit: cost ratio was higher with green gram–potato (2.02) followed by fallow-mustard/potato sequence (1.79).

Developing N recommendations based on soil nitrate content in southern hills

Excess nitrogen causes environmental degradation due to leaching into underground water resources. Precision application to meet crop needs reduces residual soil NO_3–N available for leaching. With this objective a trial was initiated with four levels of nitrogen (60, 90, 120 and 150 kg N ha^{-1}) in three different varieties (Kufri Giriraj and two advance hybrids *viz*., OS/94-D-204 and OS/93-L-956) during the *summer* season of 2008 at Ooty. This trial was repeated during the year 2009. The nitrate nitrogen of 0 to 30 cm depth and 0 to 90 cm depth was significantly correlated. Results showed that the nitrates could be thus estimated from the levels in surface soil through regression equation between surface and deep soil layers.

Fertilizer requirement of Kufri Himsona in southern hills

Fertilizer requirement of newly released processing variety (Kufri Himsona) for North Indian plains was compared with Kufri Giriraj to its suitability for southern hills. With recommended NPK dose Kufri Himsona recorded only 23 % of yield obtained with Kufri Giriraj. Higher levels of fertilization to Kufri Himsona could not improve tuber significantly. The yield of processing grade tubers (>75 g size) was also poor compared to the yield of Kufri Giriraj.

Nutritional management of seed potato crop in southern hills

Variety specific fertilizer requirement were estimated for producing seed crop of potato in Nilgiris. A trial was initiated with 27 different combinations of N, P and K levels in two varieties of potato *i.e.*, Kufri Giriraj and Kufri Swarna during the year 2008 and the same trial was repeated during the year 2009 by including three more varieties. The results indicate that there were differences in fertilizer requirement of varieties especially with respect to seed sized tuber production. In case of Kufri Giriraj more number of seed sized tubers were recorded (25-75 g) with NPK applied @ 75:135:75 kg/ha. Similarly in case of Kufri Swarna this requirement was only 75:112.5:75 kg/ha. In case of Kufri Himalini NPK @ 60:135:60 kg/ha produced more number of seed sized tubers. Kufri Jyoti produced more number of seed sized tubers by NPK @ 60:112.5:60 kg/ha. Kufri Girdhari recorded higher number of seed sized tubers by NPK @ 60:90:90 kg/ha. This indicates that seed crop is to be fertilized at little lower rates than that of ware crop and among the varieties Kufri Girdhari required least quantities of fertilizers. Among the varieties the performance of Kufri Swarna was better in terms of total yield in comparison with other varieties. However, the number of tubers produced was more in Kufri Jyoti.

Technology for production of seed sized tubers for newly released potato cultivars

At Modipuram, potato variety Kufri Pukhraj produced significantly higher total and net tuber yield (45.5 and 41.7 t/ha, respectively) followed by Kufri Anand and Kufri Chipsona -3 in comparison to variety Kufri Surya. Row spacing of 60 cm gave significantly maximum total and net tuber yields as compared to 67.5 cm inter-row spacing. The intra-row spacing of 15 cm produced significantly higher total, net and seed sized tuber yields against 20 cm intra-row spacing. The total and net tuber yield as well as seed sized tuber yields were significantly higher at 60 x 15 cm spacing with 1,11, 111 plants/ha followed by the yields of 67.5 x 15 cm

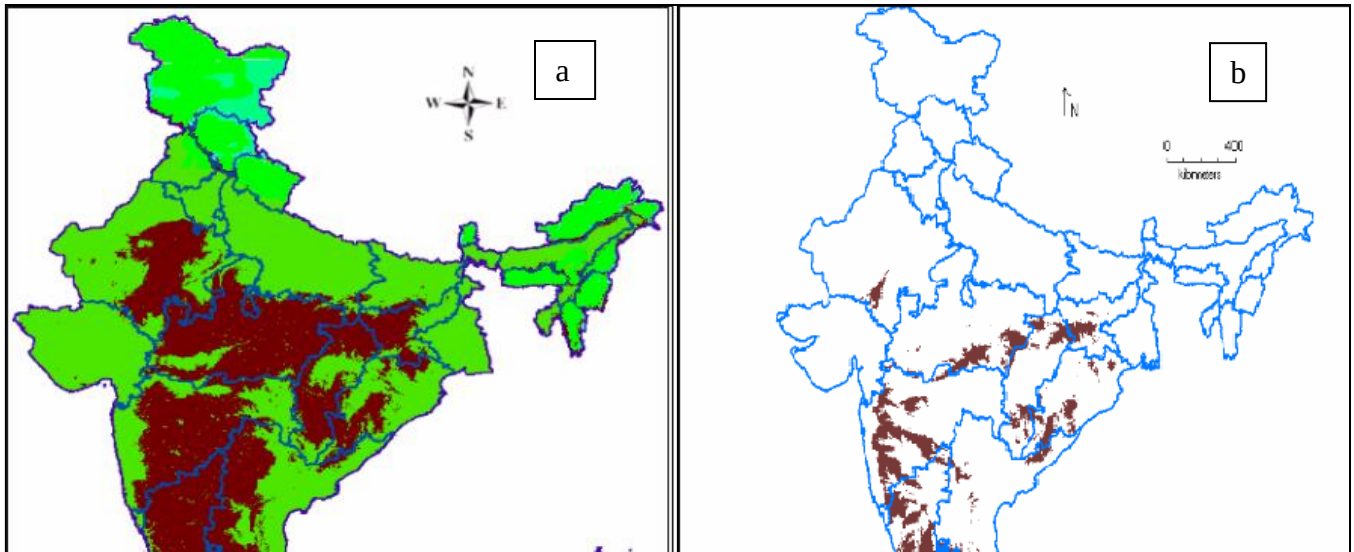
spacing (98,765 plants/ha) in comparison to 60 x 20 and 67.5 x 20 cm spacing with 83,333 and 74,074 plants/ha, respectively.

Development and use of decision support tools

GIS based delineation of sites suitable for *kharif* potato cultivation in India

Kharif potato constitutes an important constituent in the potato scenario of the country. Not only that it occupies an important place in the cropping systems in central and southern parts of India where it adds to the economic viability of the cropping systems, but its role as the source of fresh potato during the lean period adds to its importance. CPRI has been making efforts not only to find ways and means to increase the area under *kharif* potato but also to improve the productivity and efficiency of production. For this purpose a clear delineation of the probable areas has to be made so that the resource position of these areas can be identified and suitable package of practices developed.

Studies were taken up to identify the plateau areas in the Central and Southern parts of the country and then delineate areas suitable for growing potato during the *kharif* season in these plateau areas. Since plateau areas are defined as flat topped lands between 300 to 1300 m altitude, places between these altitudes were delineated from worldclim database of 2.5 minutes resolution (Fig 1a). However, not all these areas are suitable for growing potato in the *kharif* season since congenial temperatures for potato in *Kharif* occurs only at high elevations. Therefore, the thermal regime of the *kharif* season of important *kharif* potato growing locations were analyzed and it was found that in areas above 600 m altitude the thermal regime during the *kharif* season was congenial for raising a potato crop. Hence, in the second step areas lying between 600 m and 1300 m altitude in the plateau areas was delineated (Fig 1b) and it is expected that in these areas potato could be grown during the *kharif* season.



experiment was repeated during autumn 2009 with four varieties *viz.* Kufri Girdhari, Kufri Himalini, Kufri Swarna and Kufri Giriraj. The genetic coefficients for two varieties *viz*. Kufri Giriraj and Kufri Swarna have been finalised based on the data recorded from the experiments (Table 4). The reliability of these coefficients were tested by comparing the simulated results obtained by running Infocrop Potato model against recorded observations from field and close correspondence between observed and simulated results were obtained.

Fig. 1. Map showing areas with altitude between 300-1300m (a) and places with altitude between 600-1300m (b) where *kharif* potato cultivation is climatically feasible.

Work out Genetic coefficients of potato varieties and develop decision support tool for crop scheduling.

Field experiments to work out the genetic coeeficients of three varieties viz. Kufri Giriraj, Kufri Swarna and Kufri Himalini were conducted in the irrigated season at Ooty. The experiment was repeated during autumn 2009 with four varieties viz. Kufri Girdhari, Kufri Himalini, Kufri Swarna and Kufri Giriraj. The genetic coefficients for two varieties viz. Kufri Giriraj and Kufri Swarna have been finalized based on the data recorded from the experiments. The reliability of these coefficients were tested by comparing the simulated results obtained by running Infocrop Potato model against recorded observations from field and close correspondence between observed and simulated results were obtained.

For developing a decision support tool for giving recommendations on crop scheduling, yield potential *etc* of potato in the Nilgiris at Taluka level, the geographical co-ordinates of different locations (234 in number) in Nilgiris were collected using GPS. The daily weather data for these sites were generated using a weather generator. The weather data has been converted into the Infocrop format and the model is being run for different simulated dates of planting of Kufri Jyoti variety for all the three crop seasons *viz* irrigated, summer and autumn seasons.

Field experiments were also conducted at CPRIC, Modipuram **t**o find out the genetic coefficient of the potato processing cultivars *viz*. Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Chipsona-3 as per requirement of INFOCROP-POTATO model. Nine plots (3.6 m x 5 m for one plot) of each above mentioned cultivar were planted and periodic samplings were carried out to derive the various coefficients (Table 2. Chemical maturity which is the developmental stage of the plant when the sucrose level is minimum in the tubers was taken as the end of the season since in processing cultivars dehaulming is recommended at chemical maturity to ensure the good storability and processing quality of the processed products specially under long term storage.

Table 2. Observations on days to 50% emergence, tuber initiation and chemical maturity and their GDD requirements for finding genetic coefficients of processing cultivars

Developmental stage	**Kufri Chipsona-1**	**Kufri Chipsona-2**	**Kufri Chipsona-3**
Days to 50% emergence	17	16	17
GDD (TU) for 50% emergence	282.4	266.9	282.4
Days for Tuber initiation	29	30	29
GDD (TU) for Tuber initiation	463.8	474.0	463.8
Days for chemical maturity*	110	110	110
GDD (TU) for chemical maturity	1220.6	1220.6	1220.6

Identification of suitable sites for seed potato production in the north eastern states through GIS

A study was conducted to find sites in the north eastern states ecologically similar to the seed producing centers in the Indo-Gangetic plains and then assess the yield potential of potato at these sites *vis a vis* those in the Indo-Gangetic plains region. In the case of the hills, the objective was to delineate high hills of the north eastern with altitude between 2400 m and 2800 m where aphid pressure is likely to be low.

The worldclim data of 2.5 m resolution were used for Niche Modeling in Diva GIS. Geographical co-ordinates of 190 locations situated in the major seed potato production states in the Indo-Gangetic plains were collected and used as training sites to determine sites similar to these locations in the north-eastern region. For this purpose the domain module of DIVA – GIS using temperature based environmental parameters was used to estimate the Gower distance. In the area classified as similar to the potato growing regions in the Indo-Gangetic plains, 14 sites *viz.* Phuloni, Kampur, Hojai, Donka, Lanka, Umrangso, Diphu1, Diphu2, Sanupathar, Golaghat, Titabor, Tulshikhar, Salema and Silonjan were selected and the daily weather data of these locations was generated using MARKSIM weather generator. The weather data was screened for delineating plausible potato growing season using thermal rules (maximum temperature less than 35 ^{0}C and minimum temperature less than 21 ^{0}C at least three weeks after the maximum temperature criterion is fulfilled). The Infocrop potato model was run for each of these locations with the simulated first date of planting fixed at ten days before the start of the season as delineated through screening rules and the other two dates of planting were staggered at ten days interval. The model output (crop duration and yield) of these sites were compared to that of the main seed producing locations in the Indo-Gangetic plains *viz.*, Jalandhar, Modipuram, Gwalior and Patna. To identify potential sites for quality seed production in the hills, 90 m SRTM data was classified into different classes based on the altitude and the high hills (between 2400 m and 2800 m altitude) were delineated.

The results showed that there are few places in the plains of the NE region which have some similarity (Fig 2) with the Indo-Gangetic plains region where it is possible to raise a potato crop in the autumn season and that the crop duration and yield potential of Kufri Jyoti in these places were similar to those in the northern Indo-Gangetic plains in three simulated dates of planting. Thus, through the study, areas for focusing ground based surveys for aphid population pressure has been indentified.

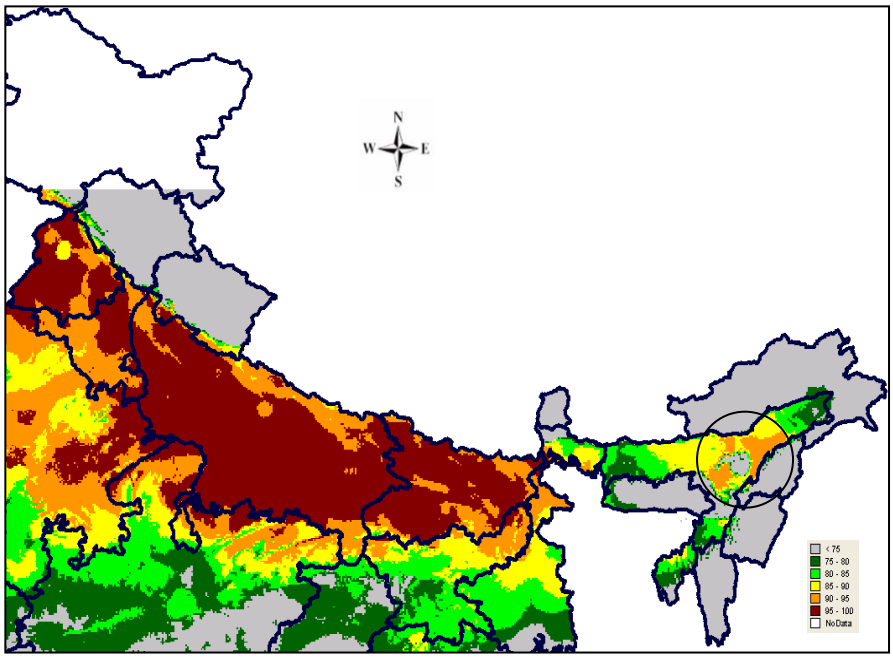


Fig. 2. Map showing areas in the northeast (light brown) having good similarity with the Indo-Gangetic plains region

In the case of the hills, traditionally in India the high hills have been the main centres of production of quality seed since high hills have relatively low aphid pressure. A similar situation may exist in the high hills of the NE which can be revealed through intensive aphid surveillance surveys. To delineate areas for undertaking field surveys, the 90 m SRTM data has been used and classified according to altitude and areas between 2400 m and 2800 m altitude have been delineated (Fig 3) for focusing of the aphid population surveys.

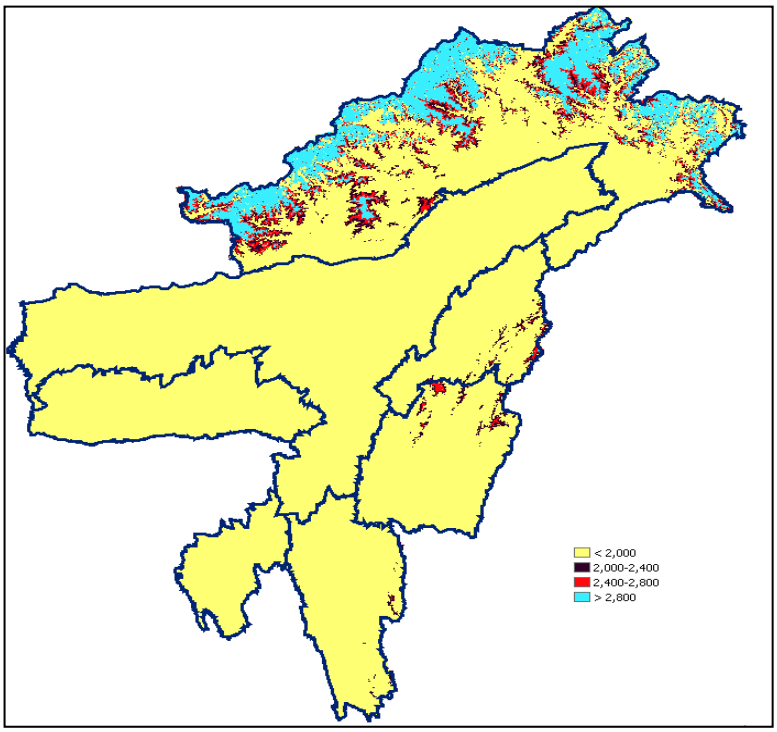


Fig. 3. Map showing areas in the high hills of the north-east (red coloured) for targeting aphid population surveys.

Identification of potential sites for deployment of varieties adapted to warm temperature

For identifying potential sites for the deployment of heat resistant varieties, a weather database developed using Marksim weather generator was screened according to three maximum temperature and minimum temperature combinations *viz*. <35˚; <18˚& >2˚; <35˚; <21˚& >2˚ and <35˚; <23˚ & >2˚, respectively. The available growing period at each of the stations according to each of the temperature scenarios were mapped in GIS and these point layers were interpolated using Kriging module. The generated surface was classified into various classes.

The growing period available under the different screening criteria in different parts of the country are presented in figures 4 a-c. The first set of conditions *i.e.* maximum temperature less than 35^0C and minimum temperature of less than 18^0C and more than 2^0C represents almost ideal conditions for high yield. The figure (4a) shows that a long duration season of more than 120 days is available in the northern Indo-Gangetic plains *i.e.* parts of Punjab, Uttar Pradesh, Bihar, parts of Jharkhand, Madhya Pradesh and Rajasthan as well as most places in the north east. Another inference that can be drawn from the figure is that about 90 to 120 days period is available in most parts of north India. This map corroborates with the present distribution of potato cultivation in India.

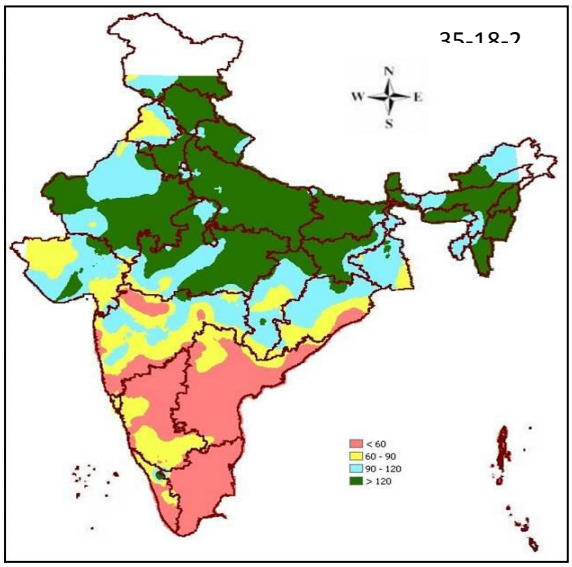


Fig. 4a. Map showing the growing period available under <35˚; <18˚& >2˚ maximum, and minimum temperature scenario, respectively

As per the second scenario *i.e.* maximum temperature less than 35^0C and minimum temperature of less than 21^0C and more than 2^0C, growing period sufficient for two crops

comprising two medium duration varieties or one medium and another short duration crop is available in the northern Indo-Gangetic plains *i.e*. parts of Punjab, Uttar Pradesh, Bihar, parts of Jharkhand, Madhya Pradesh and Rajasthan as well as most places in the north east. Sufficient growing period for raising a medium duration crop also becomes available even in South India (Fig. 4b).

Fig. 4b. Map showing the growing period available under <35˚; <21& >2˚ maximum, and minimum temperature scenario, respectively

In the case of the third scenario *i.e.* maximum temperature less than 35^0C and minimum temperature of less than 23^0C and more than 2^0C, sufficient growing period for raising a long duration crop of 120 to 150 days or for two crops comprising two medium duration varieties or one medium and another short duration crops (150-180 days) becomes available in most parts of the country. Further, barring a few places in the extreme south, growing at least a short duration crop would be feasible in most parts of the country (Fig 4c).

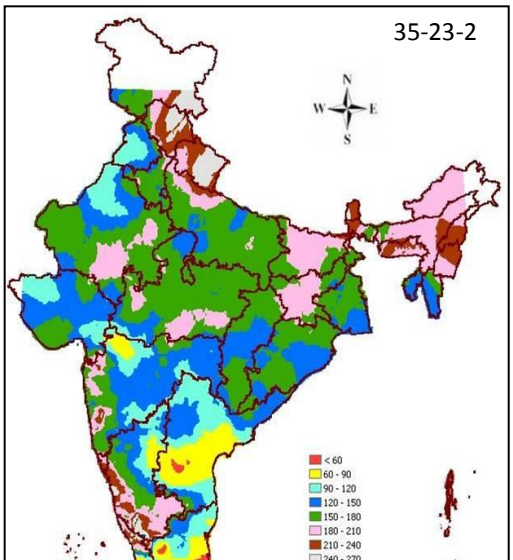


Fig. 4c. Map showing the growing period available under <35˚; <23 & >2˚ maximum and minimum temperature scenario, respectively

Mapping abiotic stress prone environments for potato in India - Soil pH.

Potato is an acid loving plant and grows well in soils with pH ranging from 5-6. However, such soils with optimum pH are not widespread but restricted to the hills. One of the soil related constraints for extending potato cultivation is the soil pH especially in the lowlands. Potato is sensitive to high pH therefore, varieties are being developed with tolerance to high pH. Mapping the soil characteristics on the basis of soil pH would enable proper deployment of such varieties. Hence, a study was conducted to develop thematic maps on the basis of soil pH. The agro-ecological zone map developed by NBSS&LUP, Nagpur was digitized and the pH of the benchmark soil of each zone was taken as the attribute for developing thematic map. The results showed that 14 zones *viz* 1.1A13Eh1, 1.2A13Et2, 2.1M9Eh1, 2.2L12Eh1, 2.3M9Et2, 2.4L12Et2, 4.1N8Dd3, 4.2P14Dd3, 5.1L4Dd3, 6.4K4Cd5, 8.1H6Dd3, 9.1N8Dm_Cd4, 10.2K4Cd5 and 10.3I6Cd5 had pH between 8-9 while three zones *viz* 5.3L7Dm4, 13.1O8Cd_Cm6 and 18.2S7Dm4 had pH more than 9 indicating that high pH tolerant varieties have potential for deployment in the districts falling under these agro-ecological zones.

Develop a decision support tool for fertilizer recommendations

Studies to develop a structure of the decision support tool for giving advice on NPK fertilizers to be applied based on the yield target, the soil test value and also accounting for the effect of green manure/FYM were taken up. A preliminary version of the DSS for the N recommendation module has been developed and is being tested against published literature.

Estimation of production potential of potato in India

The potential productivity of potato was estimated by running the Infocrop Potato model for potential situations for the longest growing season at more than 800 stations in the country

using weather data generated through MARKSIM weather generator. A database of potential productivity of each of the ten potato varieties *viz* Kufri Ashoka, Kufri Chandramukhi, Kufri Pukhraj, Kufri Jawahar, Kufri Jyoti, Kufri Bahar, Kufri Lalima, Kufri Badshah, Kufri Sindhuri and Kufri Sutlej linked with spatial attributes was created. Thematic mapping of these yield data is under progress.

Assessing prospects of potato using remote sensing, GIS and crop modeling

Advance assessment of potato crop acreage and production is essential for gearing up the procurement machinery, taking long-term export and import decisions and effective post-harvest management of the potato crop since it is a semi perishable crop and the volume of produce is very large. The cultivation of potato in large contiguous plots over large parts of Indo-Gangetic plains makes use of remote sensing a practical proposition for acreage estimation of this crop.

Work on acreage and production forecast of potato through remote sensing and GIS is in progress in collaboration with Space Applications Centre (ISRO), Ahmedabad. For further refinement of potato acreage estimation methodology using remote sensing and GIS, entire Uttar Pradesh and Bihar states were classified for potato classes using October 08 to January 09 satellite AWiFS data from IRS-P6 satellite. An unsupervised classifier was used using NDVI and LSWI values of 3-4 dates and NIR and Red band data of peak vegetative period. The classified images thus obtained were divided in 5 x 5 km^2 grids which were further classified into different segments according to proportion of potato area in grids.

The analysis for winter potato acreage estimation was done using IRS-P6 AWiFS data. For remote sensing estimates, the IRS-P6 AWiFS data acquired during September – December 2009 were used for Punjab and western Uttar Pradesh. Image analysis was done on TM tiles of 2 X 2°. For potato crop acreage estimation, NDVI and LSWI values of all dates and values of all the four bands of peak vegetative period date were used in algorithms. The production of potato was estimated through INFOCROP-POTATO crop simulation model. During 2009-10 winter potato acreage estimated through remote sensing and GIS was 78.2, 450.6, 152.9 and 364.0 thousand hectares in the states of Punjab, Uttar Pradesh, Bihar and West Bengal. While the corresponding figures for potato production in these states was 1739.2, 11373.1, 1726.0 and 8375.6 thousand tonnes. The total acreage in these 4 states was

estimated as 1045.7 thousand hectares and total potato production as 23213.9 thousand tonnes.

Models for pre harvest tuber yield forecasting using INFOCROP-POTATO model were further improved for the states of Uttar Pradesh, West Bengal, Bihar, Punjab, Haryana, Madhaya Pradesh and Gujarat. Representative sites of 33 potato growing clusters in various states were identified based on relative contribution to total acreage in different states. The Acreage rather than production in districts with concentrated clusters of potato cultivation provided a better estimate for extrapolating weighted mean productivity in a state. There was close agreement between observed and predicted tuber yield.

Potato+ peas intercropping

Increasing input cost and serious environmental concerns have made it essential to manage efficiently two key inputs *viz.* nutrients and water. Both these resources are scarce in nature and their judicious use is mandatory to mitigate the declining factor productivity besides maintaining the land and environmental quality. Utilization of varietal and genetic variability with respect to their efficiency to nutrients and water use along with development of strong management strategies are the aims of this programme.

Nutrient efficiency of different potato cultivars

Potato is highly input efficient and responsive crop. Field studies have clearly shown wide variation of response and efficiency of nutrients and water by different potato cultivars. In light of this it is important to harvest varying potential of these cultivars to improve efficiency of land, water and nutrients. This will ensure minimum damage to the environment as well as reduce the cost of inputs for resource poor potato growers. Under this project experiments at Jalandhar, Patna and Ooty were conducted with recent varieties and hybrids to evaluate them for their efficiency to applied and soil available nutrients. Besides large number of recently developed hybrids were tested at Jalandhar under nutrient stress and sufficiency situation for their efficiency.

Efficiency of hybrids in Indo-Gangatic plains: The hybrid JX 576 produced significantly higher tuber yield than other five cultivars tested at Jalandhar particularly under nutrients stress *i.e.* at lower doses of nitrogen, phosphorus and potassium (Figs. 5, 6, & 7). It gave 12 to 79 q/ha higher tuber yield under nitrogen stress (No nitrogen applied), 11 to 159 q/ha higher yield under phosphorus stress and 49 to 193 q/ha higher tuber yield under potassium stress than other five cultivars tested. The hybrid JX 576 required lower doses of nitrogen, phosphorus and potassium than other cultivars to produce particular fixed tuber yield in the same field (Table 3). For example, the cultivars Kufri Badshah, Kufri Jyoti, Kufri Pukhraj, Kufri Pushkar, Hybrid JX 576 and Kufri Chipsona-1 needed 95, 191, 56, 42, 28 and 150 kg N/ha to produce tuber yield of 200 q/ha, respectively. The varieties Kufri Pukhraj and Kufri Pushkar required 39 and 21 kg P_2O_5/ha to produce tuber yield of 350 q/ha, respectively whereas the hybrid JX 576 achieved yield of 350 q/ha with 7 kg P_2O_5/ha in the same field. Similarly, hybrid JX 576 produced tuber yield of 404 q/ha without any potassium application, whereas, cultivars Kufri Pukhraj and Kufri Pushkar needed 94 and 33 kg K_2O/ha to produce a tuber yield of 375 q/ha.

Table 3. Rates of N, P_2O_5 and K_2O required by different genotypes to obtain fixed yields

Cultivar	**N rates (kg/ha) for fixed yields of**				
	200 q/ha	**250 q/ha**	**300 q/ha**	**350 q/ha**	**425 q/ha**
Kufri Badshah	95	163	282	np	np
Kufri Jyoti	191	272	Np	np	np
Kufri Pukhraj	56	102	166	np	np
Kufri Pushkar	42	75	112	156	247
JX 576	28	55	85	121	206
Kufri Chipsona-1	150	np	np	np	np
	P_2O_5 rates (kg/ha) for fixed yields of				
	225 q/ha	**290 q/ha**	**350 q/ha**	**400 q/ha**	**450 q/ha**
Kufri Badshah	-ve	58	np	np	np
Kufri Jyoti	-ve	np	np	np	np
Kufri Pukhraj	-ve	3	39	np	np
Kufri Pushkar	-ve	-ve	21	65	np
JX 576	-ve	-ve	7	25	49
Kufri Chipsona-1	12	82	np	np	np
	K_2O rates (kg/ha) for fixed yields of				
	250 q/ha	**270 q/ha**	**300 q/ha**	**375 q/ha**	**425 q/ha**
Kufri Badshah	27	46	92	np	np
Kufri Jyoti	99	171	np	np	np
Kufri Pukhraj	-ve	-ve	1	94	np
Kufri Pushkar	-ve	-ve	-ve	33	np
JX 576	-ve	-ve	-ve	-ve	37
Kufri Chipsona-1	82	np	np	np	np

-ve = means higher than fixed yield was achieved in the absence of N, P or K
np = not possible because maximum achievable yield under the given conditions was less than fixed yield

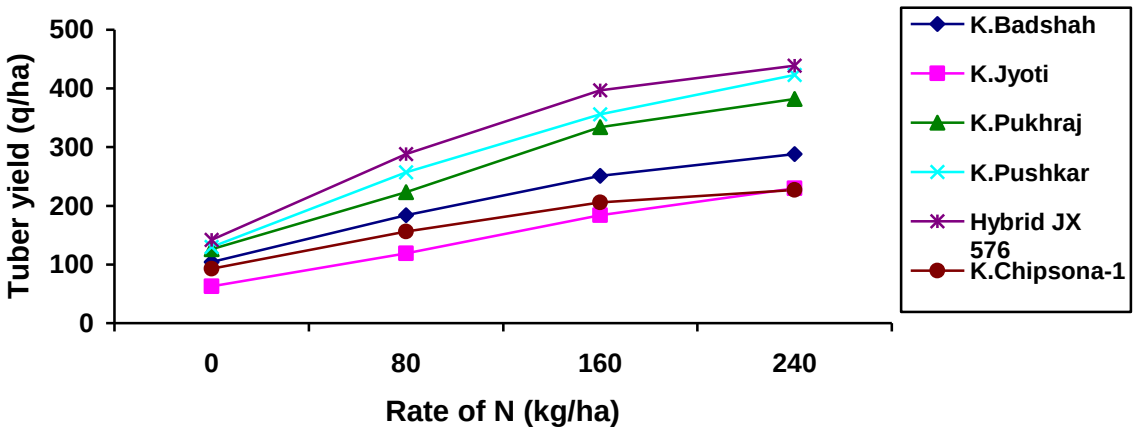


Fig. 5. Tuber yield of six potato cultivars/hybrid as affected by nitrogen application

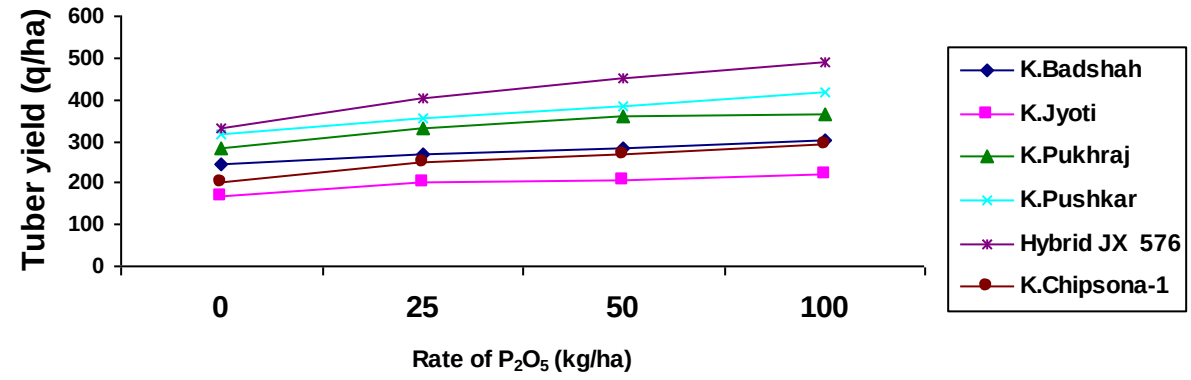


Fig. 6. Tuber yield of six potato cultivars/hybrid as affected by phosphorus application

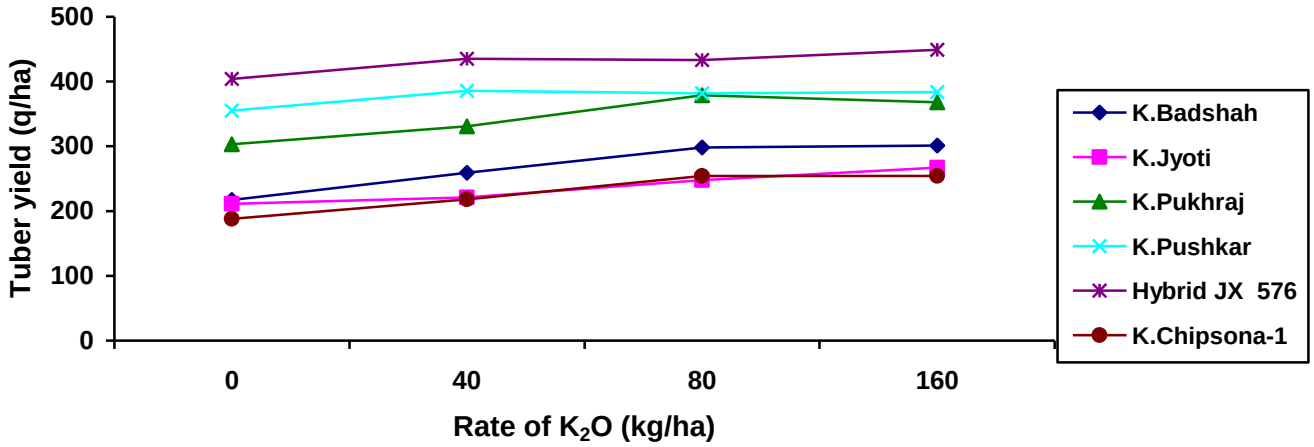


Fig. 7. Tuber yield of six potato cultivars/hybrid as affected by potassium application

At Patna, the hybrid JX 576 produced significantly higher mean tuber yield than all other cultivars tested (Table 4). The hybrid produced 30 to 77 q/ha higher tuber yield under nitrogen stress (No nitrogen applied) than other three cultivars tested. The hybrid JX 576 required lower doses of nitrogen than other cultivars to produce particular fixed tuber yield in the same field (Table 5). For example, the cultivars Kufri Jyoti, Kufri Pukhraj, Kufri Pushkar and Hybrid JX 576 needed 211, 94, 93 and 66 kg N/ha to produce tuber yield of 350 q/ha, respectively.

Table 4. Yield of potato cultivars/hybrid as affected by nitrogen application at Patna (2009-10)

Cultivar	Total tuber yield (q/ha)				
	Rate of N (kg/ha)				
	0	80	160	240	Mean

Kufri Jyoti	191	243	334	360	282
Kufri Pukhraj	238	341	387	400	342
Kufri Pushkar	231	342	414	492	370
JX 576	268	382	407	465	381
Mean	232	327	385	430	
CD (0.05) Cultivar mean= 34.2, Rate mean=34.2 Cultivar x rate=68.4 (NS)					

Table 5. Rates of N required by different genotypes to obtain fixed yields

Cultivar	**N rates (kg/ha) for fixed yields of**			
	250 q/ha	**300 q/ha**	**350 q/ha**	**400 q/ha**
Kufri Jyoti	70	133	211	np
Kufri Pukhraj	8	45	94	196
Kufri Pushkar	13	51	93	139
JX 576	-ve	21	66	123

-ve = means higher than fixed yield was achieved in the absence of N
np = not possible because maximum achievable yield under the given conditions was less than fixed yield

Development of varieties for water and nutrient use efficiency

At Modipuram, hundred hybrids including some released varieties were evaluated. Advanced numbers *viz.* J.93-58, JF-4841, JP-132, JX-214, E-4486, J.93-4, JX-118, J.92-148, JEB/A-53, MS/82-717, JN-2207, MS/78-62, 83-P-142, SLB/K-23, JX-123, JD/A.3-4, JX-1, MS/84-864, JX-24, E-4451, JTH/C-107, JAL/A-83, J.92-164 and J.92-159 produced maximum yield as compared to other hybrids/advanced numbers tried under sub optimal conditions (four irrigations). The productivity of these advanced cultures (>37.5 t/ha) was at par with potato yields obtained under sub-optimal and optimal conditions (5&7 irrigations, respectively). The variety Phulwa White produced most number of tubers followed by Lal Multi I, Gulabia, Kufri Red and DRR (Red) as compared to others.

Phosphorus efficiency of hybrids in Nilgiri hills: The hybrid OS/93-D-204 produced higher tuber yield than other five cultivars tested particularly under P stress *i.e.* in the absence of P application (Table 6). It gave 10 to 75 q/ha higher tuber yield under P stress (No P applied) than other five cultivars tested. The hybrid OS/93-D-204 and cultivar Kufri Himalani required lower doses of phosphorus than other cultivars to produce particular fixed tuber yield in the same field (Table 7). For example, the hybrid OS/93-D-204 and cvs., Kufri Himalani, Kufri Girdhari, Kufri Giriraj and Kufri Jyoti needed 18, 17, 31, 102 and 116 kg

P_2O_5/ha to produce tuber yield of 150 q/ha, respectively. Results showed that based on the control yield (No P applied) and dose of P required to produce fixed tuber yield in the same field, the hybrid OS/93-D-204 was most P efficient followed by cvs., Kufri Himalani, Kufri Girdhari, Kufri Giriraj and Kufri Jyoti.

Table 6. Tuber yield of potato cultivars/hybrid as affected by Phosphorus at Ooty (2009)

Cultivar	**Total tuber yield (q/ha)**						
	Rate of P_2O_5 (kg/ha)						
	0	**45**	**90**	**135**	**180**	**225**	**Mean**
Kufri Himalani	92	240	262	265	257	242	226
Kufri Girdhari	105	195	202	208	234	305	208
OS/93-D-204	115	201	235	245	270	239	218
Kufri Jyoti	65	69	147	154	180	139	126
Kufri Swarna	85	101	109	116	157	161	122
Kufri Giriraj	40	103	110	163	200	104	120
Mean	84	152	178	192	217	198	
CD (0 .05)	**Cultivar mean 60**		**Rate mean 60**		**Cultivar x rate 150**		

Table 7. Rates of P_2O_5 required by different genotypes to obtain fixed yields at Ooty

Cultivar*	**P_2O_5 rates (kg/ha) for fixed yields of**			
	120 q/ha	**150 q/ha**	**200 q/ha**	**250 q/ha**
Kufri Himalani	3	17	43	80
Kufri Girdhari	-ve	31	99	170
OS/93-D-204	-ve	18	54	112
Kufri Jyoti	67	116	np	np
Kufri Giriraj	63	102	np	np

*Quadratic equation was not best fit for data of cv. Kufri Swarna
-ve = means higher than fixed yield was achieved in the absence of P
np = not possible because maximum achievable yield under the given conditions was less than fixed yield

Screening of hybrids for N efficiency: One hundred hybrids were tested under nitrogen deficient and sufficient conditions at Jalandhar. The tuber yields of different hybrids varied between 78 and 398 q/ha under N stress (No nitrogen) with a mean of 193 q/ha whereas tuber yields varied between 143 and 595 q/ha under sufficient nitrogen (240 kg N/ha) with a mean of 331 q/ha. The 46 hybrids having yield more than 193 q/ha (mean yield of all hybrids) under no N application were selected for further testing during next year.

Root Studies

Varying response and efficiency of potato cultivars warrant further investigation of the causes behind these phenomena. Roots parameters are supposed to be one of the most important factor influencing nutrients and water uptake under stress and under sufficiency. Experiments at Shimla, and Jalandhar with most popular cultivars and recent hybrids were aimed to quantify root parameters which might be influencing nutrient uptake from soil and applied source affecting the efficiency of cultivars.

At Shimla field experiment were conducted at Lower Lab during summer (April planting) and during autumn (September planting) and simultaneously sand culture studies were also under taken. During summer season varieties suitable for hill region cultivation like Kufri Jyoti, Kufri Giridhari, Kufri Himsona, Kufri Himalini, Kufri Sailja and Kufri Kanchan were studied besides other promising varieties like Kufri Pukhraj, Kufri Sutlej, Kufri Badshah and Kufri Chipsona-1. During autumn season varieties suitable for plains like Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chandramukhi, Kufri Jyoti, Kufri Pukhraj, Kufri Sutlej and Kufri Surya were included in the study.

During summer crop Kufri Himsona showed higher values for per plant root volume and weight as compared to other hill cultivars followed by Kufri Girdhari and Kufri Kanchan. Whereas these values for Kufri Sailja and Kufri Himalini were lower than those for Kufri Jyoti. Similar trend was observed for root: shoot ratio among hill cultivars. Among other cultivars of plains Kufri Pukhraj and Kufri Sutlej showed higher values for root weight, root volume and root:shoot ratio as compared to Kufri Jyoti and other cutivars. During autumn planting high yielding varieties like Kufri Pukhraj, Kufri Sutlej, Kufri Badshah and Kufri

Chipsona-1 showed higher values for root attributes as compared to Kufri Jyoti and other varieties in the field and as well as in sand culture. At 35 days after planting root fresh weight was highest for Kufri Chipsona-1 followed by Kufri Pukhraj, Kufri Badshah, Kufri Surya and Kufri Sutlej. In root dry weight Kufri Bahar, Kufri Pukhraj and Kufri Chipsona-1 were leading cultivars. In sand culture Kufri Sutlej and Kufri Pukhraj were leading cultivars with respect to these root parameters.

Root parameters as related to N efficiency of potato cultivars: At Jalandhar eight varieties important for the region were grown at varying N level to see the effect of N on different root attributes of these varieties. At 28 days after planting, the most N efficient hybrid JX 576 had significantly higher mean shoot dry weight per plant (3.12 g/plant) than all other cultivars/hybrid except cv. Kufri Pukhraj (2.75 g/plant) which also had mean shoot dry weight per plant statistically similar to it (Table 8). The cv. Kufri Sutlej had significantly higher mean root length per plant (2300 cm/plant) than all other cultivars/hybrid except hybrid JX 576 (1961 cm/plant) which also had mean root length per plant statistically similar to it (Table 9). The cv. Kufri Sutlej had significantly higher mean root surface area per plant (423 cm^2/plant) than all other cultivars/hybrid except hybrid JX 576 (390 cm^2/plant), Kufri Pukhraj (385 cm^2/plant) and Kufri Surya (368 cm^2/plant) which also had mean root surface area per plant statistically similar to it (Table 10). The cv. Kufri Pukhraj had significantly higher mean root volume per plant (6.76 cm^3/plant) than all other cultivars/hybrid except hybrid JX 576 (6.27 cm^3/plant) and Kufri Sutlej (6.53 cm^3/plant) which also had mean root volume per plant statistically similar to it (Table 11).

Results showed that mean shoot dry weight, mean root length, mean root surface area, and mean root volume per plant of most N efficient hybrid JX 576 at 28 days after planting were statistically at par with the highest obtained in any cultivars/hybrid tested. For example cv. Kufri Sutlej had the highest mean root length and mean root surface area per plant at 28 days after planting among all the cultivars/hybrid tested but mean root length and mean root surface area per plant of hybrid JX 576 were not statistically less than those of cv. Kufri Sutlej. Further cv. Kufri Pukhraj had the highest root volume per plant among all the cultivars/hybrid tested but root volume per plant of hybrid JX 576 was statistically at par with that of cv. Kufri Pukhraj. Most nitrogen efficient hybrid JX 576 had significantly higher mean root length (1961 cm/plant), mean root surface area (390 cm^2/plant), and mean root

volume (6.27 cm^3/plant) than least N efficient cultivar Kufri Jyoti which had mean root length of 1356 cm/plant, mean root surface area of 273 cm^2/plant and mean root volume of 4.41 cm^3/plant.

At harvest also Hybrid JX 576 was the highest yielder followed by Kufri Pushkar and Kufri Pukhraj at all levels of N. Correlation among N levels, tuber yield, shoot dry weight, root length, root volume and root surface area per plant showed highly significant values (Table 12). N levels increased the root parameter and subsequently the yield. Thus increase in root attributes like root length, root volume and root surface area per plant played important role in increasing tuber yield.

Table 8. Shoot dry weight (g/plant) of different potato cultivars/hybrid as influenced by N application at 28 days after planting

Cultivar	Rate of N (kg/ha)				
	0	80	160	240	Mean
Kufri Jyoti	1.29	1.19	2.19	1.36	1.51
Kufri Jawahar	0.65	1.35	1.71	1.62	1.33
Kufri Bahar	0.67	1.50	2.20	1.98	1.59
Kufri Sutlej	1.20	2.16	3.07	3.17	2.40
Kufri Pukhraj	1.76	2.70	3.03	3.53	2.75
Kufri Pushkar	1.42	1.70	2.22	2.92	2.07
JX 576	1.95	2.60	3.41	4.50	3.12
Kufri Surya	0.74	1.80	2.74	2.29	1.89
Mean	1.37	1.90	2.48	2.58	
CD (0.05) Cultivar mean = 0.53		Rate mean= 0.36		Cultivar X Rate = 1.06	

Table 9. Root length (cm/plant) of different potato cultivars/hybrid as influenced by N application at 28 days after planting

Cultivar	Rate of N (kg/ha)				
	0	80	160	240	Mean
Kufri Jyoti	1467	1158	1488	1312	1356
Kufri Jawahar	857	1556	1529	1495	1360
Kufri Bahar	1399	1661	1777	1731	1642

Kufri Sutlej	1902	1869	2852	2577	2300
Kufri Pukhraj	1394	1653	2451	1562	1765
Kufri Pushkar	1069	1915	1675	2162	1705
JX 576	1742	1875	2306	1920	1961
Kufri Surya	1469	1888	2211	1791	1840
Mean	1451	1694	1980	1825	
CD (0.05) Cultivar mean= 428.2 Rate mean = 285.5 Cultivar X Rate = 856.4 (NS)					

Table 10. Root surface area (cm^2/plant) of different potato cultivars/hybrid as influenced by N application at 28 days after planting

Cultivar	Rate of N (kg/ha)				
	0	**80**	**160**	**240**	**Mean**
Kufri Jyoti	302	231	301	256	273
Kufri Jawahar	208	295	298	284	271
Kufri Bahar	245	309	317	331	301
Kufri Sutlej	301	369	540	482	423
Kufri Pukhraj	295	360	498	386	385
Kufri Pushkar	226	346	328	395	324
JX 576	343	380	429	406	390
Kufri Surya	296	380	427	371	368
Mean	302	231	301	256	273
CD (0.05) Cultivar mean = 59.0 Rate mean = 39.4 Cultivar X Rate= 118.0 (NS)					

*Root surface area = 22/7 x mean root diameter x root length and Mean Root radius = (7/22 x Root volume/ root length)$^{1/2}$

Table 11. Root volume (cm^3/plant) of different potato cultivars/hybrid as influenced by N application at 28 days after planting

Cultivar	Rate of N (kg/ha)				
	0	**80**	**160**	**240**	**Mean**
Kufri Jyoti	5.06	3.69	4.88	4.00	4.41
Kufri Jawahar	4.06	4.50	4.80	4.31	4.42

Kufri Bahar	3.44	4.75	4.56	5.06	4.45
Kufri Sutlej	3.88	6.19	8.50	7.56	6.53
Kufri Pukhraj	4.97	6.25	8.13	7.69	6.76
Kufri Pushkar	3.91	5.13	5.22	5.97	5.05
JX 576	5.44	6.25	6.44	6.97	6.27
Kufri Surya	4.95	6.13	6.63	6.19	5.92
Mean	4.69	5.34	6.11	5.95	
CD (0.05) Cultivar mean=0.78 Rate mean=0.53 Cultivar X Rate =1.56					

Table 12. Correlation among N levels, yield, shoot dry weight, root length and root surface area per plant.

Parameters	N level	Yield	Shoot dry weight	Root length	Root surface area
Shoot dry weight	0.968	0.980	1.000	-	-
Root length	0.812	0.862	0.933	1.000	-
Root surface area	0.859	0.900	0.960	0.996	1.000
Root volume	0.908	0.938	0.985	0.981	0.994

Integrated nutrient management in potato in north western plains

A field experiment was conducted at Modipuram with two potato cultivars Kufri Surya and Kufri Chipsona-3and five fertility treatments. NPK (100%) through inorganic fertilizers gave significantly higher yield of Kufri Surya and Kufri Chipsona-3 (28.0 and 34.8 t/ha, respectively),which was at par with potato yield of 75% NPK through inorganic fertilizers + 25% N through FYM. The yield of potatoes was significantly less with 100% NPK applied through FYM. Similar trend was also observed in case of large and medium grade tuber yields and numbers.

Role of bio-fertilizers in nutrient management of potato crop

In the present context of expensive chemical fertilizers and growing concern of environmental safety, the role of bio-fertilizers is regaining its importance. Deterioration of soil health due to excessive use of chemical fertilizer needs to be restored by putting more and more crop and eco-friendly microbial inoculums in soil. North-western hill soils rich in organic carbon is right place to evaluate the potential of these hetrotrophic microbes. Experiments at CPRI and at farmers fields in Shimla were conducted to evaluate the potential of Azotobacter and phosphate

solublizers in supplementing the chemical fertilizers to meet the exhaustive demand of potato crop.

Combined application of *Azotobacter* and phosphate solubulising bacteria (PSB): Field experiment was conducted at Shimla to evaluate role of bio-fertilizer (*Azotobacter* +PSB) on NPK economy in potato cv. Kufri Jyoti. Combined application of 75% NP and 100% K along with tuber inoculation with biofertilizer proved to be more effective in terms of growth attributes and total tuber yield (Table 13). The significant effect of NPK along with tuber inoculation with biofertilizer was also observed on uptake of N, P and K by tubers.

Table 13. Effect of NPK and bio-fertilizers on yield (q/ha) and uptake (kg/ha)

Treatments	Yield	N uptake	P uptake	K uptake
Control+K Full	112.3	29.1	8.0	31.5
PSB+K Full	166.7	48.0	12.5	45.1
Azotobacter+K Full	157.3	46.0	11.6	47.9
PSB+ Azotobacter+K	179.5	48.8	15.0	53.2
100% NPK+K Full	223.7	53.9	16.0	61.0
75% NP+PSB+Azoto+K Full	216.0	63.1	16.7	65.0
75% N+ Azoto+ PK	184.8	46.4	13.5	52.2
75% P+ PSB+NK Full	191.7	53.3	15.6	58.0
50%+ NPK +PSB+Azoto+FYM	207.9	56.1	17.4	66.6
50%+ NP +PSB+Azoto+K Full	185.7	50.2	15.6	58.8
CD at 5%	20.1	3.6	1.2	5.7

Azotobacter and N economy: Field experiment was conducted at Shimla to evaluate the effect of *Azotobacter* on N economy in potato cv. Kufri Jyoti. Ten treatments involving combination of N *viz*., control, 30, 60, 90 and 120 kg N/ha with and without *Azotobacter* were replicated three times using RBD design. Plant emergence counted at 40 days after planting showed no significant effect on plant emergence with application of nitrogen and *Azotobacter*. Growth attributes of plants like plant height, number of shoots/plant and number of leaves/plant increased with increasing levels of nitrogen application alone or along with *Azotobacter*. Application of *Azotobacter* alone and in combination with fertilizer significantly increased tuber yields over control. Combined application of nitrogen @ 90 kg/ha along with tuber inoculation with *Azotobacter* proved to be more effective in terms of total tuber yield.

On farm response studies of phosphorus solubilzing bacteria: Field trials were conducted on farmer's field at Kufri during 2009 to investigate the potato response to phosphorus solubilzing bacteria with different doses of phosphorus application.. Yield attributes of potato increased with increasing doses of P fertilizer and phosphorus solubilzer bacteria and maximum yield attributes were obtained with application of 100 kg P_2O_5/ha along with phosphorus solubilzing bacteria applied through seed inoculation which was at par with 75 kg P_2O_5/ha+phosphorus solubilzing bacteria or 100 kg P_2O_5/ha through fertilizer. Phosphorus solubilzing bacteria alone or in combination with application of different doses of P significantly enhanced dry matter content of tubers. Highest increase was obtained with 75 kg P_2O_5/ha + phosphorus solubilzing bacteria, which was at par with 100 kg P_2O_5/ha + phosphorus solubilzing bacteria and 100 kg P_2O_5/ha. Maximum tuber numbers were observed with 75 kg P_2O_5/ha and phosphorus solubilzing bacteria followed by 100 kg P_2O_5/ha the recommended dose of P and 100 kg P_2O_5/ha + phosphorus solubilzing bacteria treatment. Application of 100 kg P_2O_5/ha along with seed inoculation with phosphorus solubilzing bacteria gave highest tuber yield which was at par with 75 kg P_2O_5/ha + phosphorus solubilzing bacteria and 100 kg P_2O_5/ha application.

Spatial variability mapping of available nutrients in potato growing pockets

Resource intensive potato crop requires high doses of fertilizers which have resulted into serious imbalances of nutrients in soils of potato growing pockets resulting into poor response to applied nutrients and environmental pollution. Since potato growing pockets can be well demarcated, the spatial variability of available nutrient in these pockets will facilitate the rate of nutrient application matching with soil nutrient status which in turn increase productivity and profitability apart from checking nutrient imbalance and environmental pollution.

Available nutrient status in potato growing pocket of Jalandhar district of Punjab

The representative soil samples from 0 to 15 cm depth were collected during October 2009 at every one kilometer distance using GPS. Additional samples were collected if required to account for more variability, depending upon visual observations.

Most of the soils were normal in reaction, with pH varying from 6.14 to 8.74. Organic C content of the soils ranged from 0.10 to 0.51% with a mean value of 0.29%, indicating that these soils were low in organic C. Available P content in the surface soil varied from 57.61 to 315.90 kg P/ha with a mean value 190.90 kg P/ha. On the basis of the critical limit fixed for potato in these soils, all soil samples of this district were found to be high in available P. Thus these soils need not require regular application of P to get optimum yield of potato. Available K content ranged from 76.16 to 507.36 kg K/ha, with a mean value 167.27 kg K/ha. Percent soil samples falling under different categories with respect to measured available nutrients at Jalandhar potato growing area is given (Table 14).

Table 14. Percent soil samples falling under different categories with respect to available nutrients of potato growing pockets of Jalandhar district

Categories	Organic C	P	K
Low	96.9	-	34.9
Medium	3.10	-	39.6
High	-	100	4.65

Water Management

Water is becoming most scarce natural resource with the changing climate and erratic weather behavior accentuating the vulnerability of high water requirement crop like potato. Efficiency of all other resources including land and nutrient is highly dependent on sound water management strategy. Besides developing sound irrigation management strategy it is also important to utilize the genetic variability of potato cultivars to increase efficacy of this increasingly scarce water resources.

Effect of water stress on tuber yield of different potato cultivars/hybrid: In an experiment at Jalandhar irrigation at 20 mm cumulative pan evaporation (CPE) produced significantly higher potato tuber yields of all the cultivars/hybrid than irrigation at 30 mm CPE (Table 15). Mean reduction in yield was about 8% from 446 to 409 q/ha. The hybrid JX 576 showed significantly higher water use efficiency than all other cultivars tested. Mean

water use efficiency of hybrid JX 576 was 164 kg tubers/mm water in comparison to 139, 123 and 104 kg tubers/mm water of cvs. Kufri Pukhraj, Kufri Badshah and Kufri Jyoti, respectively.

Table 15. Tuber yield and water use efficiency of different cultivars/hybrid as influenced by different irrigation levels at Jalandhar (2009-10)

Cultivar	Yield (q/ha)				Water use efficiency (kg/mm)			
	Irrigation at CPE* of			Mean	Irrigation at CPE* of			
	20 mm	25 mm	30 mm		20 mm	25 mm	30 mm	Mean
Kufri Badshah	413	399	381	398	110	122	138	123
Kufri Jyoti	354	341	311	335	94	105	113	104
Kufri Pukhraj	468	448	430	448	125	137	156	139
JX 576	548	525	514	529	146	161	186	164
Mean	446	428	409		119	131	148	
CD. (0.05)	Variety =17.1 Irrigation=14.3 Variety x Irrigation= 31.4				Variety =5.3 Irrigation=4.4 Variety x Irrigation= 9.6			

* Cumulative pan evaporation

Phasic water need of the potato: In a field trial at Shimla irrigation water was applied at two soil moisture regimes at 75% available soil moisture (asm) and 50% asm at different growth phases i.e. stolen formation, tuber initiation and tuber formation phase of potato which coincide with drought period in Shimla hills. Optimum irrigation (irrigations with 200 mm water) during stolonization and tuber initiation and tuber formation stage at 75% asm regime gave maximum potato yield (250 q/ha) followed by imposition of mild water stress (50% asm) at stolonization stage and no water stress thereafter with 150 mm of irrigation (240 q/ha) potato yield, though these treatments were not significant among each other, indicating that the potato crop can tolerate mild water stress at stolonization stage thereby resulting into 25% saving in irrigation water. However, continuous water stress or withholding irrigation at stolonization or tuber initiation and tuber formation stage adversely affects potato yield. The lowest crop yield 135 q/ha was observed under rainfed conditions indicating the need for applying irrigations in potato crop in the north western hills.

Computing phasic water need of potato under conventional and modern irrigation methods.

Productivity and quality of potato depend upon the proper balance between soil air and soil moisture in plant's root zone which can be achieved by the sound water management practices.

Therefore, a field experiment was conducted at Modipuram to compute phasic water need of four potato cultivars (Kufri Bahar, Kufri Pukhraj, Kufri Sutlej and Kufri Anand) under drip, sprinkler and furrow methods of irrigation. The irrigations applied at 150% cumulative pan evaporation (CPE) level gave significantly higher yield of potato under drip as well as sprinkler irrigated crop which was at par with that obtained when irrigations applied at 125% CPE under drip irrigation (Fig. 8). In case of furrow irrigation, the yield of potato was significantly higher when irrigations were applied at 20 mm CPE as compared to 25 and 30 mm CPE. Potato cultivar Kufri Pukhraj produced significantly higher yields and tuber numbers followed by Kufri Anand in comparison to other varieties tried under modern irrigation methods.

Optimizing irrigation water and nitrogen needs of potato.

An experiment was conducted at Modipuram with two potato cvs. Kufri Pukhraj and Kufri Anand, ten treatments of nitrogen doses and application schedules and two irrigation levels (under optimal and sub-optimal conditions). Irrigations applied at 20 mm CPE produced significantly higher yield of both varieties Kufri Pukhraj and Kufri Anand (39.3 and 38.6 t/ha, respectively) as compared to irrigations given at critical stages of crop *i.e.* per-emergence, stolen formation, tuber initiation, early tuber enlargement and late tuber enlargement stage. Similar trend was also noticed in case of tuber numbers. Application of 180 kg N/ha produced higher yield of both the varieties in comparison to other N levels which was at par with that of 150 kg N/ha. The split application of N (1/3 as basal at planting + 1/3 at earthing-up + 1/3 at 15 days after earthing-up) produced higher yield of potatoes in comparison to two and four splits with all N levels. The yield of both cultivars at 180 kg N/ha with two splits was at par with 150 kg N/ha applied in three splits.

Effect of raised bed planting method on potato under drip fertigation.

In raised bed planting patterns under drip fertigation at Modipuram, the single drip layout fertigation system for raised bed triple row potato planting with 1,25,000 plants/ha gave significantly higher yield (41.4 t/ha) along with 50% water saving as compared to furrow irrigation which produced 31.8 t/ha. This was followed by the treatment with 100% NPK fertigation for double row planting along with single drip placed at 90 cm spacing with

1,11,111 plants/ha and double row planting with single drip lateral placed at 120 cm spacing for same plant population.

Effect of bed planting patterns on potato production under sprinkler fertigation

At Modipuram, raised bed/triple row planting at 120 cm spacing with 1,25,000 plants/ha under sprinkler irrigation produced significantly higher yield (41.2 t/ha) along with 40% water saving as compared to traditional furrow irrigation which gave 31.8 t/ha. This treatment also produced significantly higher yields of large (>75 g) as well as medium grade (25-75 g) tubers as compared to other treatments, which may be used as seed material for planting of additional area under potato without sacrifice in yield.

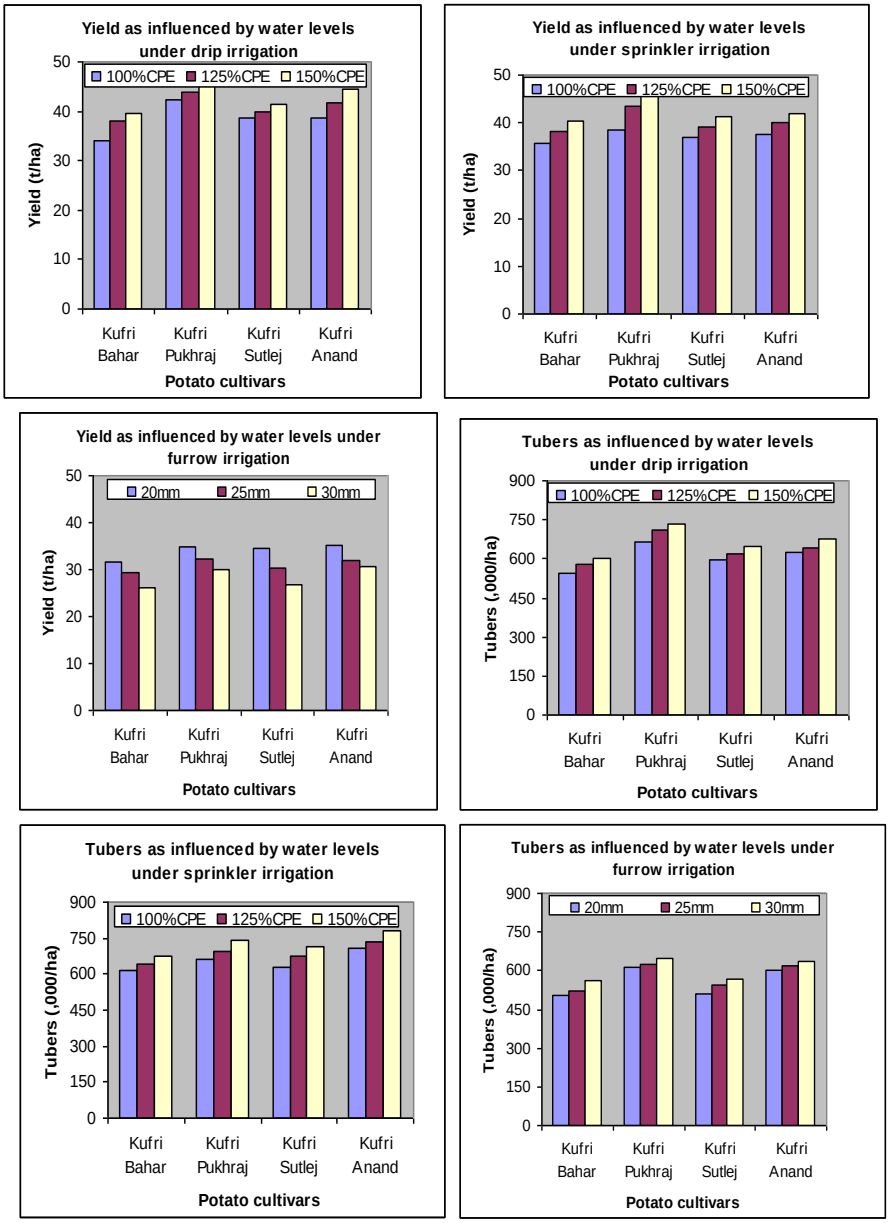


Fig.8.Yield and tuber numbers as influenced by water levels under different irrigation methods

Studies on Long Term Manurial/Fertilizer Application and Organic Farming in Potato Production

Sustainability on long term basis is important for any cropping system, which can be ensured only if the nutrients removed from soil are replaced. Declining soil fertility in many areas have resulted due to reduced availability of not only primary fertilizer nutrients, but that of secondary and micronutrients as well. Therefore, maintaining fertility of soil in environmentally friendly and economically viable manner is the main aim of long term fertility experiment. A long term manurial/fertilizer experiment to study the effect of application of organic manure, crop residue and inorganic fertilizers on sustainable crop productivity in three promising potato based crop systems is continuing since 2006-07 on the same site at Modipuram.

Long term manurial/fertilizer experiment on potato based cropping systems

Seven manurial/fertilizer treatments (Table 16) were imposed on three crop sequences *viz* C_1 potato–wheat–rice, C_2 potato–onion–maize and C_3 potato–green gram–sesamum**.** The results revealed that the yield of wheat, potato, onion and maize crops were highest, where 100% recommended NPK was applied through inorganic fertilizers (Table 16, 17 & 18). However, in case of rice, maize and sesamum, yields were at par in organic and inorganic treatments. In all the cropping systems, the tuber size and number were higher in fertilizer applied treatments. Application of secondary nutrients along with 100% NPK did not increase the productivity of any system appreciably. The system productivity was highest (76.45 t/ha) in maize-potato-onion crop sequence followed by rice-potato-wheat (54.72 t/ha). The lowest PEY (36.46 q/ha) was recorded in sesamum-potato–green gram sequence (Fig. 9).

Under organic treatments, the tuber size remained smaller compared to treatments, receiving NPK through inorganic fertilizers in all the cropping systems. The incorporation of residue of preceding crop was not found effective in enhancing the crop yields. In case of rice, wheat and maize grain/straw ratio was 0.78, 0.67 and 0.21, respectively. Among the treatments, the highest grain/straw ratio in rice (1.43), wheat (0.82) and maize (0.24) was found in absolute control, 100% organic + crop residue and 100% inorganic+crop residue, respectively. The weed population was more in organically raised crop, where herbicide application is prohibited.

Unlike previous years, the wheat crop grown organically exhibited yellowing in January, 2010, perhaps due to slow release of nitrogen under exceptionally low temperature. Later

with rise in temperature in February, the organically grown wheat crop turned green. In case of green gram, biotic loss damage to the extent of 70% was observed. Leaf area index (LAI) was higher in inorganic treatments as compared to organic treatment.

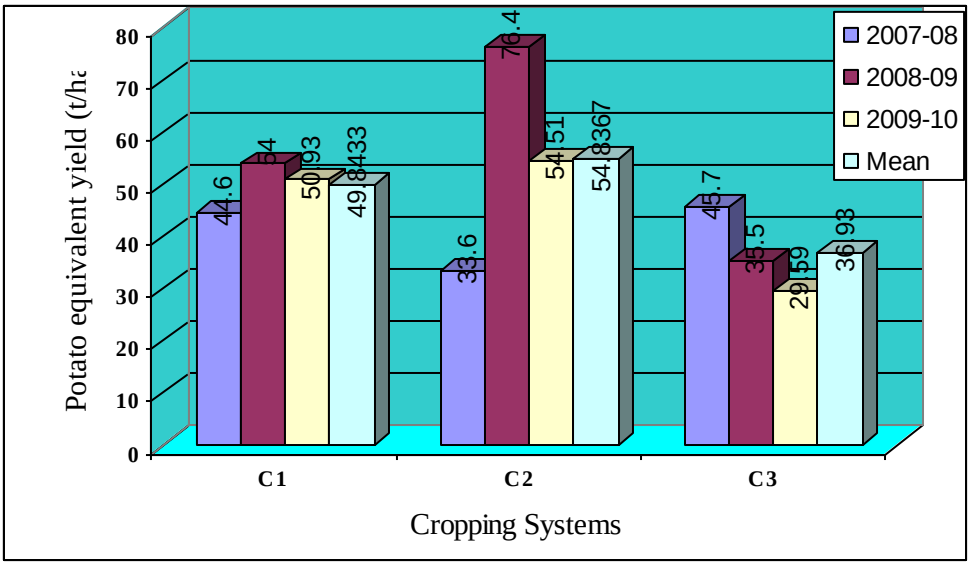


Fig. 9. System productivity in long term experiments in different years.

Table 16. Yield of rice–potato-wheat cropping system and potato equivalent yield (PEY) under different nutrients options.

S. No.	Treatment	Yield of crops (q/ha)					
		Wheat		Rice		Potato	PEY
		Grain	Straw	Grain	Straw		
1.	Absolute control	31.85	32.59	32.97	65.56	71.34	302.67
2.	100% NPK through inorganic	41.67	55.74	51.48	95.08	218.82	554.44
3.	100% NPK through organic	38.70	48.52	49.81	72.22	147.23	491.29
4.	50% inorganic + 50% organic	41.30	70.00	52.78	92.04	210.82	523.05
5.	100% inorganic + secondary nutrients	42.96	76.85	59.44	85.81	247.47	584.31
6.	100% inorganic + crop residue	46.11	75.33	56.11	89.31	245.39	623.78
7.	100% organic + crop residue	35.74	55.74	58.70	89.28	136.07	486.02
	CD ± 0.05	11.75	18.64	7.82	15.03	15.48	--

Table 17. Yield of maize–potato–onion and potato equivalent yield (PEY) under different nutrients options.

S.No.	Treatment	Yield of crops (q/ha)					
		Onion		Maize		Potato	PEY
		(q/ha)	Bulbs (lakh/ha)	Grain	Stalk		
1.	Absolute control	98.0	3.21	22.05	29.84	78.27	246.10
2.	100% NPK through inorganic	251.20	4.30	37.59	91.51	261.96	655.11
3.	100% NPK through organic	165.7	3.53	33.22	66.28	169.18	449.19
4.	50% inorganic + 50% organic	254.3	4.44	39.56	69.34	249.34	642.96
5.	100% inorganic + secondary nutrients	275.3	4.73	41.53	84.84	263.58	698.04
6.	100% inorganic + crop residue	287.2	5.03	38.25	73.34	260.76	689.32
7.	100% organic + crop residue	159.9	4.51	32.89	66.84	161.95	434.99
	CD ± 0.05	44.5	0.78	4.67	7.05	37.24	--

Table 18. Yield of green gram–sesamum–potato and potato equivalent yield (PEY) under different nutrients options.

S.No.	Treatment	Yield of Crops (q./ha)					PEY
		Green gram		Sesamum		Potato	
		Grain yield	Straw Yield	Grain Yield	Stalk Yield		
1.	Absolute control	1.86	3.36	4.03	20.18	84.41	143.97
2.	100% NPK through inorganic	2.49	4.51	6.04	26.48	283.36	358.59
3.	100% NPK through organic	1.57	2.85	5.66	27.59	179.08	243.34
4.	50% inorganic + 50% organic	2.15	3.90	5.70	26.58	233.38	302.92
5.	100% inorganic + secondary nutrients	2.10	3.81	5.71	29.81	301.52	371.43
6.	100% inorganic + crop residue	3.01	5.45	6.58	29.27	308.87	393.27
7.	100% organic + crop residue	1.27	2.29	5.60	26.85	208.90	268.31
	CD ± 0.05	1.29	2.35	1.12	5.98	36.09	--

Impact of long term use of organic and inorganic sources of nutrients on physical, chemical and biological properties of soil, pest complex and quality of produce.

The highest dry matter content was recorded in C_3 (potato–green gram–sesamum) cropping system, which was at par with other two cropping systems. Among the seven treatments, the dry matter content was highest in treatment receiving 100% organic fertilizer through vermicompost, which was at par with treatment receiving 50% organic + 50% inorganic and 100% NPK + secondary nutrients.

The soil analysis after potato harvest revealed that incorporation of crop residue as well as use of organic manure, with or without fertilizers improved the organic carbon content of soil. The tuber quality was at par in all the three cropping systems, but there was great difference in organic and inorganic treatments. Incorporation of crop residues slightly decreased the reducing and non reducing sugar contents. The grain/bulbs nitrogen content was higher in treatment receiving 100% NPK through inorganic sources. The mean nitrogen uptake by rice, wheat, maize, sesamum and green gram grains was 80.05, 48.45, 80.32, 20.87 and 20.93 kg/ha, respectively. In wheat grains, zinc and copper uptake varied from 99-271 and 2-9 g/ha, respectively. In rice the corresponding uptake was 137-190 and 10-13 g/ha, respectively. Depending on treatment, the zinc and copper uptake by potato tubers varied from 48- 146 and 3-12 g/ha, respectively.

The treatment–wise microbiological analysis of rhizosphere of all the three cropping systems, after harvest of *kharif* crops revealed that maximum population of bacteria was found when all NPK were applied through organic manure and minimum in control, where no nutrients were applied. In contrast, the maximum population of Actinomycetes was recorded, in treatment, receiving all NPK through fertilizers along with secondary nutrients. Unlike bacteria, the Actinomycetes population was minimum in organic manure treatment. In general among the three cropping systems, the bacteria and Actinomycetes population was maximum in potato–green gram–sesamum and minimum in potato–wheat –rice crop sequence, respectively. The microbiological analysis of potato rhizosphere reveled that maximum population of bacteria ($7.72 \text{ X } 10^{10}$) was recorded in treatments, where organic manure was applied.

The treatment-wise analysis after potato, onion and maize harvest in potato-onion-maize cropping system, giving highest PEY revealed that different nutrients application options had no appreciable effect on pH, EC, available N and DTPA extractable Zn, Cu and Fe. The application of nutrients through organic manure increased the soil organic carbon, available P and K significantly and decreased the bulk density, which is desirable.

Rice cultivar *Sugandha-5* was infested by fungal disease. The disease severity was low under organic and control treatments as compared to inorganic treatment. Sesamum crop had an insect problem as there was severe attack by hairy caterpillar on all the treatments.

Organic farming for potato production

Inappropriate and excessive uses of pesticides and fertilizers have resulted in deterioration of soil health and environmental quality. The contamination of food, fodder, water and fibre is becoming a threat to human beings, animals. A far sighted view than myopic chemical agriculture is needed to manage the intricate emerging issues like soil degradation, declining factor productivity, emergence of new pests and diseases, vanishing of friendly flora and faunae. Organic farming being environmentally friendly appears to be the alternative to the high chemical input based production system. Field studies were conducted at Modipuram,

Meerut to develop agro techniques for organic potato production and to study the impact of organic and inorganic source of nutrients on quality of produce, soil fertility and its physical properties.

Effect of fertilizers and vermicompost alone and in different combinations with inorganic fertilizers on tuber production

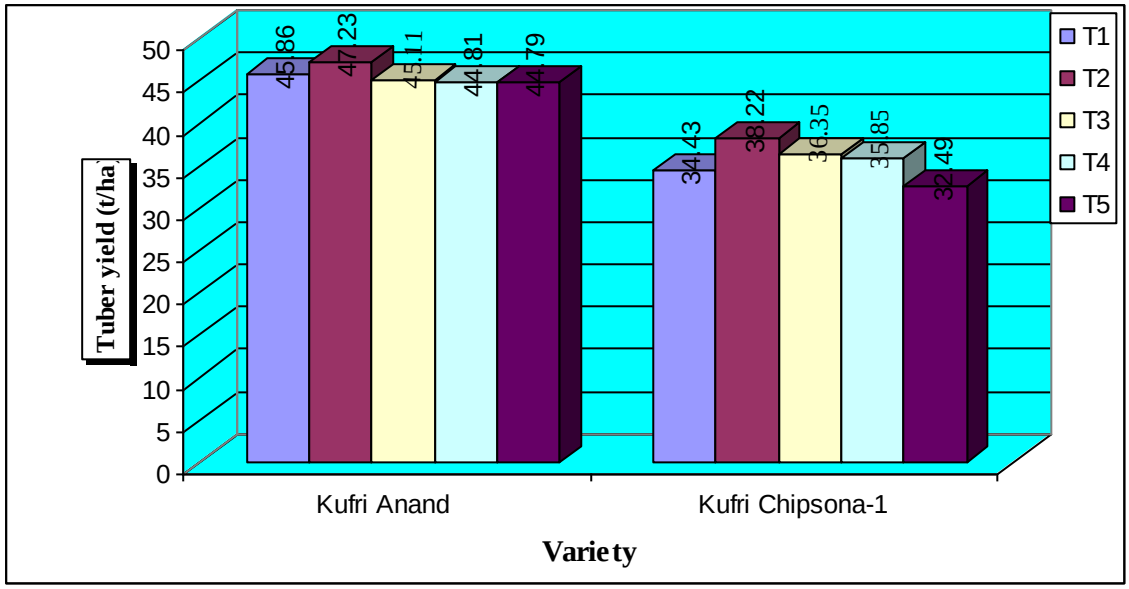
The experiment was initiated during 2002-03 and is being continued without changing the site/location. Till 2008-09, irrespective of variety, 100% organically raised potato crop, exhibited yellowing from 45 days onwards (Fig. 10), causing significant reduction in tuber yield. However, in 2009-10, unlike previous years, the organically raised crop remained green till maturity (Fig. 11). This may be due to relatively rapid release of nitrogen from organic manure under abnormal high temperature during early crop growth period in 2009-10. As a result compared to 2008-09, the tuber yield increased by 47.2 and 53.3 percent in Kufri Anand and Kufri Chipsona-1, respectively.

Application of variable ratios of fertilizers and vermicompost, to supply nutrient equivalent of 210-80–120 kg/ha as N, P_2O_5 and K_2O, showed that the average tuber yield in Kufri Anand through fertilizers and vermicompost was 45.9 and 44.7 t/ha, respectively. Statistically, the difference in yields through two nutrients supply systems, were non significant in both the cultivars. The maximum tuber yields in Kufri Anand (47.3 t/ha) and Kufri Chipsona-1 (38.2 t/ha) were obtained with application of vermicompost (25%) + NPK fertilizers (75%), primarily due to more large and medium sized tubers in Kufri Anand and Kufri Chipsona -1, respectively.

The application of 100% fertilizer, 25% vermicompost+75% fertilizers, 50% Vermicompost+50% fertilizer, 75% vermicompost+25% fertilizer and 100% vermicompost in Kufri Anand produced 45.86, 47.24, 45.12, 44.81 and 44.79 t/ha of tuber. In case of Kufri Chipsona-1, the corresponding yields were 34.44, 38.23, 36.35, 35.86 and 32.50 t/ha (Fig. 12). The soil analysis revealed that organic manuring increased the electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium and DTPA extractable Zn, Cu and Fe, while decreasing the pH slightly.

Fig. 10. Yellowing of leaves in Kufri Anand after 45 days in organically raised crop till 2008-09

Fig. 11. Continuation of greening till maturity in 2009-10 in leaves of organically raised crop of Kufri Anand



T_1: 100% Fertilizer, T_2 : 25% vermicompost + 75% fertilizer, T_3 : 50% vermicompost + 50% fertilizer, T_4 : 75% vermicompost + 25% fertilizer, T_5 : 100% vermicompost.

Fig. 12. Effect of fertilizer and vermicompost on tuber Yield

Effect of biofertilizer (B_5) application along with fertilizers and organic manure on tuber production in three potato cultivars

The application of B_5 with recommended dose of NPK @ 180:80:100 kg/ha through inorganic fertilizer and organic manure (vermicompost) was studied in three commercial potato cultivars. The results revealed that tuber yields were reduced, when B_5 was applied with fertilizers. In contrast, B_5 increased the tuber yield by 1.57, 1.47 and 1.53 t/ha in Kufri Surya, Kufri Pukhraj and Kufri Bahar, respectively, when applied with vermicompost. Statistically, the differences in yields due to B_5 application were non significant in all the three commercial cultivars. The cultivar Kufri Surya developed early yellowing/senescence resulting in 38 and 28% lower yields than Kufri Pukhraj and Kufri Bahar, respectively.

Effect of organic, inorganic and integrated nutrients supply systems on tuber production

In permanent organic trial, continuing since 2002-2003, response to different nutrient options varied with cultivars. The highest organic tuber yield (46.16 t/ha) from vermicompost was recorded in Kufri Chipsona-3, followed by Kufri Pukhraj (47.23 t/ha), Kufri Bahar (37.88 t/ha), Kufri Chipsona -1 (31.79 t/ha) and Kufri Surya (25.96 t/ha). In case of FYM, the

corresponding yields were 40.40, 38.33, 35.95, 35.35 and 24.67 t/ha, respectively. Unlike the last seven years, the application of nutrients through fertilizers did not give better yield than vermicompost (organic source) and in case of Kufri Chipsona -3, it was 2.03 t/ha (approx. 5%) less than organic yield (Fig. 13). The highest tuber production (48.06 t/ha) from fertilizers was obtained in Kufri Pukhraj, followed by Kufri Chipsona -3 (42.43 t/ha), Kufri Bahar (36.89 t/ha), Kufri Surya (26.02 t/ha). The integrated nutrients supply (1/2 fertilizers+1/2 vermicompost) improved the tuber yield significantly in only two cultivars Kufri Bahar (39.25 t/ha) and Kufri Surya (31.79 t/ha).

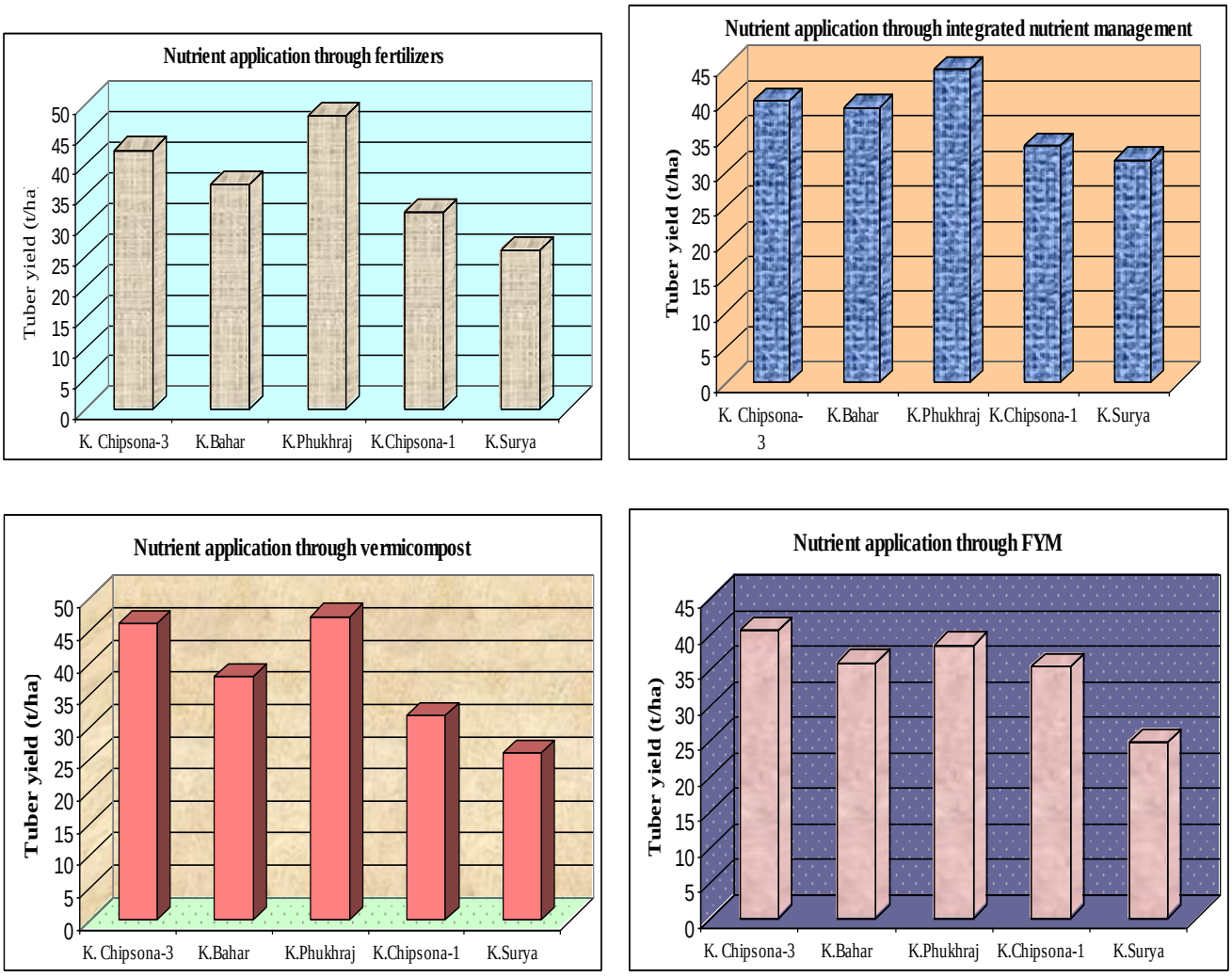


Fig. 13. Varietal response to nutrients application through different options.

Nutrients management under organic farming system in north western hills

Plant nutrients derived from various organic sources play an important role in sustaining soil productivity giving safer agricultural produce, besides protecting environment. Results of field experiment carried out at Shimla during 2009 showed that plants growth parameters *viz.*

plant height, number of leaves per plants, leaf area and number of tubers/plants increased in treatments where bio-culture of A*zotobactor* and phosphobacteria was inoculated with either vermicompost or FYM in comparison to other treatments. These treatments also increased the average tuber weight of large and medium size tubers in comparison to other treatments. The application of bio-culture alone with vermicompost gave highest tuber yield (260 q/ha). Bio-fertilizer applications along with vermicompost or FYM improved potato yield over use of vermicompost or FYM alone and control. The application of bio-culture along with vermicompost improved soil organic carbon content, available soil moisture retention, soil porosity besides soil fertility.

Mechanization of Potato Cultivation

Farm mechanization is needed for timely completion of cultural operations, save on labour cost and precise application of inputs for higher crop production. Keeping this in view the research programme aims to design and develop tools and aids for small and marginal farmers, design and develop equipment and machines for small scale potato processing and development of equipment for seed potato production.

Design and development of planting, intercultural and harvesting and grading, tools and aids for small and marginal farmers.

Fabrication work of the manually operated multipurpose toolbar with four numbers of attachments, was carried out. Multipurpose toolbar also known as tool carriers are meant for attaching various types of tools for efficient utilization of power. It consists mainly of an ergonomically designed handle, a pneumatic wheel (of size 87.5 mm X 200 mm) and a tool mounting assembly. Handle of the toolbar consists mainly of GI pipe of 12.5 mm diameter. Tool mounting assembly has been provided in the system in such a manner that all the developed attachments can be very easily fitted or taken out of this assembly. Provision of a pneumatic wheel in the system, apart from rendering smooth movement of the implement in the field, also add to the stability in depth of cut during the operation. The multipurpose

toolbar (Fig.14) with attachments is light weight and can be easily transported to the work site and operated by a person. Following attachments have been fabricated for use with this manually operated push type multipurpose toolbar.

1) **Single row three-tined intercultivator:** This attachment consists mainly of three numbers of tines for weeding and intercultivation purposes in the potato crop. To cover the whole area of the furrow profile, a duck foot sweep and two numbers of reversible shovels were provided in this attachment. These tines have been fitted on the frame made up mainly of angle iron. Whereas one tine is bolted in the front, two tines are bolted at the rear of the frame. The frame is provided with many holes. The desired spacing between the tines can be easily obtained by selecting the proper holes on the frame of the attachment. The effective field capacity of this attachment is 0.4 ha/day. Overall dimensions of the attachment are 270X440X210 mm.

2) **V-shaped blade weeder attachment:** It consists mainly of a MS flat sharpened on one side. This MS flat blade has been bent in such a way so as to properly fit in the furrow profile for efficient weeding. The attachment is suitable for scrapping and removing the small weeds which in turn renders the subsequent earthing up operation easier. The attachment can cover an area of 0.06 ha/hr. Overall dimensions of the attachment are 550X320X260 mm.

3) **Improved soil crust breaking attachment:** This attachment can be used to break up the crust formed on the soil due to rains prior to plant emergence. It consists mainly of two numbers of curved serrated drums. Each drum has nine numbers of serrated MS plates welded on two MS pipe sleeves and fitted on the MS shaft of 22 mm diameter. These serrated plates have been so welded on MS pipe sleeves provided on the shaft that no soil is allowed to clog in between these blades. There are nineteen numbers of serrations on each serrated plate. This attachment is placed on the ridges and the toolbar is pushed forward, resulting in breaking of the soil crust. Provision has been made in the attachment for its use at crop row spacing of 600 mm or 650 mm. One has only to remove the split pins, change the location of the crust breaking drum at desired row spacing and insert the split pin in the hole. The effective field capacity of this attachment is 0.25 ha/hr. Overall dimensions of the attachment are 900 X 220 X 190 mm.

(4) Load carrier attachment: This attachment fabricated for use with the toolbar can carry any type of load *viz*. potato bags, potato baskets *etc*. It consists mainly of 12.7 mm diameter GI pipe. These GI pipes (two numbers) spaced at 160 mm apart, have been bent in a semicircular shape. GI pipe supports have also been provided to render strength to this assembly. On one of the supports, a lock type nut & bolt system has also been provided to prevent any movement of the assembly during operation. A wheel assembly consisting of two numbers of solid rubber lined wheels (diameter 175 mm & width 50 mm) with shaft of 25 mm diameter and 380 mm length were also fabricated. This can be easily fitted to or taken out of this attachment, as per the requirement. Provision of a wheel assembly has been made with this attachment, in order to have proper stability during operation and also for reducing drudgery and time involved during handling. The attachment can carry two potato bags of 50 kg each. Overall dimensions of the attachment are 870X380X260 mm.

Improved manually operated wheel hoe

This manually operated push type of wheel hoe consisting mainly of an iron wheel (of diameter 280 mm) and three numbers of sweep tines, have been improved in its weeding mechanism. The tines have been fitted on the frame with the help of nut and bolts. A number of holes have been drilled on the frame for the rear two tines so that these can be adjusted, as desired for ridges with varying heights and profiles. A light weight wooden handle provided with the tool helps in pushing the machine forward. The effective field capacity of this equipment is 0.4 ha/day.

Development and evaluation of a power weeder

Preliminary work on the fabrication of weeding system of rotary blade type of power weeder was initiated. Fabrication work of the frame of the weeder and L-shaped cutting blades (made out of 32 mm size flat) of variable lengths for use in the weeding drum of the unit, is under progress. Lengths of these blades have been kept variable so that it accurately matches with the furrow profile for efficient weeding purposes.

Fig. 14. Manually operated multipurpose toolbar with single row three tined intercultivator attachment

Development of equipment and machines for small scale potato processing.

Development of a low cost potato peeler

A prototype of power operated potato peeler was designed and fabricated. It is a batch type peeler for small processing units. It can also be operated manually, where electricity is not available. The prototype consists of a main frame, rotating drum with projections, water inlet, top cover and an electric motor as prime mover. The specifications and working features of prototype peeler are given (Table 19). The whole system is mounted on an adjustable base frame, which can tighten the v- belt, when loose (Fig. 15).

During actual operation, a batch of tubers to be peeled is fed to the drum through the feeding inlet and outlet gate and the gate is fitted and secured with bolt. The power is supplied to rotate the drum by operating the electric prime mover. The water is also sprinkled over the tubers rotating with the peeler drum through the perforated pipe system. The supply of the water can be controlled by adjusting the tap. The drum was found to operated efficiently at 65 RPM. The peels continuously get drained along with the waste water from one side of the drum during the process. After a gap of 5-6 minutes, it was found that the peels get removed and the peeled tubers can be removed from the inlet cum exit gate by removing the bolt. The peeled tubers can be collected through an inclined chute in a water bath. The second batch of tubers are then filled again and the process is repeated. One person is required for continuous operation of the machine *i.e*. for feeding of drum for peeling and removal of peeled potatoes.

Table 19. Specifications and working features of the prototype peeler

S .No	Item	Specifications
1	Overall Dimensions (mm)	
	Overall Length	750
	Overall width	620
	Overall height	1200
	Weight (approx.)	45 kg
2	Main Frame size (mm)	
	Length	750
	Width	620
	Height	700
	Material	MS angle 25x25x6 mm
3	Drum size (mm)	
	Length X Diameter	560x400
	Material	Stainless steel
4	Water tank	
	Length X width X height (mm)	180x180x270
	Capacity (Litre)	Five
	Material	Stainless steel
5	Power source	Electric motor 0.5 HP –single phase 1430 rpm
6	Capacity	200 kg/hr
7	Peeling efficiency	82%
8	Peeling loss	3%
9	Labour requirement (man-hrs/q)	0.3
10	Approx cost (Rs)	8000/-

Fig. 15. Power operated potato peeler and a view of potato peeled with prototype peeler

Design and development of machine for making potato slices

Design of a power operated potato slicer was prepared. It consists of a main frame, the continuous type potato slicing mechanism, water supply cum disposal system and the power transmission system which further consists of an electric motor, reduction gear box and v-belt pulley system. The main frame of the prototype which is rectangular in shape was fabricated using 30x30x6 mm MS angle sections. The provision is made in the frame to fix and support the electric prime mover and the other functional units. The further fabrication work is in progress.

Development of implements for seed potato production

Design and fabrication of a mini aeroponics prototype for potato mini tuber production

A new prototype of aeroponics for conducting experiments on potato minituber production was designed, developed and tested. This system consists of a growth chamber, nozzles, nutrient solution tank, high pressure pump, filter, electrical and electronic components and other accessories. High density insulation material, synthetic sheets, mild steel, Poly vinyl chloride, foggers and electrical components were used to fabricate this system. After fabrication, the system was run idle for 200 hrs for pre-planting testing (Fig. 16). Three cultivars were planted for actual testing of the system. Source of planting material was *in vitro* propagated plantlets. Plantlets were hardened for 15 days in hardening chamber before shifting to growth chambers. Details of the outcome of this testing are shown (Table 20, 21.

Another model of aeroponics for 30 plants was developed to demonstrate technology in technology shows. Besides all the basic components this model is equipped with wheels and can be transported to the desired place.

Table 20. Details of aeroponics prototype

Component	Function
Growth Chamber	Encloses root system and provides firm platform for holding plants and has space for root growth.
Misting unit	Fogging in the growth chambers for saturating roots when ever required as per need of crop and environmental factors.
Solution chamber	Contains all the essential nutrients in liquid form and collects back the return solution.
Pump	Supply nutrient solution to foggers at high pressure as per prefixed time interval.
Filter	Filtration of impurities present in nutrient solution.
Valves	Control solution flow direction.
Electrical unit	For adjusting fogging on and off time.

Table 21. Response of different potato cultivars in aeroponics system

Parameter	Cultivars		
	Kufri Chipsona-3	Kufri Surya	Kufri Bahar
Date of planting in aeroponics	Dec 1, 2009	Dec 1, 2009	Nov 18, 2009
Crop duration	95 days	95 days	105 days
Avg. plant height	45 cm	29 cm	28 cm
Avg. number of nodes/plant	50	30	22
Avg. number of leaves/plant	60	36	25
Maximum root length	60 cm	55 cm	50 cm
Canopy diameter	37 cm	27 cm	22 cm
Number of minitubers/plant	26	18.5	17.6

Fig 16. Crop raised through aeroponics and minitubers

Design, development and testing of high capacity mechanized seed potato treatment system

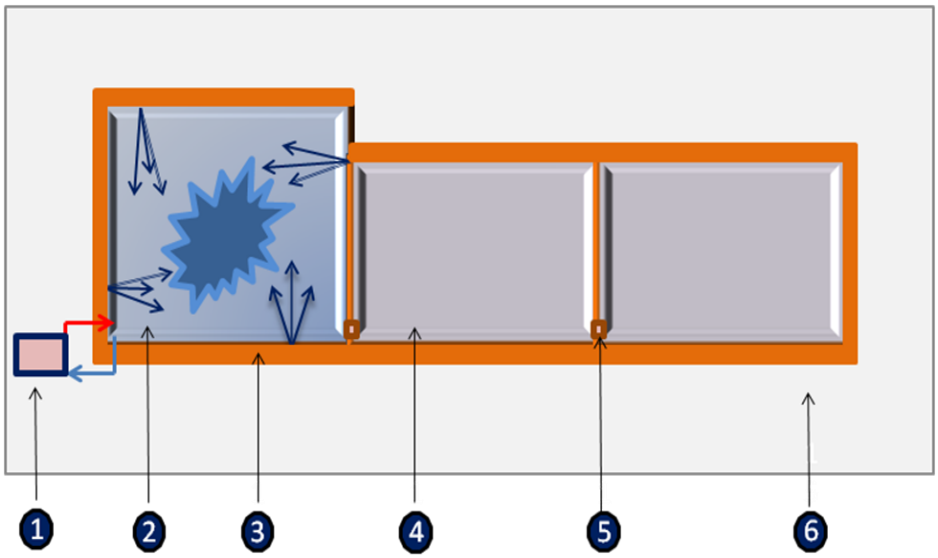
Presently, at all scales of seed potato production, tuber treatment is carried out manually after heaping the produce for 2-3 weeks. Seed tubers are dipped manually in tanks made of cement concrete, bricks, metal or plastic. Before treatment tubers are generally washed to remove dirt, soil and other foreign matter for making treatment more effective. During last couple of years, different designs of small trolleys and forklifts along with high capacity pallets were introduced at different stations of CPRI for fast handling and treatment of seed stocks. To further increase the rate of treatment, reduce human drudgery and to avoid direct contact of workers with chemicals, a mechanized seed treatment system was designed and tested at CPRIC, Modipuram. This includes deep and wide washing and treatment tanks, high pressure high volume washing system and specially designed pallets which are moved by a fork lift. In this system human power is not used for washing or treatment, but only for filling trays and unloading of trays. Fork lift carries (30 trays at a time) potatoes from heap to the washing tank, dips the load in washing tank first then in treatment tank and then carries these to the drying shed. Load (potatoes) is kept idle in the treatment tank for a time period as per recommendations of the institute.

Tanks- There are three tanks one for clean water washing and two for chemical solution for treatment of seed stocks (Fig. 17). Wash tanks walls have been provided with 1.25" diameter GI pipes for water circulation. A centrifugal pump is installed in such a way that its suction pipe is connected to the wash tank and delivery pipe again comes back in to the wash tank. Delivery is divided in such a way that water comes out through four pipes and stirs water to wash the seed load inserted in the tank.

High capacity pallets- For mechanized seed treatment special pallets have been designed (Table 22). These pallets can handle a load of 45 trays (900 kg) for general handling and 30 (600 kg) trays for treatment. These pallets are unique in the sense that these can be lifted both from bottom or from top as per requirement. Frame of the pallets is made of square pipes of 38 and 25 mm. Floor of the pallets is provided with a net of 12 mm square pipes (Fig. 17) in such a way that water drains down instantly through the openings when load is taken out of the treatment/wash tanks. With this system about 70-80 q seed material can be treated in one hour with one fork lift (Fig.18). For continuous work 12 workers for filling and emptying the trays are required.

Table 22. Description of mechanized treatment system

Component	**Number**	**Function**	**Specifications**	**Material of construction**
Washing tank	One	Washing of tubers	3600x2700x740 mm	Cement concrete
Treatment tank	Two	Chemical treatment of the tubers	3600x2020x740 mm	Cement concrete
Embankment	Four sides	Hump for fork lift	300x140 mm section	Reinforced concrete
Pump	One	Pressurized pumping of water for washing	5 hp, head 24 m, suction and delivery 73 mm	Steel
Embedded washing pipes	Four	For stirring of water in wash tank	32 mm diameter opening	Galvanized iron
Pallets	Five	For treating and moving seed tubers	1800x1800x1200 mm	Mild steel



1. Water supply unit
2. Wash tank
3. Reinforced bank
4. Treatment tank
5. Connector
6. Inward sloping floor

Fig 17. Schematics of tanks for mechanized seed treatment

Fig 18. (1) Washing/treatment channels, (2) perforated pallet, (3) dipping of tubers for washing and (4) washed tubers ready for treatment

DIVISION OF PLANT PROTECTION

Management of late blight

Late blight of potato caused by *Phytophthora Infestans* is the most important diseases known to destroy potato crop completely within in a fortnight, if weather conditions are congenial for disease. The pathogen is highly variable and changes with a slight change in environment, fungicides deployed or the host genotype grown for the effective control of the disease. *P. infestans* population has to be therefore monitored regularly across the country for checking development of resistance and new races of the pathogen. There is a continuous need to develop varieties resistant to the disease since the varieties prossessing resistance succumb to the new races of the pathogen with the passage of time. In addition to conventional breeding there is a need to take up molecular breeding using marker-assisted selection.

Disease and pathogen profile: Late blight disease was recorded in Meerut on ^{7}th January, 2010, subsequently, it was noticed in Muzaffarnagar and Hapur districts in UP. Disease severity in these districts ranged from 5-50%. Most of the Indo –Gangetic regions either did not get late blight infection or it was recorded at the crop maturity, consequently crop losses were insignificant. The disease appeared in the last week of July on cv. Kufri Shailja in Shimla hills and severity ranged from 50-90%. Stem infection was predominant wherever the disease was recorded**.**

Monitoring of *P.infestans* population for mating types, physiological races and metalaxyl resistance: There has been a marked increase in metalaxyl resistant population of *Phytophthora infestans* during 2009. A total of 33.3% population in Rajasthan exhibited tolerance at 400 ppm, 50% population in West Bengal at 300 ppm and 13% population in Shimla hills at 300 ppm. In Punjab and Bihar, 39.3% and 50% population, respectively exhibited tolerance at 200 ppm. Eighty percent isolates during 2010 in western UP were tolerant at 100ppm whereas 40% isolates were tolerant at 200ppm. A_2 mating type was not detected in Rajasthan, Punjab, Uttarakhand, Karnataka and Bihar states while in HP hills, it was 100%. A_2 mating type was however detected in low frequency in West Bengal (Fig.1). *P. infestans* races in Rajasthan (Kota), West Bengal (Kalyani), Punjab (Jalandhar) and Bihar (Patna) consisted of 9-11 genes complex races. Virulence genes 1, 2, 3, 4, 10 &11 were prevalent in all the isolates in Punjab; virulence gene R8 was least distributed (77.8%) followed by R6 & R7 (88.9% each) & R5 and R9 (94.4% each). Frequency of occurrence of 11 genes was 100% in Rajasthan and West Bengal while in Punjab and Bihar it was 44.4% and 58.3%, respectively (Table 1). Mt haplotype Ia was first reported in 2002 and since then it is being recorded on continuous basis. During the current year, analysis of the pathogen population collected from Karnataka, Himachal Pradesh, Uttar Pradesh and Uttarakhand revealed that 62.5% of the isolates belonged to the Ia haplotype, whereas the remaining 37.5 % consisted of Ib type (Fig.2). It tends to suggest that the new population which was introduced during 2002 is on the rise and it is in the process of displacing the old population.

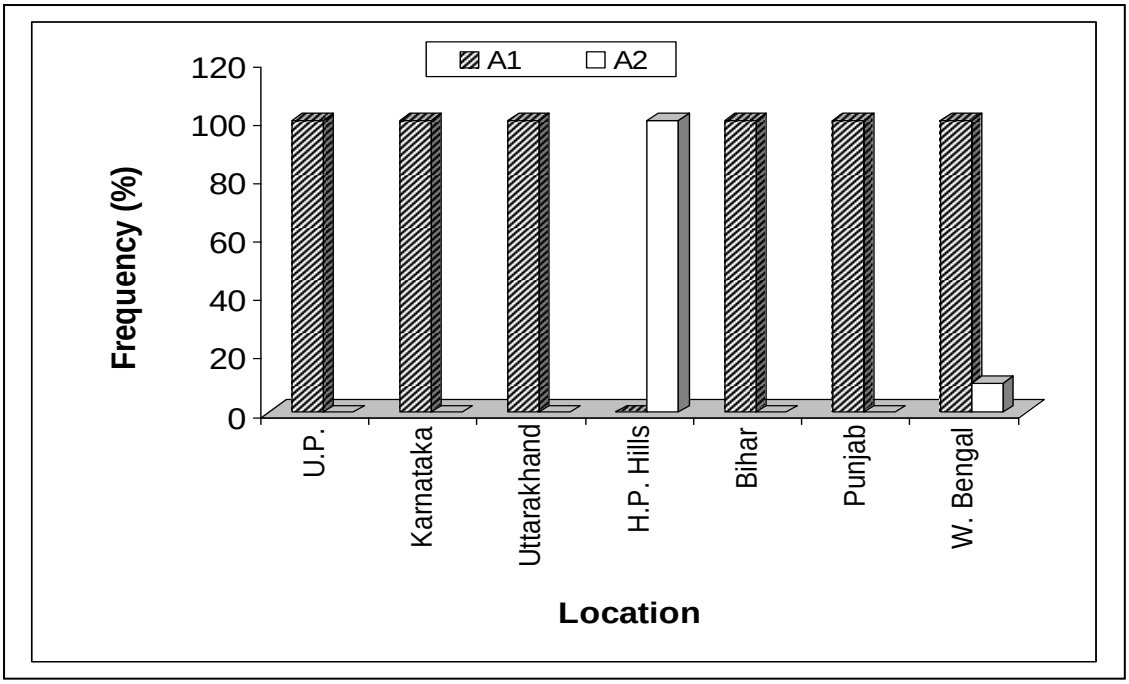


Fig.1. Frequency of A_1 and A_2 mating types

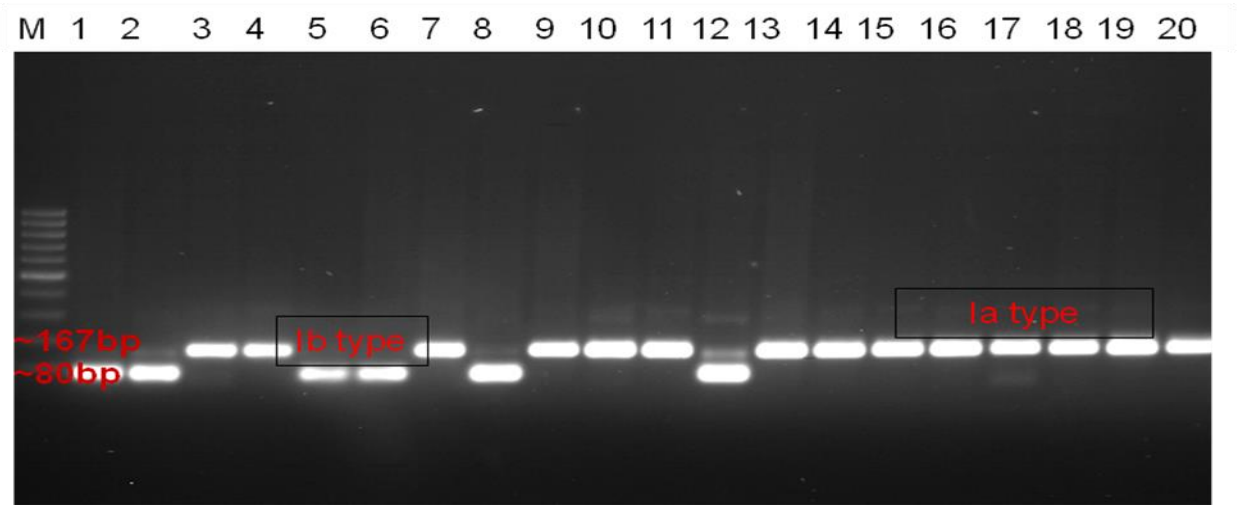


Fig.2.Mt haplotyping with Primer P2F2 & P2F2 + digested with MspI (Lane1-20; *P. infestans* isolates) Molecular Marker (M):100bp

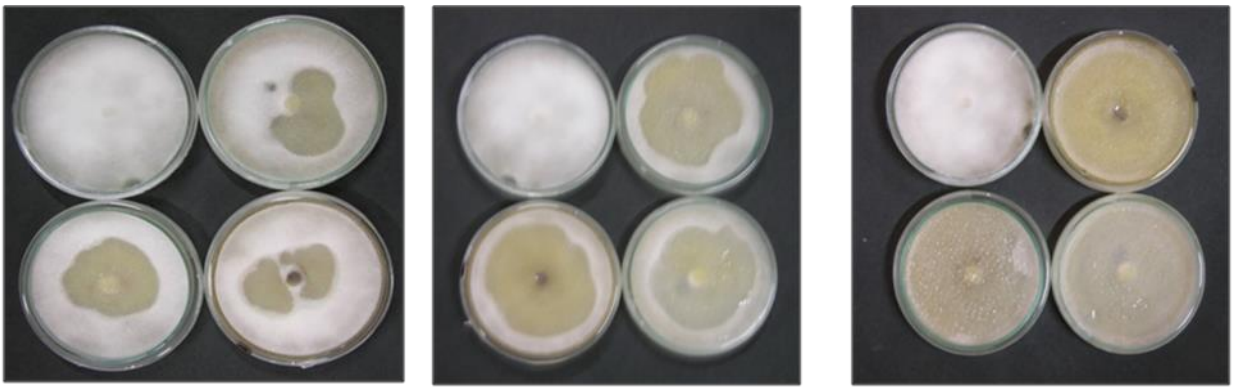
Disease epidemiology: JHULCAST model was once again validated during current crop season. JHULCAST model forecasted late blight appearance during 6- 10 January, 2010.The actual appearance of the disease coincided with this period (7 January, 2010) indicating its validity. Based on last five years data decision rules for applying need -based fungicides are being developed.

Table 1: Racial spectrum of *Phytophthora infestans* in different parts of the country

Location	No. of isolates	Race identified	Frequency (%)	No. of genes
Rajasthan (Kota) (2009)	03	1.2.3.4.5.6.7.8.9.10.11	100	11
West Bengal (Kalyani)	02	1.2.3.4.5.6.7.8.9.10.11	100	11

(2009)				
Punjab (Jalandhar) (2009)	36	1.2.3.4.5.6.8.9.10.11 1.2.3.4.5.6.7. 9.10.11 1.2.3.4. 6.7.8.9.10.11 1.2.3.4.5. 7.8.9.10.11 1.2.3.4.5.6.7.8. 10.11 1.2.3.4.5. 7. 9.10.11 1.2.3.4.5.6.7.8.9.10.11	8.33 22.22 5.56 11.11 5.56 2.78 44.4	9-11
Bihar (Patna) (2009)	12	1.2.3.4.5.6.7.8.9.10.11 1.2.3.4.5.6.7.8. 10.11 1.2.3.4.5.6.7. 10.11 1.2.3.4.5.6.7. 9.10.11 1.2.3.4.5.8.9.10.11	58.3 16.67 8.33 8.33 8.33	9-11

Disease Management : Amongst four fungicides namely, sectin (fenamidone 10% + mancozeb 50%), curzate (cymoxanil 8% + mancozeb 64 %), ridomil (metalaxyl 8% + mancozeb 64 %), and mancozeb (72 %WP), Curzate and sectin proved equally effective (11.66 % DI) as compared to control (95% DI). Twenty five microbial isolates collected from different locations were characterized for their bio-control activities. Among them Pseudomonas *sp* (single isolates) showed 35%, 60% and 100 % inhibition over control after 24, 48, and 72 hrs respectively in dual culture (Fig.3) .This isolates was found effective against *P. infestans* when tested on detached leaves.



24hrs after inoculation **48 hrs after inoculation** **72 hrs after inoculation**

Fig.3. Inhibitory effect of *Pseudomonas sp* on the growth of *P.infestans* (*In vitro*)

Project 2: Breeding for high yielding, late blight resistant cultivars for Indian Hill

The project aims at the development and release of medium maturing cultivars having broad spectrum resistance to late blight. The frequent breakdown of blight resistance in the cultivars world-over makes the task of breeders difficult and challenging because the pathogen is also continuously evolving and new races are appearing at a much faster pace compared to the release of resistant cultivars. Nevertheless, this is a natural process and we are striving hard to win this race against the pathogen.

About 70,000 hybrid TPS was produced from 47 successful crosses attempted between selected late blight resistant parental lines. Over 10,000 seedlings from twelve crosses were screened and over 1,000 resistant ones were selected for further evaluation under field conditions. The highest number of resistant seedlings were obtained in the cross

CP 2011 x SM/94-44 (15.2%) followed by QB/A 9-120 x SM/94-44 (12.7%), CP 2379 x SM/94-44 (10.6%) and SM/94-44 x HR 2-6 (9.4%). In preliminary generations (F_1C_1-F_1C_4), 375 hybrids were evaluated and 60 hybrids were selected. In advanced generations, 13 hybrids were evaluated and 10 hybrids were retained for further evaluations.

Wild/semi-cultivated resistance sources have also been exploited to strengthen the resistance breeding programme at the institute and resistant meiotic tetraploids were (MTs) produced. Amongst five MTs, VMT 5-1 produced significantly higher yield than the best control Kufri Himalini., Hybrids were developed possessing combined resistances to late blight and Potato Virus Y. Ten such hybrids with three controls were evaluated in a replicated trial at Modipuram and five hybrids i.e. LBY 15, 16, 17, 24 and 26 were retained for further evaluation. Based on their consistent performance during the last couple of years, hybrids LBY-15 and LBY-17 were selected for introduction into AICRP (P) for multi-location trials.

Molecular markers that are tightly linked to the R-genes imparting blight resistance in potatoes are pre-requisite to practice marker assisted selection. An attempt was made in this direction and specific primers for R genes (R1 and R3a) have been identified from the published reports. Markers SPUD 237 and R1AS have been identified for major gene R1. Similarly, cLET5E4 and GP 185 have been identified for gene R3a. The following primers for these markers have been synthesized and the process for their validation in late blight differentials has been initiated (Fig. 2).

Sr. No	Name	Primer sequence (5' – 3')
1	SPUD 237 F	TTC CTG CTG ATA CTG ACT AGA AAA CC
2	SPUD 237 R	AGC CAA GGA AAA GCT AGC ATC CAA G
3	R1AS F	CAC TCG TGA CAT ATC CTC ACT A
4	R1AS R	CAA CCC TGG CAT GCC ACG
5	cLET5E4 F	CCA GGC ATG CTC AAT TTG GAG T
6	cLET5E4 R	TTC CCT GTT TGG ACT ACT TGT GGA
7	GP 185 F	CTG GTA ATA GTA GTA ATG ATT CTT CGT C
8	GP 185 R	TTG TTC AAT GGA GCA CTT GC

In order to protect our precious hybrids developed at the institute, the work on DNA fingerprinting was initiated on 42 advanced hybrids and released varieties using SSR markers. The DNA fingerprinting has been completed using one SSR marker i.e. Stu 6 (Fig 1) and further work is in progress.

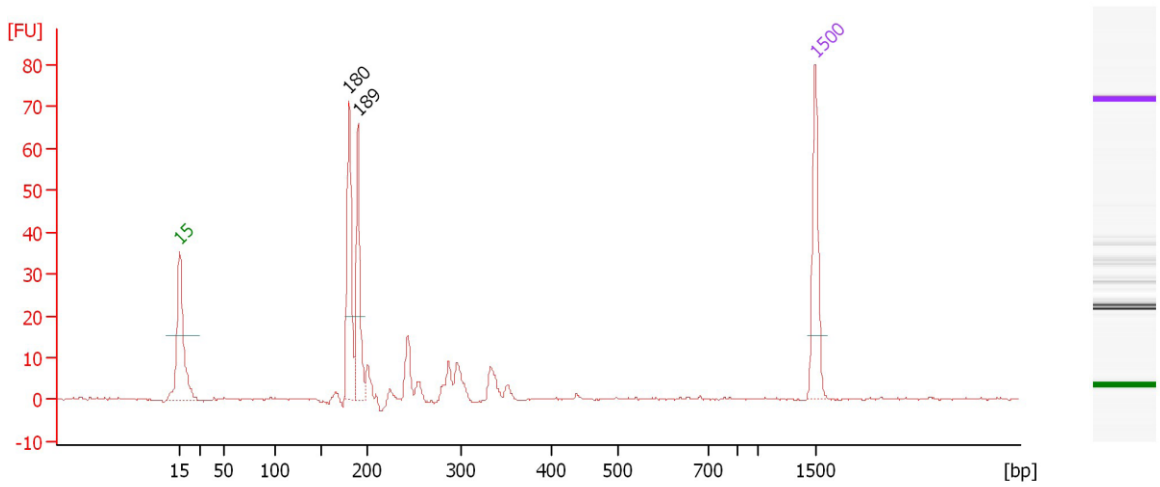


Fig.1. Electropherogram and gel-like image of Kufri Himalini obtained with Stu 6 SSR primer

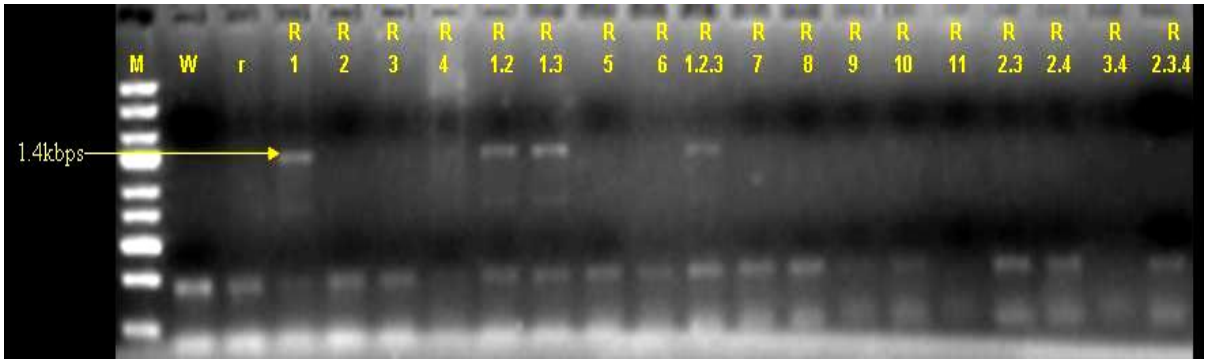


Fig.2. Validation of R1AS in late blight differentials: Lanes 1-Marker; 2-Water; 3-21 late blight differentials.

Diagnostics and detection of pathogens in potato.

Application of diagnostics for potato viruses and viriod indentification is absolutely essential for breeders seed production and for the international exchange of potato germplasm. The indigeniously developed diagnostics makes the country self reliant and eliminate the need to import costly diagnostic kits.

Maintenance of virus and viroid cultures: Pure cultures of Potato Virus X, S, Y, A, M and PLRV were maintained on *Nicotiana glutinosa ,Dutura stramonium, N. glutinosa* and *D. metel* potato variety Craigs Defiance Green Mountain, Saco and Kufri Surya respectively. Cultures of potato apical leaf curl virus was maintained in tubers collected from CPRIC, Modipurm and PSTVd in CP 1291, 1641, 1874, 2419 and 3166.

Immuno-electron microscopy (IEM) for virus testing: A total of 188 mericlones of 91 germplasm accessions were checked by IEM for different viruses. At least one mericlone each of 51 accessions were found free from PVX, and 52 accessions wre free from PVS. Seventeen accessions were free from PVM; 11 from PVY and 8 from both PVX and PVY. Besides, the accession G1807 from SCRIwas found free from PVX, PVS, PVY, PVM, and PVA. Samples from Kufri Himalini, Kufri Lauvkar, Phulwa Splashed 2194 and Phulwa White were found infected with different viruses.

Screening of germplasm for virus resistance: A total of 148 germplasm accessions were screened against PVY and PVX by mechanical inoculation followed by das-ELISA. Thirty four accessions showed combined resistance during first year of screening while 7 accessions (CP 1057, 1579, 1648, 3414, 3834, 3847 and 3916) showed combined resistance to PVX and PVY for two successive years. Twelve potato genotypes having multiple disease resistance to late blight and PVY were screened for resistance to PVX and PVY. All the genotypes (LBY-2, LBY-4, LBY-7, LBY-11, LBY-14, LBY-15, LBY-16, LBY-17, LBY-18, LBY-19, LBY-22, LBY-24 and LBY-26) showed combined resistance to both PVX and PVY.

Screening of *in-vitro* accessions for PSTVd: One hundred and twelve germplasm accessions were tested for the presence of PSTVd though NASH; two accessions (CP 1840 and 1915) were infected with PSTVd. Seventy seven germplasm accessions and 30 in vitro cultures of DUS reference collection were spotted on nitrocellulose membrane for NASH testing.

Production and utilization of ELISA kits: The Alkaline Phosphates based ELISA kits were produced against Potato Virus X, S, Y, A M and PLRV. The above ELISA kits were used for

testing of samples under different research programmes of the institute and the DBT sponsored NCS-TCP project.

ELISA testing of potato samples: Three hundred seventy three samples received from M/S Technico Agriscience Ltd., Chandigarh; 227 of M/s Pepsico India Holding; 12 samples of M/S Elegant Flower Co Pvt. Ltd, Kolkata; and 6 samples of Horticulture Training Institute, Uchani, Karnal were tested for PVX, PVS, PVY, PVA, PVM, and PLRV by das-ELISA. Only 2 samples of M/S Technico Agriscience Ltd., Chandigarh were positive for PVX and PVS; all others were free from viruses. One sample each of M/s Pepsico India Holding were found positive to PVX and S, 3 to PVY, 2 to PVA, 5 to PVM and 4 to PLRV. In case of M/S Elegant Flower Co Pvt. Ltd, Kolkata 3 samples were infected with either PVX or PVS or both. The samples received from the Horticulture Training Institute, Uchani, Karnal were infected with either PLRV or PVX except one culture of Kufri Pukhraj.

Post-entry quarantine testing: Nine potato varieties viz. Ausha, Challisha, Dohazari Sada, Hagrai, Jsubilati, Indurkani, Sadaguti, Shilbilati and Sindurkauta received from Bangladesh were tested for post-entry quarantine clearance; all were positive for multiple virus infection. All the varieties were planted in the glass house and tested for the presence of PVX, PVS, PVY, PVA, PVM and PLRV by das –ELISA. All the varieties exhibited sever mosaic and positive to multiple virus infection. These samples were also spotted on NCM for the detection of PSTVd. Four genotypes (TECH-0034, TECH-5077, Hermes, and Atlantic) imported by M/s Technico Agri Science, Chandigarh were checked all were free from the quarantined pathogens. However, one culture (Atlantic) was infected with PVM.

Expression of recombinant coat proteins of potato viruses in *E. coli*: The coat protein genes of PALCV and PVX were amplified using gene specific primers with restriction sites and proof reading enzyme. The amplified products were purified and restricted to generate blunt and sticky ends for ligation into the expression vectors (p-MAL-C5X and pMAL-P5X New England Biolabs). The ligated products were used in transformation of *Escherichia coli* strain K12 TB1 by heat shock method. The recombinant colonies were identified through colony PCR and finally confirmed through sequencing. Over-expression of these recombinant clones was carried out by using inducer Isopropylthioßgalactosidase (IPTG). Fusion protein of 67kd and 72Kd was observed in SDS-PAGE analysis of crude protein extract of recombinant *E. coli* expressing coat protein gene of PVX (Fig. 1) and PALCV, respectively. Out of two vectors, cytoplasmic (C5X) and periplasmic (P5X) vector, the expression of coat protein gene of PALCV was better in C5X vector than in P5X vector and in case of PVX the expression was more in P5X vector. The fusion protein was purified with amylase resin column and digested with Xa factor and release of coat protein of PALCV was confirmed in SDS- PAGE (Fig. 2). The purification of coat protein of PVX is under progress.

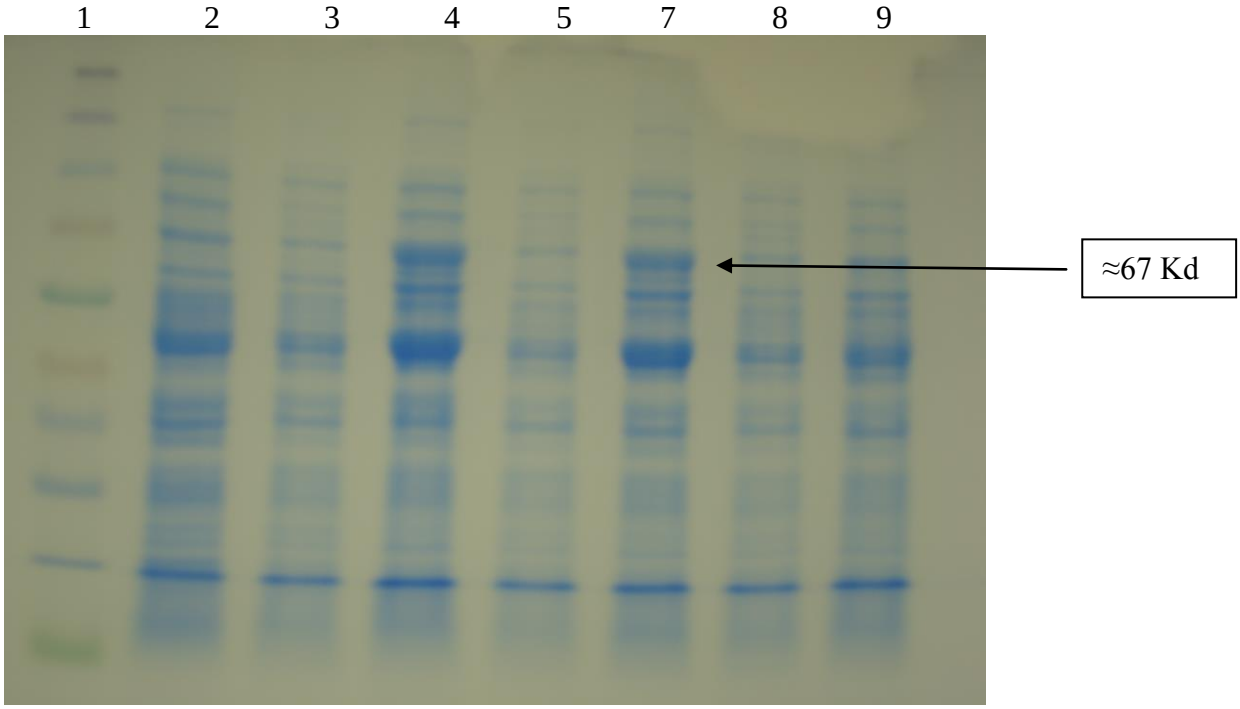


Fig. 1. PAGE separation of recombinant coat protein of PVX. Lane 1- Protein marker, Lane 2 – Non transformed *E. coli* , Lane 3, 5- Uninduced (pMAL-P5X+ CP gene of PVX), Lane 4, 7- Induced (pMAL-P5X+ CP gene of PVX), Lane 8- Uninduced (pMAL-C5X+ CP gene of PVX), Lane 9- Induced (pMAL-C5X+ CP gene of PVX)

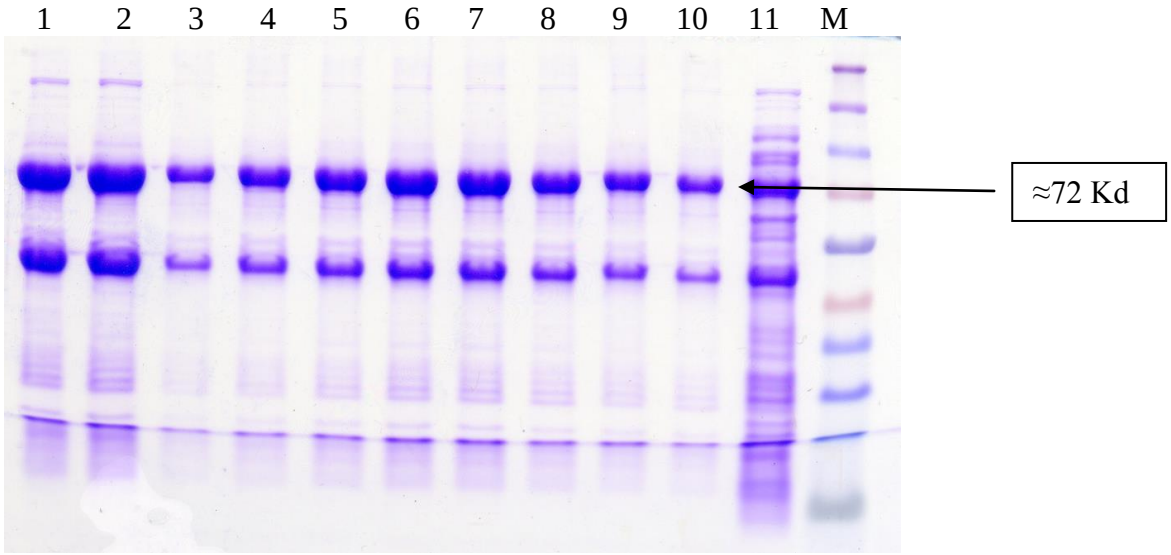


Fig.2. PAGE separation of purified recombinant coat protein of PALCV. Lane 1-10 – Purified fractions of fusion protein (Maltose binding protein + coat protein gene of PALCV), Lane 11- Crude sample, Lane 12- Protein marker.

Dipstick assay for the detection of potato viruses: Dipstick assay was standardized for the detection of five potato viruses viz., PVX, PVA, PVS, PVM, PVY using antisera raised by conventional method. Virus specific IgG was conjugated with colloidal gold nano-particles. Dipsticks were prepared by assembling sample pad, conjugate release matrix, working membrane and absorption pad and cut into strips. Virus specific IgG conjugated with colloidal gold particles was loaded on conjugate release matrix and virus specific IgG and antirabbit IgG was loaded on working membrane and allowed to dry. Extracts of healthy and infected samples were prepared in sample buffer and the dipstick was dipped in the sample

extracts for 1 min and placed horizontally for band development. The kit detected maximum of two viruses simultaneously. Separate kit has been developed for simultaneous detection of PVY+PVX, PVA+PVS, PVY+PVM. Three bands (2 for viruses and 1 for control) were detected when the sample is infected with two viruses; one virus-specific band and the control band were detected when it was infected with one virus (Fig. 3).

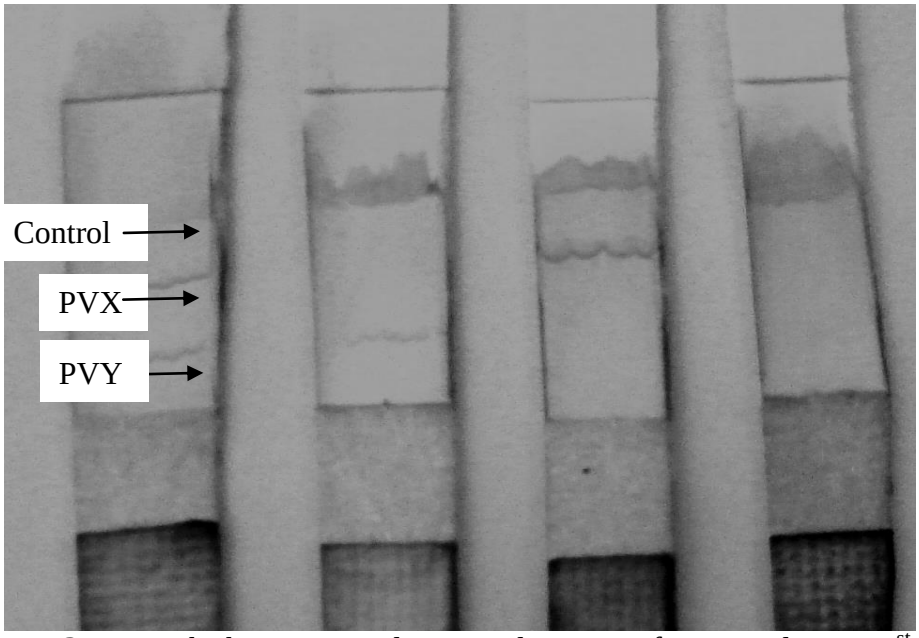


Fig. 3. Dipstick showing simultaneous detection of PVY and PVX. 1st from left: sample with PVY and PVX infection; 2nd : sample with PVY infection only; 3rd: sample with PVX infection only; 4th: healthy check.

Standardization of PCR protocol for the detection of potato viruses: Four different set of primers were designed to amplify the coat protein genes of PALCV, PLRV, PVX, PVA, PVS, PVM, and PVY. The standardization of PCR protocol with different annealing temperature and primer is under progress.

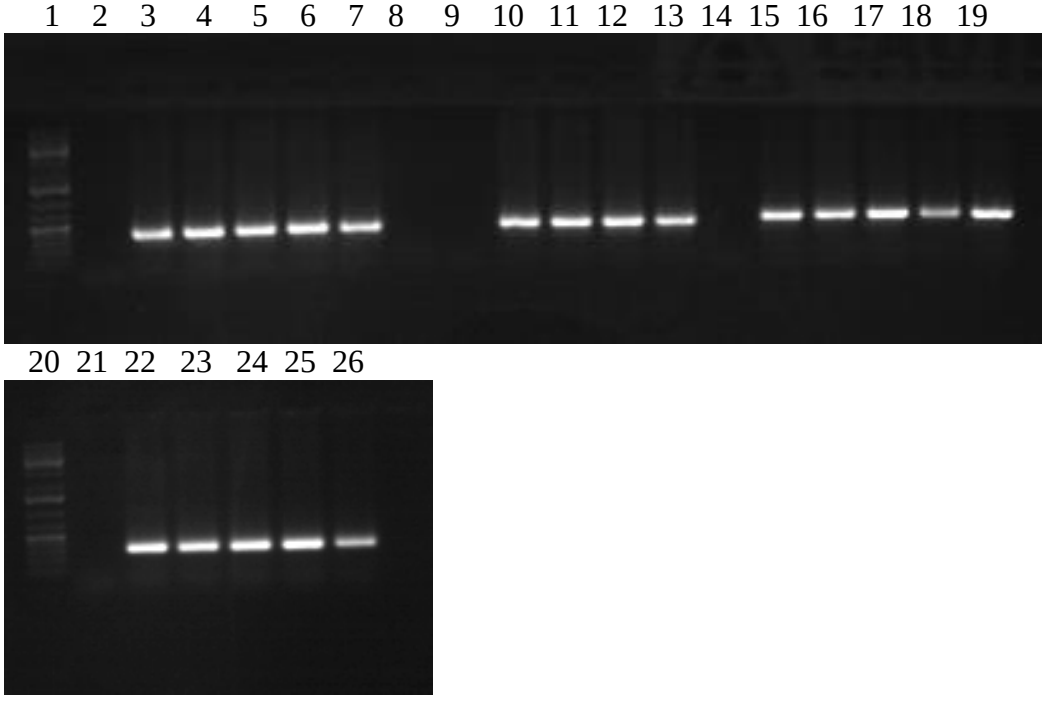


Fig. Standardization of PCR protocol and primers for PALCV.
Lane 1, 20- 1 Kb ladder, Lane 2,8,14,21- negative control, Lane 3-7, 9-13, 15-19 and 22-26 – amplification of coat protein gene of PALCV using four different primers and annealing temperatures

Transgenics for resistance to potato apical leaf curl virus: The popular variety of the region Kufri Badshah and the early maturing variety Kufri Pukhraj were used for genetic transformation with the replication-associated protein gene (*AC1*) of the Potato apical leaf curl virus to obtain pathogen-derived resistance. The gene was sub-cloned in the binary vector pBinAR in antisense orientation and as hairpin loop to derive the transformation vectors pGTLC1 and pGTLC2, respectively. The transformation vectors were mobilized into the *Agrobacterium tumefaciens* strain EHA105 by freeze thaw method and used for genetic transformation.

The internodal stem segments of Kufri Badshah microplants were used for genetic transformation. Approximately 400 explants were cocultivated with EHA105 harboring the binary vector pGTLC1 (containing replicase gene in antisense orientation). Three hundred putative transgenic shoots were regenerated out of which only 61 lines could produce roots in presence of 100 mg/L kanamycin. Those plants were checked by PCR for gene integration and eleven lines were positive for integration of replicase gene in antisense orientation (Fig.). The positive lines were grown inside a transgenic green house and tubers have been obtained from the first clonal generation.

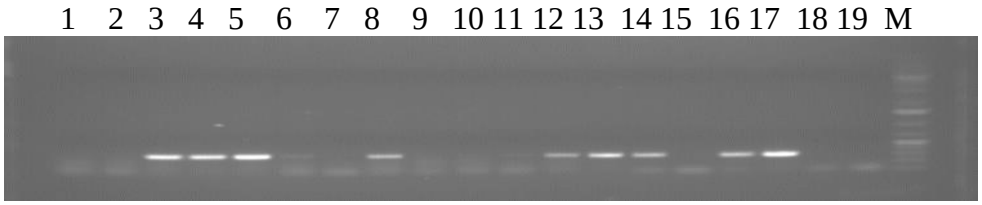


Fig.PCR amplification of replicase gene in putative transgenic lines (Kufri Badshah)
Lane - 3,4,5,6,8,12,13,14,16 -putative transgenics, 17- positive control, 18- Non transgenic control, 19-negative control, M- Marker

Similarly, the variety Kufri Badshah was also transformed with the replicase gene as hairpin loop (pGTLC2) to confer resistance by posts transcriptional gene silencing. Approximately 500 internodal cuttings were cocultivated and putative transgenic shoots were regenerated. Shoots developed roots in presence of 100 mg/L kanamycin and the rooted plants were tested by PCR for gene integration and 35 positive lines have been identified so far (Fig.).

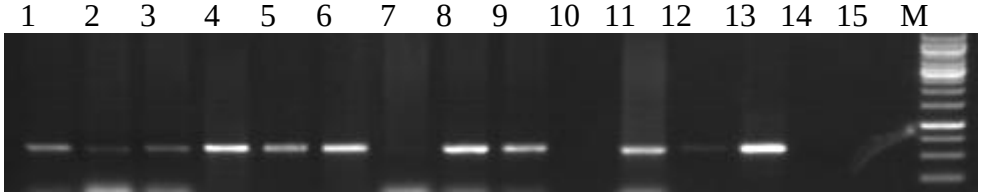


Fig. PCR amplification of replicase gene in putative transgenic lines (Kufri Badshah)
Lane-1,2,3,4,5,6,7,8 9 11,12 - Putative transgenics, 13 - Positive control, 14 – Non transgenic control, 15 - Negative control, M - Marker

The early variety Kufri Pukhraj was also transformed with the antisence construct of the replicase gene and 150 putative transgenic shoots have been regenerated. Rooting in presence of kanamycin was observed in 48 lines and out of which sixteen lines have so far been confirmed in PCR analysis for positive gene integration (Fig. 3).

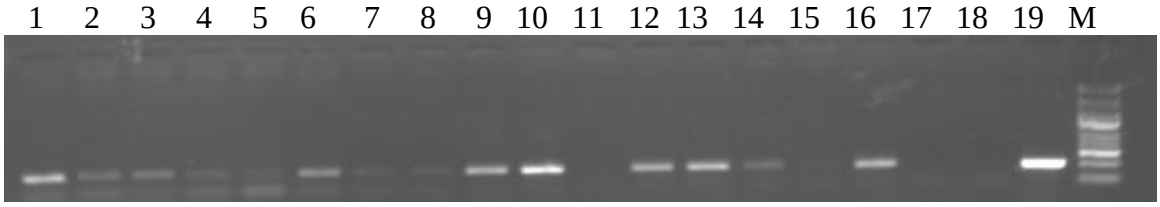


Fig. PCR amplification of replicase gene in putative transgenic lines (Kufri Pukhraj)
Lane-1,2,3,4,5,6,7,8,9,10,12,13,14,16 - Putative transgenics, 17- Non transgenic control, 18 - Negative control, 19 - Positive control, M- Marker

Similarly Kufri Pukhraj was transformed with the hairpin construct. Approximately 150 internodal cuttings were transformed, from which 100 shoots were regenerated. Twelve regenerated shoots showed rooting in 50 mg/l of kanamycin. Among the twelve rooted plants, six plants were found positive for gene integration in PCR analysis (Fig.).

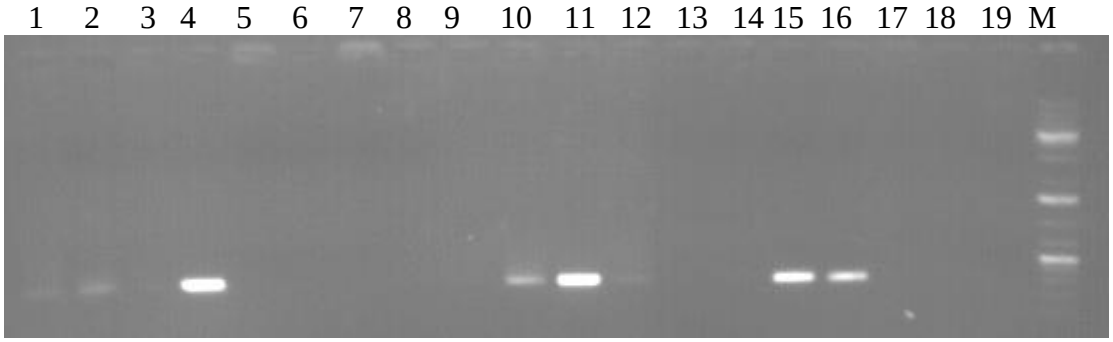


Fig. PCR amplification of replicase gene in putative transgenic lines (Kufri Pukhraj)
Lane-1,2,,4,10,11,12,15 - Putative transgenics, 16 - Positive control, 17 -Negative control, 18,19 – Non transgenic control, M - Marker

Transgenics for PVY resistance: The early potato variety Kufri Pukhraj has been transformed with the PVY CP gene in either sense, antisense or non-translatable orientation. Fifteen transgene-positive lines for sense (KPYS-1, 4, 7, 8, 9, 10, 11, 13, 18, 20, 21, 22, 36, 38, and 42, Fig.); 4 for antisense (KPYAS-3, 11, 24, and 35, Fig.); and 10 for non-translatable construct (PVYNT-2, 3, 4, 5, 6, 9, 14, 17, 25, and 26, Fig.) were developed. PVY resistance of the positive lines is being evaluated under glass-house condition.

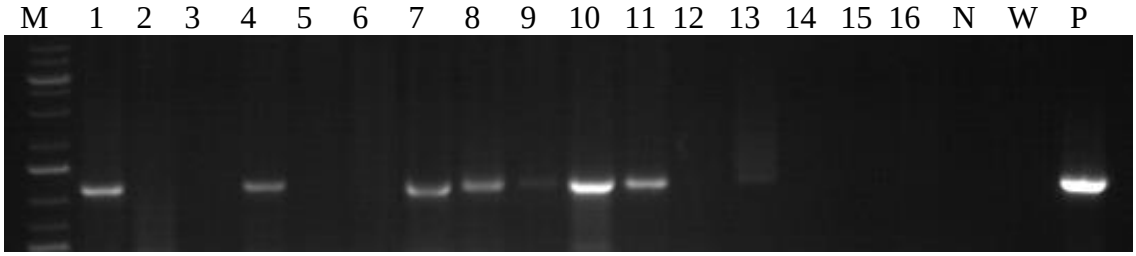


Fig.3. PCR of the genomic DNA of transgenic lines containing CP sense construct, amplified with the specific primers (showing 1100bp band): M = Gene ruler 1Kb marker (MBI Fermentas), W = Water control, N = Negative control, P = Positive control, Lanes 1 to 16 = Transgenic lines.

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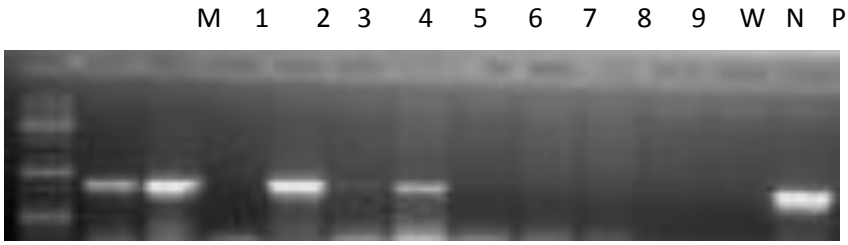


Fig.2.PCR of the genomic DNA of transgenic lines containing fused gene, amplified with the *specific* primers (showing 1100bp band): M = Gene rule 1Kb marker (MBI Fermentas), W = Water control,

N = Negative control, P = Positive control, Lanes 1 to 9 = Transgenic lines.

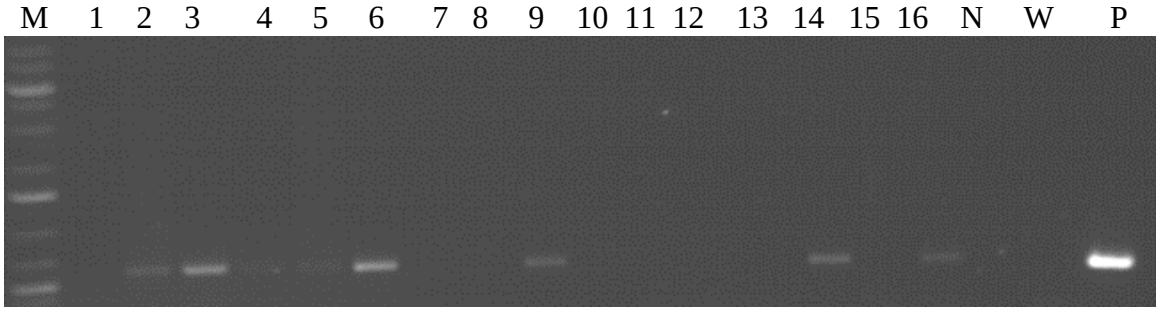


Fig.4 PCR of the genomic DNA of transgenic lines containing fused gene, amplified with the specific HP1primers (showing 650bp band): M = Gene rule 1Kb marker (MBI Fermentas), W = Water control,

N = Negative control, P = Positive control, Lanes 1 to 16 = Transgenic lines.

Fig. Rooting of putative transgenic lines in MS medium containing 100mg/l Kanamycin

Integrated disease management

Soil and tuber borne diseases greatly impair quality and market value of potato tubers. Pathogens causing such diseases are disseminated far and wide to new areas through seed tubers and soil. Diseases such as black scurf and common scab disfigure potato tubers where as diseases such as soft rot and dry rots affect the produce directly causing economic losses. These diseases are generally controlled by the farmers through seed treatment with organomercurials which are universal poisons and hazardous to human health and environment. With growing concern about quality of potato, human health and environment use of hazardous chemicals are greatly discouraged and thus there is a great need to find safe and eco-friendly alternatives to manage the soil and tuber borne diseases. Research work carried out at CPRI has resulted in development of some environment friendly technologies

which can take care of most of soil and tuber borne diseases. These are solarization of sick fields, seed treatment with boric acid, *Trichoderma viride*, *Bacillus subtilis* (B5) and plant extracts. An integrated approach involving one or more of these technologies can greatly reduce our dependence on pesticides and improves quality of the produce.

Russet scab of potato

Russet scab of potato is a serious problem in seed production especially in north-western plains. Twenty one potato varieties were screened for their resistance to russet scab under field conditions. Based on average disease severity the varieties were arranged in descending order of resistance as follow: Kufri Phushkar (11.6%), Kufri Anand (12.2%), Kufri Jawahar (15.8%), Kufri Phukhraj (16.6%), Kufri Chipsona -1 (17.7%), Kufri Ashoka (18.3%), Kufri Dewa (21.8%), Phulwa (24.4%), Kufri Chipsona 3 (26.3), Kufri Giriraj (26.6%), Kufri jyoti (30.3%), Kufri Khyati (33.1%), Kufri Satlej (35.6%), Kufri Louvkar (39.8%), Kufri Surya (43.0%), Kufri Chandramukhi (43.4%), Kufri Badshah (43.8%), Kufri Bahar (46.3%), Kufri Sindhuri (59.9%), Kufri Sherpa (62.9%) and Kufri Lalima (66.5%) (Table 1). Potato variety possessing resistance to russet scab was further evaluated in farmer's field at Hoshiarpur against pitted type of common scab. Results of the trial revealed that the disease severity in Kufri Pushkar was only 4.2 percent as against 9.6 per cent in Kufri Chandramukhi and thus it possessed resistance against pitted type of common scab as well. (Fig.1).

A total of 1859 germplasm accessions from CP No. 1507 to 3355 were evaluated against russet scab. Of these 108 were found promising with no russet scab incidence (Table 2). Out of ten treatments evaluated for control of russet scab in a field trials soil application of stable bleaching powder @ 3q/ha was the most effective. The disease severity decreased from 47.4% in untreated control to 24.5% in plots applied with stable bleaching powder @ 3 q/ha in soil before planting (Fig.2). No reduction in yield was observed by application of the bleaching powder. Fields infested with common scab pathogen have been identified at Gwalior and Meerut region for carrying out further experiments on management of pitted type common scab.

Management of other tuber disease of potato

Collected and maintained 45 isolates of *Ralstonia solanacearum* and 15 isolates each of *Fusarium*, and *Rhizoctonia spp.* None of the three biocontrol agents received from NBAII, Bangalore viz. *T.viride* (PDBC- TV-23, *T.harzianum* (PDBC- TH-10), *T. virens* (PDBC-TVS-10) provided significant control of black scurf and *Bacillus subtilis* BS KD-4, KD-7), *Pseudomonas fluorescens* (KD-4, ND-4B) against common scab in two field trials. Storage of potato varieties in heaps after harvest in February revealed very low rotting up to mid of June. The rotting builds up rapidly after July 1 and reach the maximum by mid of July. Soft rot was a major component of storage rots (79.2 %) followed by dry rots (9.9%) and charcoal rot (10.9%).

A survey conducted in Indore and Ujjain districts of Malwa region of Madhya Pradesh revealed that bacterial wilt was present in fifteen out of twenty two fields surveyed in eight villages of the region. The incidence varied from zero to sixty percent. Incidence was significantly higher in fields where the farmers had used local seeds and negligible where certified seed was used. The survey indicated that all the varieties grown in the region viz. K. Jyoti, Kufri Chipsona-1, K. Laukar or Antlantic were affected by the disease. Brown rot affected tubers were present in thirteen out of fifteen fields surveyed in eight villages and the disease incidence ranged from zero to seventy percent.

Table 1: Screening of different potato varieties against russet scab planted on different dates

Varieties	Sept 25	Oct 10	Oct 25	Nov 10	Mean Disease severity (%)
Kufri Khayati	42.3	23.8	33.3	33.1	33.1
Kufri Phushkar	19.0	4.2	10.0	13.3	11.6
Kufri Anand	16.4	15.2	9.6	7.7	12.2
Kufri Chipsona-1	20.8	8.8	24.9	16.2	17.7
Kufri Giriraj	30.8	5.7	34.8	35.0	26.6
Kufri Phukhraj	22.2	4.6	11.8	27.2	16.6
Kufri Ashoka	24.9	9.2	11.8	27.2	18.3
Kufri Satlej	40.6	24.8	35.1	42.0	35.6
Kufri Jawahar	20.6	6.9	20	15.7	15.8
Kufri Sherpa	69.8	57.5	64.3	59.8	62.9
Kufri Lalima	81.2	64.5	68.7	51.7	66.5
Kufri Bahar	45.3	49.0	55.3	35.6	46.3
Kufri Badshah	62.2	31.1	51.0	31.0	43.8
Kufri Dewa	34.8	9.6	29.8	12.8	21.8
Kufri Louvkar	50.0	43.8	41.6	23.8	39.8
Kufri Sindhuri	63.9	58.1	68.6	49.1	59.9
Kufri Jyoti	34.8	35.0	25.1	26.1	30.3
Kufri Chandramukhi	48.3	32.7	56.3	36.3	43.4
Phulwa	14.4	29.0	32.2	21.8	24.4
Kufri Surya	56.6	35.2	-	-	43.0
Kufri Chisona -3	-		41.8	14.3	26.3

Table 2: Evaluation of germplasm accessions for resistant to russet scab

Germplasm accessions found resistant to russet scab
CP Nos. 1602,1699,1724,1736,1766,1771,1784,1796,1798,1800,1814,1815,1817,1827,1832,1835,1836, 1848,1878,1895,1911,1913,1920,1924,1969, 1975,1990,2016,2041,2054,2082,2085,2 091, 2103, 2116,2118,2131,2132,2134,2148,2162,2171,2180,2184,2187,2192,2196,2201,2202, 2217,2235,2246,2283,2287,2294,2297,2300,2301,2302,2307,2310,2312,2313,2314,2317, 2321,2347,2350,2363,2368,2370,2376,2381,2385,2394,2397,2402,2403,2406, 2413,2414, 2417,2422,2428,2927,3036,3048,3068,3078,3177,3178,3182,3183,3189,3193,3194,3196, 3198,3205,3207,3210,3245,3250,3254,3269,3270,3295

Table 3: Control of russet scab through chemicals and antibiotics

Treatments	Emergence (%)	Disease severity (%)	Yield q/ha
Untreated (Control)	100	47.4	416.7
Stable Bleaching powder (soil application @ 1q/ha	100	37.5*	421.7

Stable Bleaching powder (soil application @ 2q/ha	99	28.1*	430.0
Stable Bleaching powder (soil application @ 3q/ha	98	24.5*	441.7
Aureofungin **(**tuber treatment @ 0.05% + soil drenching at earthing)	96	36.3*	310.0
Aureofungin **(**tuber treatment @ 0.10% + soil drenching at earthing)	93	42.5	313.3
Aureofungin (tuber treatment @ 0.20% + soil drenching at earthing)	95	43.2	311.7
Streptocycline (tuber treatment @ 0.10% + soil drenching at earthing)	97	51.2	300.0
Aureofungin **(**tuber treatment @ 0.20% + soil drenching at earthing)	96	41.8	301.7
Streptocycline (tuber treatment @ 0.30% + soil drenching at earthing)	94	37.3*	280.0
SE + CD (0.05)	1.75 NS	2.79 8.09	14.2 41.2

* Significant at 5% probability level

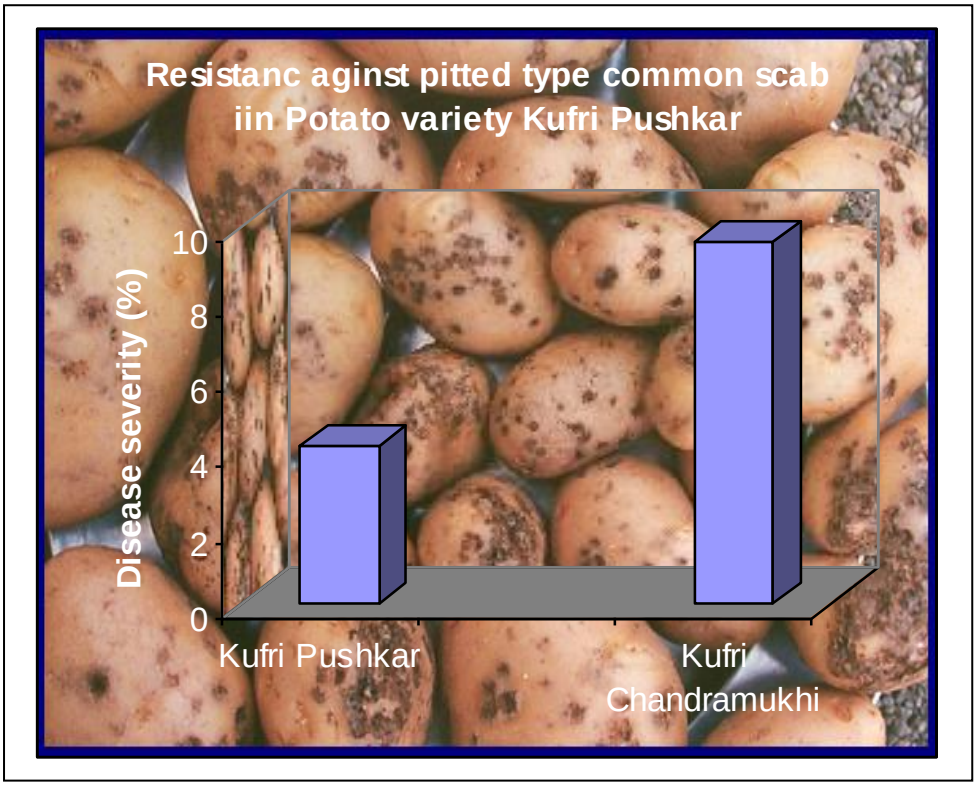
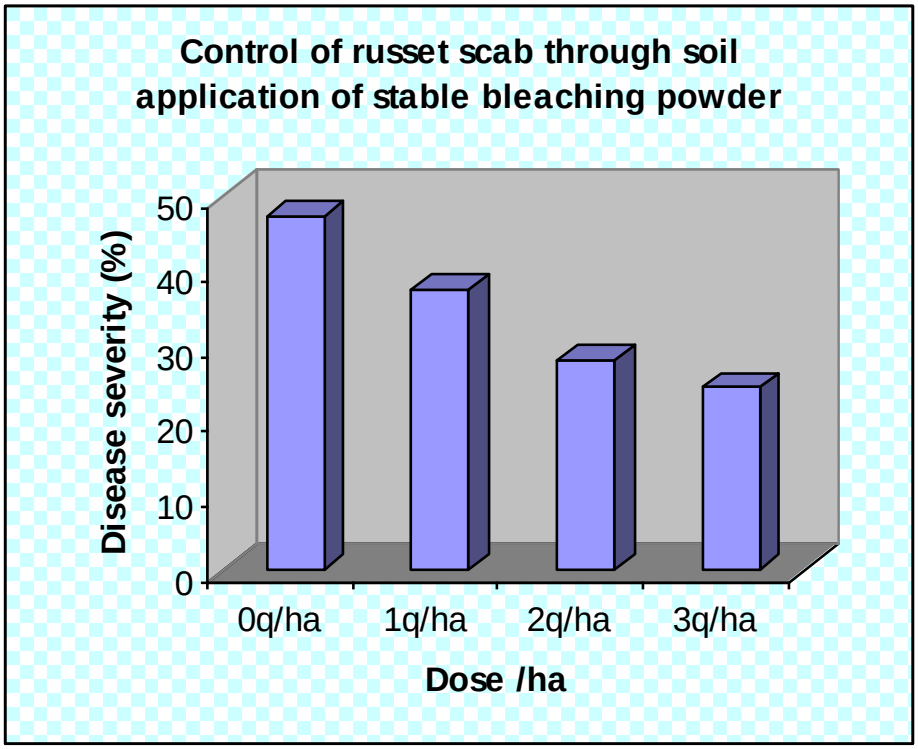


Fig. 1 : Resistance in Potato variety Kufri Pushkar against common scab

Fig. 2: Control of russet scab through soil application of stable bleaching powder



Integrated pest management

Potato crop is attacked by several important insects, mites and arthropod pests at different stages of its growth and in stores. Control through pesticides poses health hazards and also results in development of resistance in pests to the pesticides. The programme aims at identification of potential eco-friendly components and use them in an integrated manner to have an economical and lasting alternatives to the hazardous pesticides. Attempts are also made to keep a tract on the new emerging pests / vectors of potato likely to occur **with changing ecological conditions and cropping pattern in the country.**

Monitoring of potato pests: *Myzus persicae* Suler was recorded as early as 12th November 2009 at Modipuram but population build up started only in mid December. Thrips were also recorded in mid January. The first appearance of peach aphid was recorded in the 3rd week of December at Gwalior which crossed the critical level (20 aphids/100 leaves) by 1st week of January, 2010.

Highest population of thrips (42 thrips/plant) was recorded during the fourth week of September, 2009. The population subsequently declined in the month of November-December, 2009. However, two peaks were recorded on potato crop first in 4th week of September and second in 3rd week of November. Maximum number of nymphal population was recorded in September. In thrips complex, *Thrips palmi* was predominant species (75-78%). Population of thrips was maximum in Kufri Chandramukhi (7.07), followed by Kufri Lauvkar (4.87), Kufri Jyoti (4.67),Kufri Sindhuri (4.27), Kufri Chipsona-1 (3.90) , Kufri Ashoka (2.70) and Kufri Chipsona-2 (0.80).

A base line survey was conducted over two years to monitor the aphid build up in four NE-states viz. Meghalaya, Sikkim, Arunachal Pradesh and Nagaland to assess the relevance of the locality as good quality seed production sites during the year 2008 and 2009. Monitoring was done weekly by using

aphid-leaf count and by using traps (water and sticky). The significant differences in aphid population were observed among the localities selected and surveyed in the altitude range of 1500-2500 above MSL. *Myzus persicae* (Sulzer) was found above critical level at almost all places irrespective of temperature, humidity and high rain fall. Virus pathogen pressure was detected from the leaf samples collected from all the locations showing the presence of all principal viruses using DAS-ELISA technique. Aphid population was monitored in Kufri Giriraj, Kufri Jyoti, Kufri Girdhari and Kufri Megha by counting the number of aphids in the underside of 100 compound leaves every week during the crop growth period. The mean number of aphids was maximum in Kufri Giriraj (26.83) followed by Kufri Jyoti (22.40) while Kufri Girdhari (7.25) and Kufri Megha (5.13) recorded less number of aphids.

The extent of PTM damage at Shillong was worked out in ten different varieties. Kufri Jyoti and Kufri Himalini recorded the maximum mean infestation of 17.51 and 15.68 per cent tubers and 1.07 and 0.91 holes per tuber at the end of 3 months of storage, while the least infestation of 7.48 per cent tuber and 0.35 holes per tuber was recorded in Kufri Megha.

Management of potato tuber moth: To avoid pesticide hazards, nine indigenous plant parts in powdered form were evaluated in potato store under high population of PTM. The seed kernels of neem (*Azadirachta indica* L.), ritha (*Sapindus mukorossi* L.) and ratna jayot (*Jatropha curcas)* and dried leaf powder of Chrysanthemum (*Chrysanthemum cinerariaefolium),* bana (*Vitex negundo* L.), Kaner (*Nerium oleander* L.), eucalyptus (*Eucalyptus globules*), stinging nettle (*Urtica dioca* L.) and lantana (*Lantana camera*) were tried. Tubers were treated with plants powder @ 10 g/Kg of potatoes and untreated potato tubers were considered as control. The observations were taken at 10 days interval till the end of two months of storage to record the percent tuber damage by PTM. Of these ritha (soap nut) @ 1.5% w/w proved most effective in minimizing the tuber damage (0-1 hole per tuber), followed by stinging nettle and eucalyptus leaf powder with 1-3 holes/tuber against 7-10 hole/tuber in control. CIPC treatment kept the PTM damage under check recording only 2-4% tuber infestation and less than 0.06 holes/tuber while in control 8-10% infestation and 0.8 holes/tuber was recorded at the end of three months of storage. Sprouting of tubers was also checked in CIPC treatment and the average sprout length of 1.72 to 2.7 mm was recorded while untreated control recorded an average sprout length of 6-7.04 mm at the end of three months of storage. The residues of CIPC were determined in treated tubers of cultivars Kufri Jyoti and Kufri Giriraj during storage under non-refrigerated conditions. The residues were found to be maximum in peels followed by whole tubers and were the least in the cortex. Kufri Jyoti showed higher residues accumulation compared to Kufri Giriraj. The residues were well below the acceptable level of 30 mg/kg and hence the tubers were considered safe for consumption.

Management of cut worms: The effect of nitrogen levels (180, 270 & 360 kg/ha) and processing varieties (Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Chipsona-3) was evaluated against cut-worm damage. Cut-worm damage was highest at 360 kg N level (1.44 – 3.34%) as compared to 180 and 270 kg N. However, there was a little difference in cut worm damage at 180 and 270 kg N levels. Soil treatment with phorate 10G @ 15 kg/ha at planting followed by drenching of ridges with Imidacloprid resulted highest markable tuber yield (424.05q/ha) as compared to control (358.8q) with less than 1% tuber damage by cut-worm. *Macrocentrus collaris* was the dominant parasite of cutworm in potato field of Shimla. The parasitization by *M. collaris* in cutworm larvae ranged from 16.66 to28.57 per cent (average 20.08 Per cent). Highest parasitization (28.57 %) by *M.collaris* was recorded in 3rd instars larvae during 16th MW.

Management of virus vectors: In main crop, thiacloprid 240SC was tested for both aphids and whitefly in potato variety Kufri Bahar. Populations of whitefly, *Myzus persicae* and *Aphis gossypii* recorded after spray of the chemical revealed that the best control was

observed by two sprays of thiacloprid at 15 days interval @ 3.5 ml/10 l given in third week of November and second week of December (Table 1a-c).

Table 1a: Effect of thiacloprid on whitefly (population /100 leaves) in main crop.

	30.11.09	14.12.09.	17.12.09	30.12.09	15.01.10
T1	8.7	2	4.7	2	0
T2	6.7	8.7	8.7	0	0
T3	8.7	18	4.7	0	0
T4	13.3	20	4.7	0	0
T5	2	11.3	0	2	0
T6	11.3	15.3	8.7	0	0
T7	11.3	4.7	0	0	0
T8	4.7	22	2	0	0
T9	4.7	6.7	0	0	0
T10	6.7	8.7	8.7	0	0
T11	2	2	0	0	0
T12	4.7	6.7	6.7	0	0
T13	4.7	6.7	0	0	0
T14	0	4.7	2	0	0
T0	15.3	13.3	0	6.7	0

Table 1b: Effect of thiacloprid on *Myzus persicae* (population /100 leaves) in main crop

	30.11.09	14.12.09.	17.12.09	30.12.09	15.01.10	24.01.10
T1	0	4.7	8.7	44.7	280	1006.7
T2	0	11.3	20	191.3	611.3	920.0
T3	0	24.7	0	2	240	506.7
T4	0	6.7	4.7	242.0	214	1426.7
T5	0	8.7	0	2.0	80.0	533.3
T6	0	28.7	24.7	168.7	127.3	848.7
T7	0	38.0	0	4.7	35.3	235.3
T8	0	13.3	2	213.3	141.0	940.0
T9	0	2.0	0	0.0	67.7	451.3
T10	0	4.7	22.0	173.3	320.3	2135.3
T11	0	8.7	0	4.7	81.3	542.0
T12	0	0.0	6.7	162.0	219.0	1460.0
T13	0	15.3	0	4.7	64.3	428.7
T14	0	4.7	2	193.3	272.3	1815.3
T0	0	33.3	15.3	126.7	120.7	804.7

Table 1c: Effect of thiacloprid on *Aphis gossypii* (population /100 leaves) in main crop

	30.11.09	14.12.09	17.12.09	30.12.09	15.01.10	24.01.10
T1	0	0	0	0	0	24.7
T2	0	0	18	0	0	8.7
T3	0	62	0	0	0	4.7
T4	0	0	0	0	0	4.7
T5	0	0	0	0	4.7	0
T6	0	38	0	35.3	2	91.3

T7	0	20	0	0	0	0
T8	0	8.7	2	2	0	33.3
T9	0	0	0	0	0	0
T10	0	15.3	0	8.7	0	8.7
T11	0	2	0	0	0	2
T12	0	2	44.7	8.7	0	40
T13	0	4.7	0	0	0	0
T14	0	26.7	0	4.7	0	31.3
T0	35.3	18	2	8.7	0	64.7

Note: T1 - 1.0 ml/10lit two sprays at 15 days interval; T2 - 1.0 ml/10lit single spray; T3 - 1.5 ml/10lit two sprays at 15 days interval; T4 - 1.5 ml/10lit single spray; T5 - 2.0 ml/10lit two sprays at 15 days interval; T6 - 2.0 ml/10lit single spray; T7 - 2.5 ml/10lit two sprays at 15 days interval; T8 - 2.5 ml/10lit single spray; T9 - 3.0 ml/10lit two sprays at 15 days interval; T10- 3.0 ml/10lit single spray; T11- 3.5 ml/10lit two sprays at 15 days interval; T12- 3.5 ml/10lit single spray; T13- 4.0 ml/10lit two sprays at 15 days interval; T14- 4.0 ml/10lit single spray; T0- Control

Imidacloprid 60FC was tested as seed dressing against whitefly and both *M.persicae* and *A. gossipy* the aphids alone and along with monceren 250SC which controls black scruf.

Table 1 Effect of imidacloprid 60FC on whitefly

	27.11.10	11.12.10	26.12.09	19.01.10	28.01.10
T1-monceren+gaucho	1.65	11.65	6.7	0	0
T2-gaucho	1.65	13.65	3.3	1.65	1.65
T3-monc	0	18.3	1.65	0	0
T4-gaucho+spray	0	16.7	6.7	0	0
T5-spray alone	0	30	0	1.65	36.7
T0-control	13.3	23.3	0	0	0

Table 2 Effect of imidacloprid 60FC on leafhopper

	27.11.10	11.12.10	26.12.09	19.01.10	28.01.10
T1-monceren+gaucho	0	6.7	11.6	6.7	4.9
T2-gaucho	0	0	15	4.9	6.7
T3-monc	0	9.9	16.8	3.3	3.3
T4-gaucho+spray	0	3.3	3.3	3.3	6.6
T5-spray alone	0	10	3.3	3.3	3.3
T0-control	3.3	6.6	30	0	0

Table 3 Effect of imidacloprid 60FC on *Myzus persicae*

	27.11.10	11.12.10	26.12.09	19.01.10	28.01.10
T1-monceren+gaucho	0	0	1.65	33.3	56.7
T2-gaucho	0	0	0	5.0	50
T3-monc	0	0	33.35	170	195
T4-gaucho+spray	0	0	0	50	73.3

T5-spray alone	0	0	0	46.7	36.7
T0-control	0	0	156.7	400	1060

Table 4 Effect of imidacloprid 60FC on *Aphis gossyii*

	27.11.10	11.12.10	26.12.09	19.01.10	28.01.10
T1-monceren+gaucho	1.65	5.0	5.0	0	0
T2-gaucho	1.65	0	0	0	0
T3-monc	0	0	5.0	63.35	40.35
T4-gaucho+spray	0	3.3	0	0	0
T5-spray alone	0	0	0	0	0
T0-control	23.3	20	20	140	90

Cattle urine extracts of three indigenous plants neem (*A. indica*), ritha (*S. mukorossi*) and ratna jayot (*J. curcas*) were evaluated against *M. presicae* under polyhouse condition. It was observed that the extracts of neem (*A. indica*), and ratna jayot (*J. curcas.*) at 5% gave 93.33 and 73.33 per cent mortality followed by ritha (*S. mukorossi*) which gave 46.67 per cent mortality after 72h of treatment. All the extracts were also found effective in reducing the population of *M. persicae* in polyhouse planted potato crop when sprayed @ 10%. Neem extract proved most effective in reducing aphid population per plant i.e., 5.33 aphid's against 54.33 in untreated plants upto 14 DAS (Day after Spray). Extracts of all the tested plants contains oil which made fine film over the leaf surface and acted as a barrier for sucking pests. Spray of neem and ratna jayot extracts in cow urine at the rate of 10%, caused 87.97 and 82.98% mortality of glasshouse white fly (*Trialeurodes vapororium* (Westhood)) after 14 DAS. All the treated plants were found superior over control in minimizing the white fly population.

Management of white grubs: Initial surveys undertaken for ascertaining the magnitude of the damage caused by white grubs in Shilloroo, Matiana, Kheradhar, Fagu in Shimla district and Kheradhar in Shirmour and their adjoining area revealed 35 to 85 % tuber damage by white grubs. Studies on the bio-intensive management of white grubs revealed that eight species of white grubs viz., *Brahmina coriacea, B. flavoserica, B. crinicollis, Holotrichia* sp, *H. longipennis, Anomala lineatopennis, A. dimidiata* and *Lepidiota stigmata* causes economic loss to the crop. The most vulnerable stages of white grubs in potato fields are newly emerged beetles and first instar grubs. Amongst various eco-friendly management practices tried against white grubs i) light traps when installed in the vicinity of potato fields proved useful for mass trapping of newly emerged mated beetles. This prevents egg laying and thus indirectly reducing the white grub's population in potato fields, ii) Garlic & nerium leaves used as mulch were found effective in reducing grubs population in potato field, iii) the extracts of neem and jatropha seed kernels in cattle urine @ 10 ml/1 lit of water when applied at the base of the potato plants at the emergence of beetles significantly reduced the white grub's populations and tuber damage in the fields, iv) the pathogencity of locally isolated bacteria were evaluated against all the instars of white grubs,of these *Bacillus cereus, B. thuringensis* and *B. subtilis* were found effective causing upto 96% mortality of white grubs and less than 1% tuber damage in treated potato fields, v) the pathogencity of locally isolated fungi were also evaluated against all the instars, of these *Aspergillus flavus, Fusarium oxysporum* and *Fusarium solani* were found effective against all stages of white grubs, vi) two EPN species i.e. *Steinernema carpocapsae* and *Heterorhabdities indica* were procured from NBAII, Bangalore and after mass multiplication applied in potato fields, of these *S. carpocapsae* caused 60-100% and *H.indica* 65-80% reduction in white grub's population in treated potato fields and vii) natural predation of the immature stages of white

grubs by the birds at the time of field preparation and natural parasitization by two dipteran flies and one hemipteran spp. were also found effective in reducing white grub's populations in potato fields.

Based on three years intensive research, the following IPM schedule is recommended against white grubs in mid hills (Table - ----).

Table Bio-intensive management of white grubs schedule found viable and Recommended to the potato farmers.

Sr.No.	Time	Management Strategy to be followed	Remarks
1.	Field Preparation	Ploughing the fields twice before planting to expose white grub's stages to harsh weather and for predation by birds.	
2.	Planting.	a) Application of Bacillus spp. formulation (Bacillus cereus, local isolates)@1X 10^{10}CFU/ m^2 or Beauveria bassinaa @5g/m^2 @ 1x10^{10}/g mixed in well rotten FYM in furrows near the seed tubers or Steinernema carpocapsae@ 1x10^5ij/m^2. b) Installation of light traps in the vicinity of potato fields for mass trapping of beetles. c) Mulching the potato ridges with garlic, bana, stinging nettles, and eucalyptus leaves.	
3.	Beetle emergence(soon after first monsoon rains) or at earthing-up time	Drenching the ridges with NSK or Jatropha seed kernels extracts in cattle urine @0.5% and 1% and near the base of the potato plants. Mass collection of beetles from the light traps and alternate host plants and killing them in kerosenized water.	
4.	Tuberization stage.	Repeat the above mentioned plants extract as drenching treatment.	
5.	Harvesting.	Schedule harvesting soon after the maturity of the crop for preventing tuber damage by 2nd and third instars white grubs.	

The above recommended schedule when followed in the endemic areas would significantly reduce the white grub population and will also reduce the yield losses by white grubs in potato crop especially in mid and higher hills of India.

In trails for the management of white grubs treatment with the EPN, *Heterorhabditis indica* recorded the least infestation at harvest of 0.05 grubs per 5 plants at harvest and per cent tubers damaged of 0.37 followed by imidacloprid (0.15 grubs/5 plants and 0.30% tubers damaged) drenching at the time of appearance of the pest.

Management of *Helicoverpa armigera* (Hubner) on potato in Northern Himalayas: *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) is polyphagous pest. It is recorded as pest of potato *Solanum tuberosum* L. as their caterpillars feed upon the foliage and cause serious damage to the potato crop. On the population build up of *H. armigera* the prevailing temperatures, relative humidity and rainfall were found to play important role.The most congenial average maximum and minimum temperature, maximum relative humidity, monthly rainfall for peak activity of *H. armigera*

during 2008 and 2009 ranged from 24.85-26.89 ^{0}C (Av. 25.87^{0}C), 15.56 – 18.58^{0}C (Av. 17.07^{0}C), 54-66.5%(Av. 60.4%) and 3.13 – 7.2 mm (Av.5.06 mm) respectively. Life cycle studies showed the mean incubation period of egg, larval and pupal period of *H. armigera* on potato was 4.4, 20.4, 7.3 days, respectively. The average fecundity of *H. armigera* was recorded as 94 eggs per female on potato leaves. The adult (female) longevity was 3.8 days. The size and weight of every stages of pest revealed that the body length of first, second, third, fourth, fifth instars measured1.4, 6.7, 123.5, 19.4, 43.9mm, width measured 0.5, 0.51, 2.2, 2.3, 3.2, and 3.5mm, and weight of the respective instar was 0.6, 0.8, 53.5, 163.3 and 305.5mg. The natural mortality in the field-collected larvae were 14.3 %.

Management of potato nematodes

Potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*) and late blight are the major biotic constraints for potato cultivation in the Nilgiris region. These problems are managed by integrating pesticides, host resistance and alternating crop sequences. The programme aims at continued research for breeding potato and selection of genotypes possessing combined resistance to Potato Cyst Nematodes and late blight besides developing suitable agronomical practices for increased potato production in the region.

Breeding for resistance to late blight and potato cyst nematodes

Ten biparental crosses involving selected PCN resistant parents were made during the year and 40,300 seeds were produced. In the F_1 generation about 13,500 true seeds belonging to 6 cross combinations were sown in boxes. Eleven thousand seedlings were transplanted in field /poly house and screened under natural conditions of late blight. On maturity, the seedlings were harvested and 1028 selections were made. In initial evaluation one thousand four hundred and eighteen hybrid clones were evaluated in single hill/observational rows along with K. Girdhari and K. Swarna as check varieties. Of these, 357 hybrids were selected. Fifty five advance generation hybrids were evaluated in four replicated trials along with Kufri Girdhari and Kufri Swarna as checks. Of these, thirty two hybrids were selected on the basis of agronomic traits and resistance to potato cyst nematodes and late blight.

Trial with advance generation promising hybrids

Of the 6 promising advance generation hybrids assessed, one the hybrid viz. OS/01-516 out yielded the best control K.Girdhari. The hybrid holds promise as it is found to be resistant to both species of potato cyst nematodes and field resistant to late blight (Table-1).

Trial with hybrid OS/93-D-204

The promising hybrid OS/93-D-204 was tested in Onfarm trials under AICRP (Potato) in farmer's field. The hybrid yielded higher than the best control in 7 locations (Kookalthorai 9.06%; Glen Morgan 8.46%; Aduthorai 14.79%; Fernhill 8.81%; Wellington 26.59%; Nanjanad 21.91%; Aadasholai 48.59%) out of 10 locations tested in farmer's field in onfarm trials (Table 2). The hybrid recorded better level of field resistance to late blight and resistance to both species of potato cyst nematodes compared to the checks (Table 3 & 4; Fig. 3). The hybrid has been recommended for release at 27th Group Meeting of Potato Workers of All India Co-ordinated Research Project (Potato) held at University of Agricultural Sciences, Dharwad (Karnataka) on 10-12 August, 2009.

Table 1. Trial with promising advance generation hybrids

Sl. No.	Hybrid/ Cultivar	Yield q/ha	Reaction**			
			Late blight*	*G. pallida*	G.rostochiensis	*Remarks*

1.	OS/94-I-126	177.34	5	R	R	
2.	OS/01-118	149.71	5	R	R	
3.	OS/01-161	105.68	5	R	R	
4.	OS/01-392	140.26	5	R	R	
5.	OS/01-497	241.36	5	R	R	
6.	OS/01-516	316.08	6	R	R	Promising
7.	K.Girdhari	276.64	6	S	S	
8.	K.Swarna	93.46	3	R	R	
9.	K.Jyoti	83.74	3	S	S	
Plot size : 9.0m^2 SE+- : 7.23 CD (0.05): 14.93 CV : 5.81 SD : 10.23						

* LB score on 1-9 scale where 9 highly resistant and 1 highly susceptible;
** R = Resistant; S = Susceptible

Table 2. Yield Performance of OS/93-D-204 in On Farm trials

	Yield (q/ha)										
	Location*										
Cultivar	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Av.**
OS/93-D-204	**317.00**	**397.33**	**313.00**	**447.00**	**543.67**	**536.33**	**157.67**	**195.33**	**507.67**	**463.33**	**387.83**
K.Giriraj	284.67	366.33	250.33	464.00	458.00	423.67	117.67	323.33	301.33	456.00	344.53
K.Swarna	290.67	356.33	272.67	446.00	420.00	365.00	129.33	274.67	341.67	532.67	342.90
K.Jyoti	279.67	357.33	242.67	435.33	499.67	421.67	116.00	268.33	316.67	400.00	333.73
CD (0.05)	12.72	12.52	8.91	19.59	14.39	14.97	9.96	16.23	8.86	14.87	
On Farm Trials : Per cent increase in yield in OS/93-D-204 over controls											
K.Giriraj	11.36	8.46	25.03	-3.66	18.70	26.59	33.99	-39.59	68.47	1.61	15.10
K.Swarna	9.06	11.51	14.79	0.22	29.44	46.94	21.91	-28.88	48.59	-13.02	14.06
K.Jyoti	13.35	11.19	28.98	2.68	8.81	27.19	35.92	-27.20	60.32	15.83	17.71

Location: 1.Kookkalthorai; 2. Glenmorgan; 3.Aduthorai; 4.Keethi; 5.Fernhill; 6.Wellington; 7.Nanjanad; 8.Thumnahatty; 9.Aadasholai; 10. Emerald

Table 3. Late Blight Reaction in On Farm Trials

Locations*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Av
Hybrid/Variety	**LB grade***										
OS/93-D-204	6	6	6	6	6	6	5	5	6	6	5.8
K.Giriraj	5	5	4	5	5	5	4	4	5	5	4.7
K.Swarna	5	5	5	6	6	5	4	5	5	6	5.2
K.Jyoti	5	4	4	5	5	5	4	4	5	5	4.6

*LB resistance grade in 1-9 scale where 1= highly susceptible & 9= highly resistant.
***Location**: 1.Kookkalthorai; 2.Glenmorgan; 3.Aduthorai; 4.Keethi; 5.Fernhill; 6.Wellington; 7.Nanjanad; 8.Thumnahatty; 9.Aadasholai;10. Emerald

Table 4. Reaction to potato cyst nematodes under controlled condition

Varieties/ Lines	***Globodera pallida***	***Globodera rostochiensis***
OS/ 93- D-204	R	R
Kufri Giriraj	S	S
Kufri Swarna	R	R
Kufri Jyoti	S	S

R= Resistant S= Susceptible

Integrated management of potato cyst nematodes

Evaluation of chemical and biological nematode management practices: Application of carbofuron and phorate @ 2 kg a.i /ha reduced the multiplication of PCN and improved the potato yield compared to the untreated control and carbofuran performed better than phorate

(Table 5). Neem cake blended with *T. viride* recorded significantly higher yield and lower PCN multiplication among the various organic amendments evaluated against PCN and was comparable with carbofuran (Fig 4). Significant biosuppression of PCN coupled with enhanced potato yield was achieved by the application of the bio control agent *Pseudomonas fluorescens* @10 kg/ha (Table 6).

Performance of potato varieties/lines individually and in combination with the nematicide revealed that varieties/ lines with carbofuran application performed better than those without carbofuran. The hybrid OS/93-D- 204 recorded relatively higher tuber yield and lower PCN multiplication than other varieties/ lines tested (Table 7).

Evaluation of cropping systems for nematode management: Potato (K. Giriraj) + broadbean intercropping in 1:1 ratio reduced PCN population by 10 per cent. However, monocropping of OS/93-D-204 was more effective than intercropping with Broadbean in managing PCN. But the yield advantage in terms of PEY was more when it was intercropped with Broadbean at a population proportion of 2:1 (Table 8). Effect of various soil management strategies on PCN dynamics revealed lower PCN population in monocropping of advance hybrid OS/93-D-204 (reduction of 22%) and it was closely followed by the recommended practice of growing potato + French beans intercropping (Table 9).

Table 5. Effect of nematicides on the multiplication of PCN and tuber yield of potato

Treatment	Yield (kg/plot)*			PCN multiplication (Rf)**		
	Kufri Jyoti	Kufri Giriraj	Kufri Swarna	Kufri Jyoti	Kufri Giriraj	Kufri Swarna
Carbofuran @ 2 kg a.i/ha	16.81	12.66	21.90	0.83	0.92	0.75
Carbofuran @ 4 kg a.i/ha	17.54	13.10	22.68	0.77	0.78	0.68
Phorate @ 2 kg a.i/ha	14.03	11.91	20.60	1.21	1.01	0.81
Phorate @ 4 kg a.i/ha	15.95	12.10	21.39	1.12	0.95	0.78
Untreated control	12.31	10.34	18.32	2.29	1.92	0.97

* Plot size = 9 m^2; ** Rf = nematode reproduction factor.

Table 6. Effect of biological control agents on the multiplication of PCN and tuber yield of potato

Treatment	Yield (kg/plot)*	PCN multiplication (Rf)**
T1-*Paecilomyces lilacinus* @ 20 kg /ha	9.17	1.34
T2- *Pochonia chlamydospora* @ 20 kg /ha	8.85	1.42
T3-*Trichoderma viride* @ 20 kg /ha	8.65	1.52
T4-*Pseudomonas fluorescens*@ 10 kg /ha	9.97	1.25
T5-*Pseudomonas sp.* @ 10 kg /ha	9.03	1.38
T6-Carbofuran @ 2 kg a.i/ha	10.30	0.89
T7-Untreated control	6.93	2.19

* Plot size = 7.2 m^2; ** Rf = nematode reproduction factor

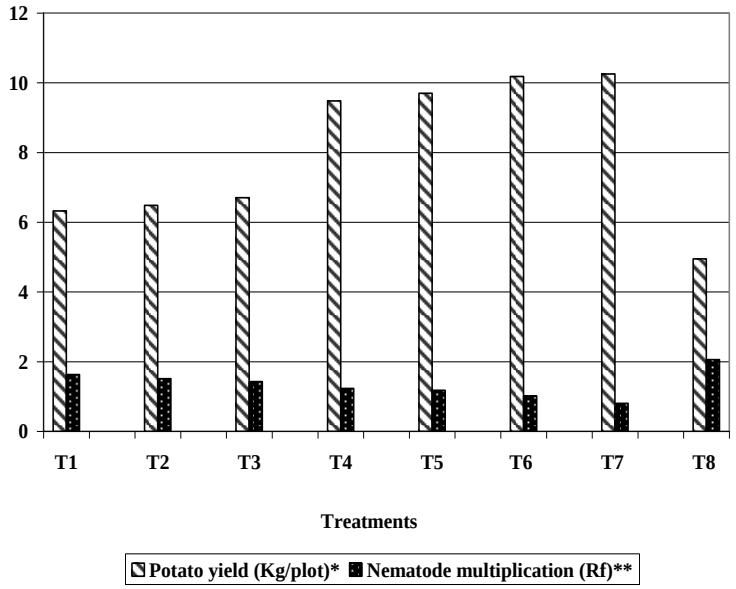
Table 7. Evaluation of resistant varieties/lines for the management of PCN

Treatment	Yield (kg/plot)*					PCN multiplication (Rf)**				
	Kufri Jyoti	Kufri Giriraj	Kufri Swarna	OS/93-D- 204	OS/94-L- 956	Kufri Jyoti	Kufri Giriraj	Kufri Swarna	OS/93-D- 204	OS/94-L- 956
Carbofuran	13.05	10.83	16.87	21.90	13.43	1.23	1.42	0.96	0.93	1.09

treated										
Untreated control	11.58	10.10	14.62	19.58	12.78	1.98	2.02	1.04	1.00	1.12

* Plot size = 9 m^2; ** Rf = nematode reproduction factor

Fig.4. Effect of organic amendments on potato yield and PCN multiplication



[T1- Eucalyptus cake @ 10 t/ha; T2 - Spent mushroom compost @ 10 t/ha; T3 - Neem cake @ 5 t/ha;,T4 - T1 + *T. viride;* T5 - T2 + *T. viride;* T6 -T3 + *T. viride* ; T7 –carbofuran @ 2 kg a.i/ha ; T8 – control]

* Plot size = 7.2 m^2; ** Rf = nematode reproduction factor

Table 8. Yield and PCN population as affected by potato intercropping with Broadbean

Treatment	PEY (kg/plot)			PCN			
	K.Giriraj	OS/D-204	Mean		K.Giriraj	OS/D-204	Mean
P+Bb(1:1)	17.34	21.26	19.3	T1	216	248	232
P+Bb(2:1)	15.59	25.7	20.65	T2	231	234	233
P+Bb(3:1)	14.33	22.18	18.25	T3	255	225	240
Broadbean	15.13	25.44	20.28	T4	202	214	208
Potato	17.38	19.85	18.61	T5	356	200	278
Mean	15.95	22.88		Mean	254	238	
	Sed	CD5%			Sed	CD5%	
V	2.72	6.16		V	3	7	
T	4.3	NS		T	5	11	
VxT	6.08	NS		VxT	7	16	

Table 9. Effect of soil management practices on yield and PCN populations

Treatment	PEY (Summer)	PEY (Autumn)	PEY of the system (t/ha)	PCN after summer harvest	PCN after autumn harvest
K.Giriraj					
T1: Monocrop-potato	10.75	4.99	15.74	358	412
T2:Potato-Cabbage (Farmers' practice)	13.14	9	22.14	269	275
T3: Potato-Cabbage (20 t FYM to potato)	11.94	9.23	21.17	288	304
T4: Potato + French beans (Intercrop) -cabbage Recommended)	18.06	7.47	25.53	232	220
OS/93-D-204					
T1: Monocrop -potato	23.15	5.46	28.61	232	194
T2:Potato-Cabbage (Farmers' practice)	20.3	8.7	29	255	223
T3: Potato-Cabbage (20 t FYM to potato)	14.43	9.57	24.99	275	251
T4: Potato + French beans (Intercrop) -cabbage Recommended)	20.73	6.97	27.69	235	205
SEd					
V	0.79	0.57	0.95	3.2	5.4
T	1.11	0.8	1.35	4.6	7.7
VxT	1.57	1.13	1.91	6.5	10.8
CD5%					
V	1.63	NS	1.98	6.7	11.3
T	2.31	1.67	2.81	9.5	15.9
VxT	3.26	NS	3.97	13.4	22.5

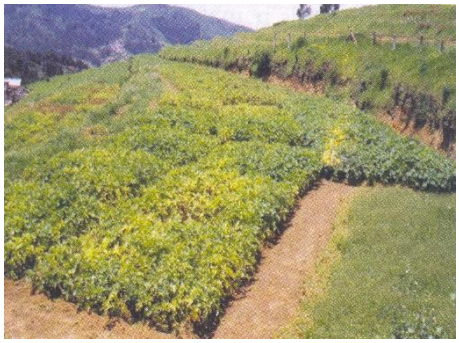


Fig.1. PCN infected crop

Fig.2. PCN on potato roots

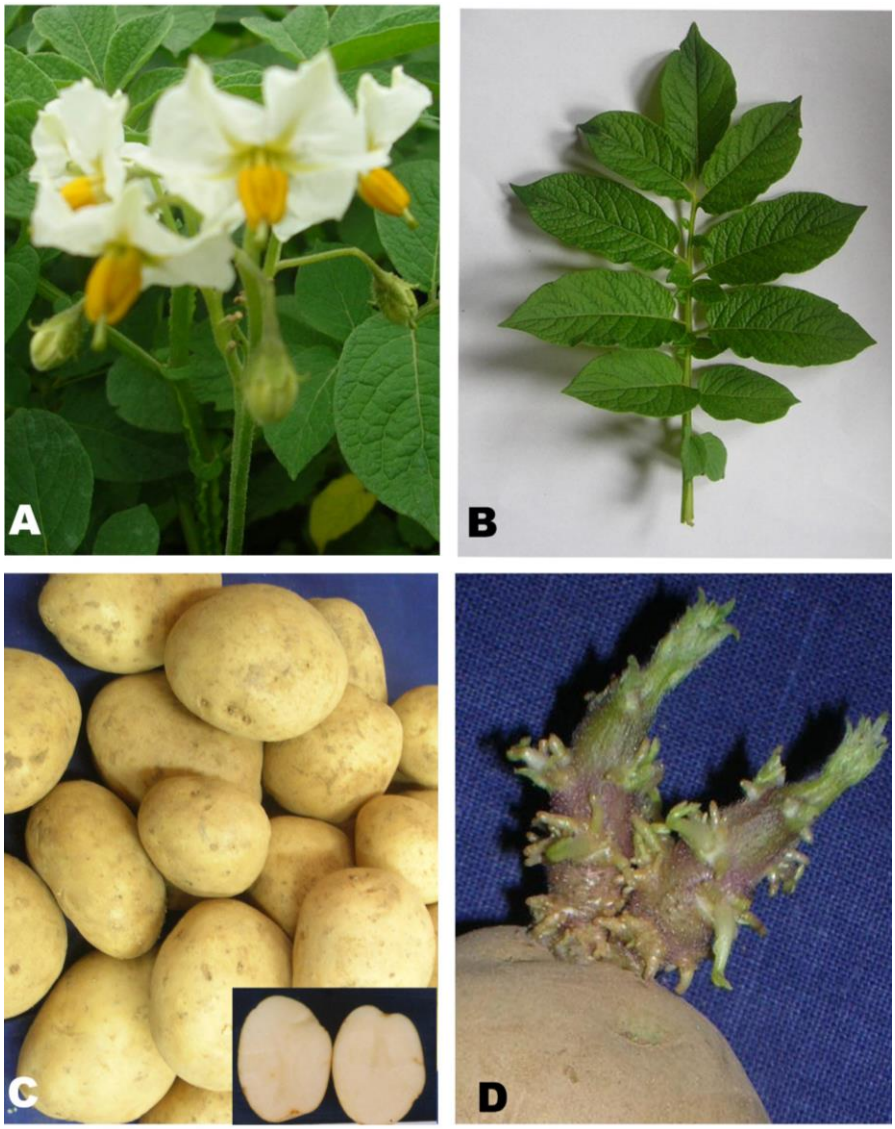


Fig.3. A. Flowers; B. Leaf; C. Tubers; D. Sprouts of hybrid OS/93-D-204

DIVISION OF CROP PHYSIOLOGY AND POST HARVEST TECHNOLOGY

Programme: Diversified Utilization of Potatoes

The aim of this programme is to process potatoes into different products & to determine the quality as well as the nutrients content of the products.

Development of a field applicable method for sugar estimation in potato tubers

For selection of potatoes suitable for processing during large scale initial screening of population in breeding programme and for sugar estimation in the field for the potato processors, availability of cheaper and simple methods of sugar estimations are desirable. The use of qualitative Benedict's reagent for the estimation of reducing sugar was tried last year. This work was continued and the procedure was standardized. The flow chart (Fig.1) showing the steps involved in the reducing sugar estimation and the results of the estimations (Table 1) are presented here. The whole kit needs a hand peeler, grater, muslin cloth, beaker, 10 ml glass pipette, test tubes (15 ml), spirit lamp and qualitative Benedict reagent. The samples showing negative results can be considered suitable for processing.

Fig. 1. Steps involved in reducing sugar estimation

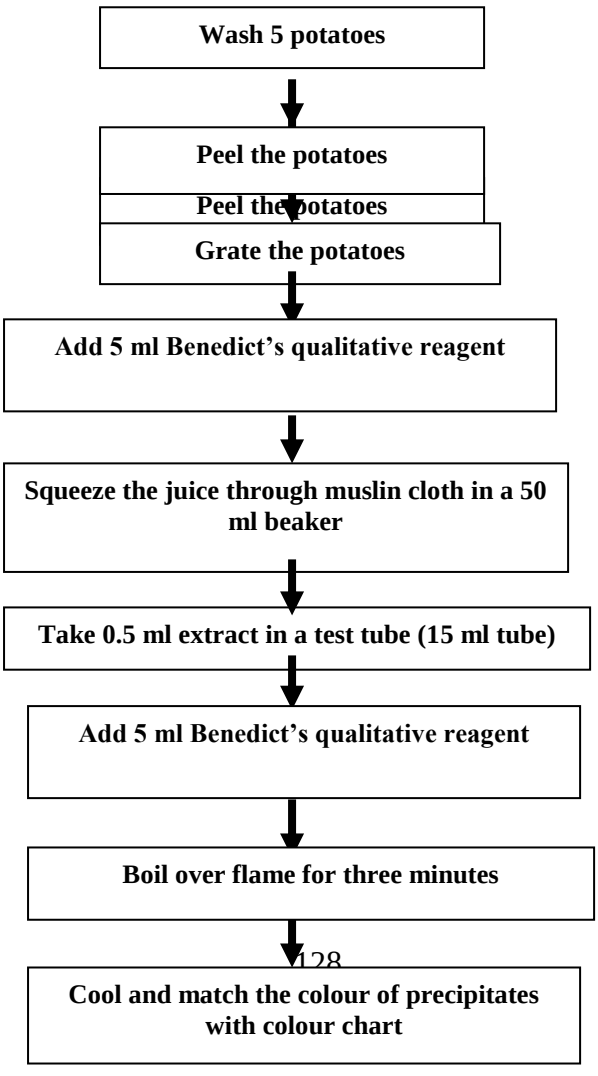


Table 1. Estimation of reducing sugars in potato tubers using Benedict's qualitative reagent

Variety	Chip Colour (Visual)	dL value	Da value	Glucose mg/100 g fr wt*	Colour of solution	Colour of precipitate	Conc. Of red. Sug. By Benedict as per ppt
K Chipsona-1	2.3	51.5	6.5	9.2	Blue	Blue	Negative (< 0.5 %)
K Chipsona-2	2.4	57.1	3.8	12.4	Blue	Blue	Negative (< 0.5 %)
K Chipsona-3	3.3	56.1	4.0	14.4	Green	Green	0.5%
K Himsona	3.9	52.7	6.9	5.3	Blue	Blue	Negative (< 0.5 %)
K Surya	2.0	54.0	4.4	15.3	Blue	Blue	Negative (< 0.5 %)
Atlantic	4.0	48.1	8.0	1.5	Blue	Blue	Negative (< 0.5 %)
Lady Rosetta	3.8	55.7	3.4	6.8	Blue	Blue	Negative (< 0.5 %)
K Bahar	7.9	39.2	9.5	263.8	Green	Yellow	1.5%
K Anand	8.5	28.3	10.6	251.4	Green	Orange red	Between 1.5-2.00%

*By YSI Biochemistry Analyser

Effect of home processing on nutritional and anti-oxidant constituents in potatoes

Influence of pressure cooking and microwave cooking on the total solids, nutritional constituents and three antioxidant compounds viz. phenols, L-ascorbic acid and total carotenes was studied in five varieties. Microwave cooking increased the total solid content as compared to raw potatoes. Pressure cooking decreased the reducing sugar and sucrose content while microwave cooking increased the contents of both the sugars. Contents of free amino acids, total phenols and ascorbic acid increased in both boiled and microwave cooked potatoes as compared to raw potatoes. The contents of anti-oxidant compounds were higher in microwave cooked potatoes (Table-2). There were significant variations in the contents of different nutrients among varieties and the effect of different cooking methods.

Table 2. Effect of home processing on anti-oxidant constituents of potatoes.

Variety	Total carotene[1] (ug)			Total phenol[1] (mg)			Ascorbic acid (mg)		
	Raw potato	Pressure cooking	Microwave cooking	Raw potato	Pressure cooking	Microwave cooking	Raw potato	Pressure cooking	Microwave cooking
K.Chipsona-1	70.3	80.9	77.1	40.3	36.1	70.4	10.79	13.34	16.83
KChipsona-3	63.6	45.2	87.7	38.9	43.4	46.0	9.84	14.92	15.24
K.Surya	155.0	168.5	169.3	54.3	80.1	83.7	13.02	14.92	19.69
K.Frysona	73.2	92.5	60.7	30.3	38.9	66.6	12.70	11.11	19.97
Kennebec	76.1	47.2	67.4	60.9	51.7	63.1	13.02	13.34	17.15
Mean	87.6	86.9	92.4	44.9	50.0	66.0	11.87	13.52	17.76

[1]per 100 g fresh weight

Preparation of extruded product

Extrusion processing in the food industry is quite popular. During extrusion cooking, a flour containing to about 20% moisture is compressed and heated above the gelatinization temperature and then expanded through die to a puffed and porous product of desired shape and size. Food manufacturers are introducing new extruded convenience foods of various shapes, flavours, colours and texture. An attempt was made to produce an extruded product using potato in collaboration with CTCRI, Thiruvananthapuram. A blend of potato (20%) and cassava (80%) flours was prepared and an extruded product was prepared using Brabender's extruder. The extruded product was compared with that prepared using 100% cassava flour. The potato + cassava flour blend produced an extruded product which was lighter in colour (Fig.2). Work is in progress to try blends of potato and cassava flours in different proportions for preparing extruded products and to determine the texture of those products.

Fig. 2. Extruded product prepared from a blend of cassava (80%) and potato (20%) flours

Preparation of potato flakes

Potato flakes were prepared from seven potato varieties including the exotic variety Kennebec. Flakes recovery was directly related to dry matter content. Kufri Frysona produced maximum flake yield (20.1%) followed by Kufri Chipsona-3 (18.5%) and Kufri Chipsona-1 (18.1%) (Table 3). Flakes prepared from processing cultivars were of acceptable light cream/light yellow colour, whereas Kufri Pukhraj and Kufri Sutlej produced light brown colored flakes with low yield recovery.

Table 3. Yield and quality of flakes prepared from freshly harvested potato varieties

Variety	Tuber dry matter (%)	Peeling loss (%)	Flakes recovery on fresh weight basis (%)	Colour of flakes
K.Chipsona1	20.85	9.50	18.11	LC
K.Chipsona3	25.7	9.19	18.52	LC
K.Surya	20.5	10.18	16.91	LY
K.Frysona	22.5	9.10	20.08	LC
Kennebec	17.1	9.70	14.35	LC
K.Pukhraj	19.65	10.96	12.83	LB
K.Sutlej	16.55	9.80	14.56	LB

LC: Light cream, LY: Light yellow, LB: Light brown

Yield and quality of Potato *Lachha*

Fresh fried potato *laccha* was prepared from freshly harvested *nine* potato cultivars. Peeling losses varied between 7.85 (K.Chipsona-2) to 11.67 (K. Jyoti) (Table 4). Yield recovery ranged between 21.8% (K. Jyoti) and 37.2% (K. Himsona). The colour of lachha prepared from processing cultivars was of acceptable light colour. Yield and quality of potato *lachha* was also studied in potatoes stored in heaps and at 10-12^{o}C for 100 days. Colour of *lachha* prepared from processing cultivars stored under both the conditions was highly acceptable, per cent recovery was higher at 10-12^{o}C and oil uptake was low under heap storage.

Evaluation of processing varieties for quality of frozen French fry

French fries of highly acceptable colour (score up to 2.5) were prepared from freshly harvested potatoes of five processing cultivars. Yield recovery was higher (44.4-44.8%) in Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Surya (Table 5), whereas

fries made from Kufri Frysona and Kennebec were firmer in texture (1530 and 1600 g force, respectively). Oil content in fries ranged from 10.5 to 12.6%.

Table 5. Textural quality of frozen French fries from freshly harvested potato cultivars

Varieties	[1]Colour	Yield (%)	[2]Texture (g force)	Oil content (%)
K. Chipsona-1	1.50	44.4	851	12.6
K. Chipsona-3	2.50	44.4	1274	12.5
K. Surya	2.00	44.8	1219	10.5
Kufri Frysona	2.00	41.9	1530	11.0
Kennebec	2.00	39.7	1600	11.5
Mean	2.00	43.04	1294.8	11.62

[1]On a 1-10 scale of increasing dark colour, chip colour score up to 3 was acceptable
[2]Higher force indicates firmer texture of fries

Decreasing oil content in potato chips

Treatment with magnesium chloride, calcium chloride and starch along with blanching at 70°C was tried last year to decrease oil content of potato chips. This year the same chemical treatments were tried at room temperature and tuber slices were dipped in magnesium chloride (0.5%), calcium chloride (0.5%) and soluble starch (0.25%) for 2.5 and 10 minutes. Two varieties viz. Kufri Chipsona-1 and Kufri Jyoti were used in this experiment. With the use of calcium chloride mean oil content was 29.3% as compared to control (33.0 %). There was uniform effect of treatment time and variety. The mean chip colour (subjective) was superior in control (7.5) as compared to calcium treatment (8.0). The chip whiteness (dL) determined objectively through Hunter colour meter were also higher in control (37.1) as compared to calcium treatment (33.3). Higher dL values are desirable. There was no effect of calcium treatment on redness (da values) of chips. The treatment of magnesium chloride (0.5%) also led to decrease in oil content as compared to control, which was independent of time and variety. There was no effect of this treatment on chip yield or subjective colour score; however the dL value was higher in the control when compared to magnesium chloride treatment. The soluble starch (0.25%) did not have any effect on the oil content of chips. On the basis of two years studies it can be concluded that calcium and magnesium treatment lead to lowering of oil content in potato chips.

Acrylamide content in potato chips prepared from Indian potato varieties

Acrylamide formed formed during the frying of potato chips is considered toxic to humans if consumed in higher concentrations. Therefore, it was felt that there is a need to determine acrylamide content in potato chips prepared from Indian potato varieties. Freshly harvested tubers of 41 Indian potato varieties grown at Kufri were processed for preparing chips as per the standard procedure. The colour grading (on 1-10 scale of increasing dark colour) was done and the chips were sampled for acrylamide determination in them as per the HPLC procedure developed in the laboratory. Reducing sugar concentration was determined in tuber samples before processing.The minimum concentrations of acrylamide were observed in processing varieties *viz.*, Kufri Chipsona-2 (40 μg/kg), Kufri Himsona (56 μg/kg), Kufri Chipsona-3 (69 μg/kg) and Kufri Chipsona-1 (109 μg/kg). These varieties also contained lower concentrations of reducing sugars in the tubers and had lower colour score (Table 6). The varieties Kufri Jyoti, Kufri Surya, Kufri Lauvkar and Kufri Chandramukhi, which are also being used for processing at commercial scale had comparatively lower concentrations of acrylamide (108-306 μg/kg). These had intermediary colour scores for chips and had less reducing sugars in their tubers. The varieties, which are considered unsuitable for processing *viz.*, Kufri Anand, Kufri Girdhari, Kufri Sutlej, Kufri Arun, Kufri Lalima, Kufri Kanchan, Kufri Pukhraj, etc. contained very high concentrations of acrylamide in them (> 1000 μg/kg). These varieties also had high concentrations of reducing sugars and showed unacceptable chip colour on frying. The acrylamide content of chips showed a positive and significant correlation with chip colour, and a positive but non-significant correlation with reducing sugar content of tubers. The results indicated that dark colour formation in chips due to high concentrations of sugars is not only undesirable, but can also be harmful as acrylamide concentration in such chips are high.

Table 6. Acrylamide content (ug/kg wt) in potato chips and its relation with chip colour score (1-10 scale) and reducing sugars concentration (mg/100 g f. wt) in tubers

S. No.	Variety	Acrylamide content	Chip colour score (CC)	Reducing sugars (RS)
1.	Kufri Alankar	474	7	176
2.	Kufri Anand	1388	6	519
3.	Kufri Arun	1459	7	92
4.	Kufri Ashoka	990	7	361

5.	Kufri Badshah	414	7	182
6.	Kufri Bahar	574	7	186
7.	Kufri Chamatkar	451	7	172
8.	Kufri Chandramukhi	108	6	125
9.	Kufri Chipsona-1	109	4	101
10.	Kufri Chipsona-2	40	4	95
11.	Kufri Chipsona-3	69	3	73
12.	Kufri Dewa	436	7	218
13.	Kufri Girdhari	3252	6	202
14.	Kufri Giriraj	812	7	187
15.	Kufri Himalini	388	7	378
16.	Kufri Himsona	56	5	97
17.	Kufri Jawahar	510	7	172
18.	Kufri Jeevan	1137	7	125
19.	Kufri Jyoti	147	6	146
20.	Kufri Kanchan	3799	7	168
21.	Kufri Khasigaro	559	7	357
22.	Kufri Kuber	410	6	380
23.	Kufri Kumar	603	6	70
24.	Kufri Kundan	292	7	293
25.	Kufri Lalima	1173	7	176
26.	Kufri Lauvkar	252	6	117
27.	Kufri Megha	444	7	157
28.	Kufri Muthu	679	7	205
29.	Kufri Naveen	771	8	160
30.	Kufri Neela	395	6	175
31.	Kufri Pukhraj	1052	6	340
32.	Kufri Pushkar	494	7	328
33.	Kufri Red	643	5	86
34.	Kufri Safed	269	7	117
35.	Kufri Shailja	594	7	150
36.	Kufri Sheetman	678	7	120
37.	Kufri Sherpa	514	7	136
38.	Kufri Sindhuri	503	6	125
39.	Kufri Surya	306	6	145
40.	Kufri Sutlej	3043	8	92
41.	Kufri Swarna	645	7	205
	Correlations	**Acryl x CC**	**Acryl x RS**	**CC x RS**
	r at 40 df = (0.30)	**0.32**	**0.06**	**0.24**

Starch recovery in potatoes after storage under different conditions

Extraction of starch from six potato cultivars stored under different conditions *viz.* heap, 10-12 ^{o}C and 2-4 ^{o}C for 90 days showed that mean dry matter content was maximum under heap storage and minimum at 2-4 ^{o}C (Table 7). Recovery of starch from stored potatoes was higher as compared to freshly harvested potatoes and was maximum (11.75%) in potatoes stored at 10-12^{o}C and minimum (9.74%) at 2-4 ^{o}C.

Table 7. Recovery of starch from potato varieties stored for 90 days (2.6.09) under different conditions

Variety	Dry Matter (%)			Recovery of starch on fresh tuber wt(%)		
	Heap	10-12^{o}C	2-4^{o}C	Heap	10-12^{o}C	2-4^{o}C
KChipsona-1	22.8	23.3	21.45	13.79	13.10	11.54
KChipsona-2	26.85	26.5	24.3	12.14	12.43	11.08
KChipsona-3	25.5	23.3	22.5	10.46	15.33	13.25
K. Surya	20.2	22.15	20.15	11.48	11.49	7.09
K. Sutlej	18.0	17.4	16.8	8.75	9.03	7.75
K. Pukhraj	19.7	18.7	17.5	7.19	9.14	7.75
Mean	22.17	21.89	20.95	10.64	11.75	9.74

Programme: Storage behaviour and processing quality of potatoes under controlled temperatures and non-refrigerated storage systems

Studies on evaluation of potato genotypes for storability and processing quality under traditional systems and elevated storage temperatures and development of variety specific techniques for storage of processing potatoes were continued. Besides efforts were made for transfer of technology on improved heap storage technology to the farmers and the processing industries through on- farm trainings and demonstrations, live phone-in programme on Doordarshan and reports/news items in the local news papers.

Industrial evaluation of heap stored potatoes of processing cultivars

CPRI has developed an improved heap storage technology for short-term storage of table and processing potatoes with the use of CIPC (isopropyl N-(3-chlorophenyl) carbamate). Potatoes of three processing cultivars stored in heaps for 90 days were evaluated for processing quality by ITC, Ltd at their laboratory in Roorkee. To make international quality potato chips undesirable colour (UC) should not exceed 5% and total potato defects (TPOD) which includes UC and external and internal defects,

should be less than 15%. UC and TPOD was nil in cvs. Kufri Chipsona-1 and Kufri Chipsona-3 and less than 5.0% in Kufri Lauvkar (Table 1) and the potatoes were remarked as highly acceptable for processing. Reducing sugars decreased and chip colour improved during storage in our laboratory analysis also. Treated potatoes remained firm and sprout free whereas untreated (control) potatoes with multiple sprouts appeared shriveled (Fig 1). Total storage losses in CIPC treated potatoes were much reduced (8-10%) compared to control (14-16%). Improved heap storage technology can thus profitably be used to preserve the quality of processing potatoes for three months at lower storage cost (15-20 Rs/q) as compared to 10-12^{o}C storage (150-160 Rs/q).

Post-harvest losses and quality of potatoes at elevated temperatures (18-39^{o}C, 15-75% RH)

Tuber treatment with CIPC was evaluated for sprout inhibition and reduction in post-harvest losses in two potato cultivars *viz.* Kufri Pushkar and Kufri Surya generally preferred for export. Even lower rates of CIPC application (20-40 ml/tonnes) suppressed sprouting and reduced total losses in potatoes. Treated potatoes of cv. Kufri Surya with low reducing sugar content (≤100mg/100g fresh weight) were suitable for processing into chips up to 80 days (Table 2), whereas cultivar Kufri Pushkar can be exported for table purpose. CIPC residues in peels of potato tubers (2.31-6.75 mg/kg fresh weight) were far below the permissible limits of 30 mg/kg tuber weight and the potatoes were safe for human consumption

Storability and processing quality of newly released potato cultivars under heap and pit

Storability of Kufri Himsona and Kufri Chipsona-3 was very good with lower total losses as compared to Kufri Chipsona-1. Kufri Jyoti recorded minimum loss (12.88%) in heap and Kufri Himsona recorded minimum loss (6.78%) under pit storage up to 90 days. Reducing sugar content in the three processing cultivars remained ≤100mg/100g fresh weight and the chip colour was highly acceptable up to mid June, whereas cv. Kufri Jyoti with higher sugar content produced dark colour chips.

Processing quality of potatoes stored in heap with CIPC

Determination of chip colour and important processing parameters in tubers of 9 processing varieties/hybrids stored in heap showed that CIPC treated potatoes

recorded lower reducing sugar and sucrose contents up to 90 days and produced chips of highly acceptable colour with more crispness as compared to untreated control potatoes. CIPC treated potatoes also recorded less peeling loss, more recovery of chips and lower oil content.

Non-toxic compounds for control of storage rots

Evaluation of tuber treatment with nine safe chemicals under heap storage showed that soft rot was the major component of rots accounting for 83.4% of total tuber rots, followed by charcoal rot (13.5%) and dry rot (2.8%). Rotting was reduced in CIPC treated tubers stored with clove oil @ 3ml/100 tubers, followed by tubers placed along with Naphthalene balls wrapped in paper @ 10g/100 tubers and Neem powder @ 20g/100 tubers (Fig 2)

Storability of processing hybrids

Evaluation of 12 advanced hybrids for storability at room temperature revealed minimum total losses in MP/04-578 followed by MP/03-626, MP/2K-516 and MP/98-172 (Fig 3) up to 90 days. Losses were at par with the control cvs. Kufri Surya and Kufri Chipsona-1.

Changes in biochemical parameters and chipping quality during storage at 10-12^{o}C with CIPC

Ten processing varieties were stored at 10-12^{o}C for 165 days to study the pattern of changes in biochemical parameters (chipcolour reducing sugars, sucrose, phenols, free aminoacids) affecting chipping quality. Mean reducing sugar contents increased up to 165 days with intermittent decrease at 105 days (Fig 4). Lowest values were recorded for Kufri Chipsona-2 and Kufri Chipsona-3 followed by Lady Rosetta. Sucrose contents decreased at 45 days and followed a zig-zag pattern later on. The mean sucrose contents were lowest in Kufri Chandramukhi, followed by Kufri Jyoti and Kufri Surya. Phenol content increased after 45 days of storage and then decreased till 165 days with mean contents being highest in Kufri Jyoti (91.8 mg/100 g fresh weight). Free amino acids decreased till 75 days and thereafter showed an increase till 135 days with highest mean contents of 735.1 mg/100 g fresh wt in Kufri Lauvkar.

In another study to evaluate chipping quality of 9 processing varieties/hybrids at 10-12^{o}C, acceptable chips were produced from Kufri Chipsona-1, Kufri Surya, Kufri Himsona, Kennebec and MP/01-916 up to 90 days while Kufri Himsona, Kufri Surya

and Kennebec produced acceptable chips up to 120 days. Chips of Lady Rosetta and Kufri Frysona were of superior texture.

Processing quality of potatoes after prolonged storage

Potatoes of four cultivars stored at 4, 8 and 12°C with CIPC treatment were evaluated for processing quality after prolonged storage up to 270 days. The reducing sugar content was quite high, being more than 800 mg/100g fr wt at 8 and 12°C even in the two processing cultivars (Table 3) and the chip colour was highly unacceptable in all the cultivars. Sucrose accumulation was also very high. Generally, there was a decrease in the phenol content with increase in storage temperature and free amino acids did not show a clear trend. Total deterioration in the processing quality of Chipsona cultivars after 9 months of storage indicate their unsuitability for processing after prolonged storage.

Effect of reconditioning on keeping and processing quality during storage

The quality of three processing varieties stored at 12ºC (RH 85%) with CIPC fog treatment twice during storage was estimated at 0 30, 60, 90 and 120 days and after reconditioning at 20ºC for 15 and 21 days after 90 and 120 days of storage. The chip colour was unacceptable in variety Kufri Jyoti even before storage and was at the border line of acceptance in varieties Kufri Chipsona-1 and Kufri Chipsona-2 (Table 4). Kufri Jyoti could not produce acceptable chips during storage even after reconditioning. In Kufri Chipsona-1 the chip colour became unacceptable after 90 days and could not be improved with reconditioning for 15 or 21 days. The chip colour was however at the borderline of acceptance in Kufri Chipsona-2, but was not improved with reconditioning. Reconditioning of tubers at 20ºC resulted in reduction of sugar content in potatoes which however did not result in improving the chip colour. Weight loss in potatoes during the reconditioning period ranging between 4.2 to 8.4% was less than 10%, the level considered threshold at which tubers become increasingly flaccid and unacceptable for marketing as they result in high peeling losses. Even after 21 days reconditioning, the potatoes did not suffer sufficient moisture loss to affect tissue turgor.

Table 1. Processing quality of heap stored potatoes tested by ITC Ltd. in laboratory at Roorkee

Parameter	Kufri Chipsona-1		Kufri Chipsona-3		Kufri Lauvkar	
	CIPC	Control	CIPC	Control	CIPC	Control
Specific gravity	1.080	1.078	1.091	1.092	1.073	1.075
[1]DMC %	20.0	19.89	22.73	22.86	18.83	19.20
[2]UC %	0.0	0.0	0.0	0.0	2.8	4.2
[3]TPOD %	0.0	0.0	0.0	0.0	3.6	5.8
[4]TWL %	10.23	16.02	9.29	14.88	8.28	14.37

[1]Dry matter content, [2] Undesirable colour, [3] Total Potato Defects

[4]Total weight loss up to 90 days of storage at CPRS, Jalandhar

Table 2. Processing quality of potatoes after 80 days at elevated temperatures (18-39°C, 15-75% RH) after CIPC (Oorja) spray treatment (cv. Kufri Surya)

CIPC/ Control	Dry matter (%)	[1]Reducing sugar (mg)	[1]Sucrose (mg)	[1]Free amino acids (mgN)	[1]Total Phenols (mg)	[2]Chip Colour score
20 ml/t	15.58	64.4	1742.7	125.4	116.4	4.5
30 ml/t	15.24	64.4	1520.4	81.8	111.9	4.0
40 ml/t	15.16	105.6	1357.7	128.6	119.2	3.5
Control	15.12	160.4	1641.3	108.1	136.8	5.5
Mean	15.28	98.7	1565.5	111.0	121.1	4.2

[1]per 100 g fresh weight

[2]On a 1-10 scale of increasing dark colour, chip colour score up to 5 was acceptable

Table 3. Changes in the processing quality of potatoes at three storage temperatures.

Cultivar	Storage temp-erature	*Chip colour		Reducing sugar (mg/100g fr wt)		Sucrose (mg/100g fr wt)		Phenols (mg/100g fr wt)		Free amino acids (mgN/100g fr wt)	
		0d	270 d	0d	270 d	0d	270 d	0d	270d	0d	270d
Kufri Chipsona-1	4°C	5.0	8.0	67	1168	71	629	31	59	155	441
	8°C		8.6		845		512		54		419
	12°C		9.0		846		464		56		438

Kufri Chipsona-2	4°C	5.0	8.0	48	1234	58	564	29	57	111	403
	8°C		8.0		1009		532		53		425
	12°C		9.0		955		478		56		403
Kufri Jyoti	4°C	6.3	10.0	78	1297	90	869	32	56	235	437
	8°C		10.0		1013		677		55		438
	12°C		10.0		1061		578		53		442
Kufri Pukhraj	4°C	7.0	10.0	283	1462	137	894	25	50	239	418
	8°C		10.0		1318		761		47		428
	12°C		10.0		1298		632		49		490

*Scored on a scale of 1-10 of increasing dark colour; chip colour score up to 4 is acceptable.

Table 4. Effect of reconditioning on processing quality and weight loss in potatoes during storage at 12 °C

Parameter	Variety	0 day	90 day of storage	Reconditioning		120 days of storage	Reconditioning	
				15 days	21 days		15 days	21 days
[1]Chip colour	K. Jyoti	6.0	5.3	5.3	6.0	7.6	7.0	7.0
	K.Chipsona-1	5.0	6.0	6.0	6.0	6.0	5.6	6.0
	K.Chipsona-2	4.3	5.0	5.0	5.0	4.6	5.0	5.0
Reducing sugar (mg/100 g fr wt)	K. Jyoti	154.7	253.8	248.9	237.7	320.4	368.3	276.2
	K.Chipsona-1	74.4	225.7	157.5	183.0	280.1	164.3	163.0
	K.Chipsona-2	64.8	268.9	160.4	148.7	316.8	162.6	165.5
Weight loss (%)	K. Jyoti	-	[2]0.24	2.69	4.66	[2]0.74	2.73	4.47
	K.Chipsona-1	-	[2]0.23	3.14	5.57	[2]2.20	3.20	6.23
	K.Chipsona-2	-	[2]0.48	4.80	7.56	[2]2.68	4.17	8.42

[1]On a 1-10 scale of increasing dark colour, chip colour score up to 5.0 was acceptable

[2]Weight loss till the tubers reached 20°C

Fig 1. Condition of tubers after 90 days of storage in heap

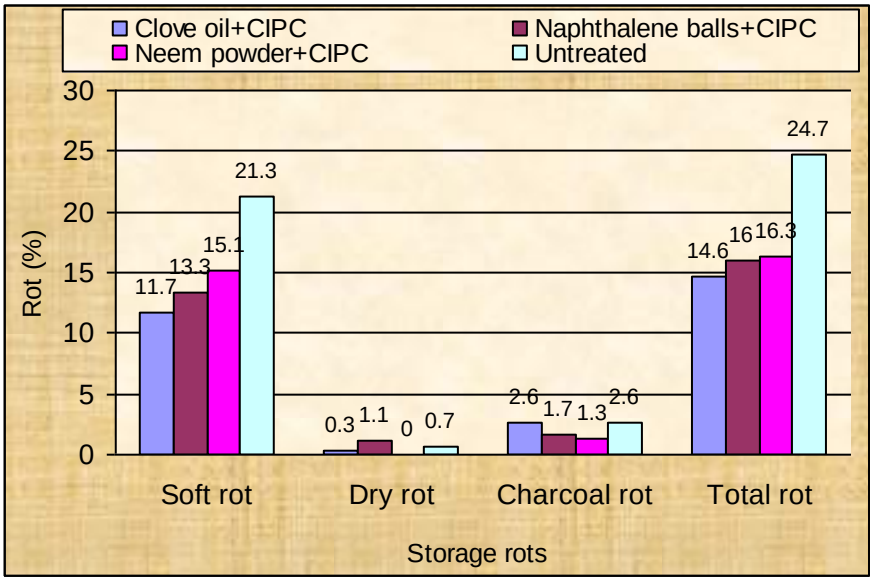


Fig 2. Reduction in storage rots with safe chemical after 105 days in heaps (cv. Kufri Sutlej).

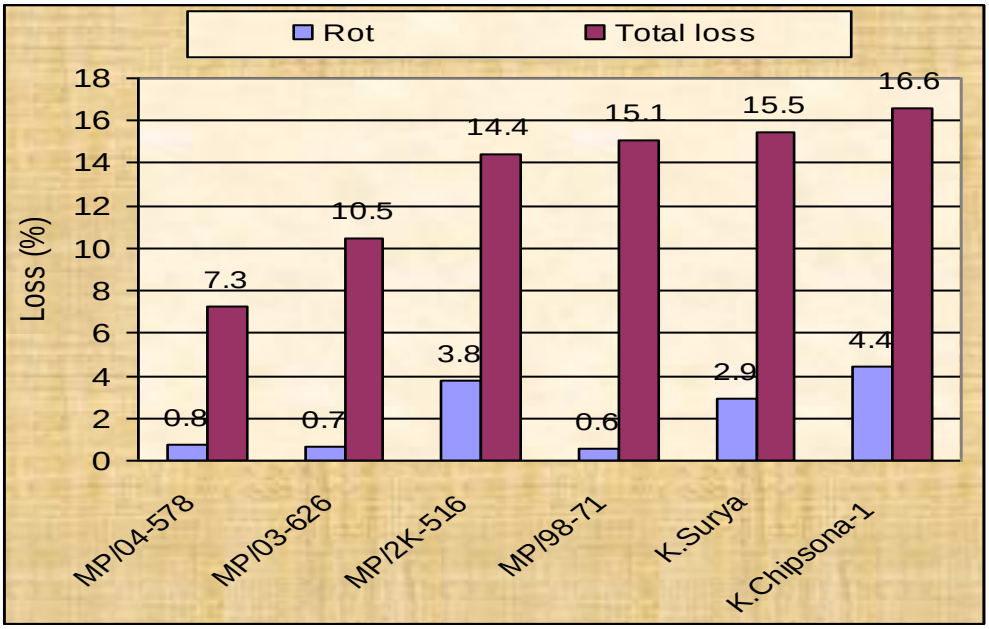


Fig 3. Losses in processing varieties/advanced hybrids after 90 days of storage at room temperature.

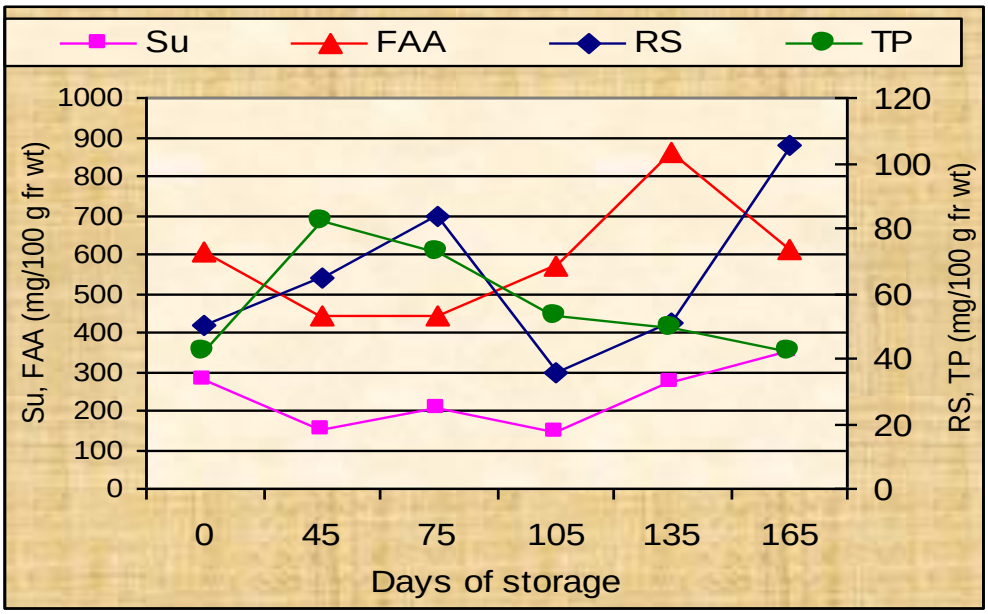


Fig 4. Changes in reducing sugars (RS), sucrose (Su), free amino acids (FAA) and total phenols (TP) in potatoes during storage at 12°C with CIPC (mean of 10 cultivars)

DIVISION OF SEED TECHNOLOGY

SEED SCIENCE AND PRODUCTION TECHNOLOGY

In India potato is cultivated in 1.5 million hactares in different agro climatic zones. Since seed is a critical input in potato cultivation and accounts for about 50% of the total cost of cultivation, seed stocks should not only free from varietal mixture but also from viral and other seed borne diseases. To maintain the crop productivity and achieve higher yield a proper technically sound seed production programme through which health standard of the seed crop is maintained is in place at CPRI and its regional stations. The conventional seed potato production programme involving tuber indexing and multiplication of breeder seed through different stages is being further strengthened through augmentation of micropropogation producing large number of *in vitro* plants, microtubers and minitubers. Every year CPRI is producing about 33000 quintal of nucleus and breeder seed out of which about 25000q is supplied to more than 20 state government as well as private seed producing agencies.

I. Conventional Seed Production System:

i) Tuber indexing: A total of 28,733 indexed tubers of 22 varieties and 2 hybrids were planted in stage-I at Modipuram (10,878), Jalandhar (1,764), Gwalior (10,980), Patna (1,319) and Kufri (3,792). Health status recorded during tuber indexing on the above centers was 96.2, 80.2, 98.6, 94.2 and 95.1 percent respectively.

ii) Nucleus seed production:

a) Stage-I (clonal multiplication): The clonal multiplication was under taken in 3.07 hectare in plains and 0.36 hectare in hills and a production of 310.38 and 71.72 quintal was obtained respectively. The average production at Modipuram, Jalandhar, Gwalior, Patna and Kufri was 104.24, 110.87, 95.15, 111.15 and 199.22 quintal per hectare, respectively (Table 7). Health status recorded in field on the above centers was 94.5, 95.2, 99.0, 98.3 and 94.13 percent respectively.

b) Stage-II (clonal increase): The production was taken in 10.65 hectare and a total production of 1,782.24 quintal was achieved at all stations in the plains. In hills only 0.85 hectare area was planted and a production of 132.00 quintal was obtained. The average production at Modipuram, Jalandhar, Gwalior, Patna and Kufri was 157.94, 150.13, 183.10, 175.81 and 155.30 quintal per hectare, respectively (Table 7). Health status recorded in field on the above centers was 93.8, 97.2, 98.7, 100.0 and 97.0 percent respectively.

c) Stage-III (bulk increase): In this stage 18.18 hectare was planted at all the four stations in the plains and a total production of 4247.86 quintal was achieved, whereas, in the hills the production obtained was 389.20 quintal in 2.08 hectare (Table 7). The average production at Modipuram, Jalandhar, Gwalior, Patna, and Kufri was 250.75, 244.84, 193.11, 239.54, and 187.12 quintal per hectare, respectively.

iii) Breeder seed production:

Stage-IV (breeder seed): In the plains 75.46 hectare was planted and 19196.0 quintal production was achieved, this includes RFS-II area of 15 hectare and production 3,555.41 quintal. In the hills, production of 689.95 quintal was achieved in an area of 4.0 hectare (Table 7). The average production at Modipuram, Jalandhar, Gwalior, Patna, and Kufri was 281.50, 252.37, 198.48, 229.43 and 172.49 quintal per hectare, respectively.

II. Hi-Tech Seed production Technology:

i) Nucleus seed production:

A) Maintenance and multiplication of virus free buffer stocks:

Disease free buffer stock tubers of twenty three varieties were planted under controlled conditions in the poly house. During its growth period samples were collected and tested for viruses PVX, PVS, PVY, PVM, PVA, PLRV and PALCV by ELISA. Total of 1206 samples were tested in twenty three varieties and all the samples were found free from all the viruses tested.

B) Production and supply of micro tubers, micro plants and buffer stocks:

A total of 39,163 *in vitro* plantlets of 20 varieties and 54,631 micro/ mini/buffer stock tubers of 18 varieties were produced at CPRI, Shimla and supplied to different stations of CPRI. A total of 7,915 *in vitro* plantlets of 18 varieties were used for planting at CPRI, Shimla and 13,108 *in vitro* plantlets were kept for further multiplication. About 8,225 *in vitro* plantlets of 12 varieties were transferred to liquid media for microtuber production. In addition to this, 47,237 *in vitro* plantlets and 9767 microtubers of eight varieties were also produced at tissue culture laboratory CPRIC, Modipuram.

C) Nucleus Seed production through tissue culturally developed material:

a) Generation-0: A total of 4,10,573 minitubers and 5, 10,242 tubers were produced from microplants (3,62,095 from 73,456), microtubers (48,478 from 24,278) and recycling of < 3 g (5, 10,242 from 1,20,015) mini tubers at Modipuram, Jalandhar, Patna, Kufri, Ooty and Shillong (Table 1). Health status recorded in G-0 on the above centers was cent-percent.

Table 1. Details of station wise microplants, microtubers and minitubers (< 3 g) planted and production obtained during 2009-2010.

Station	Planting material	Planted (Nos.)	Establish-ment (%)	Mini/tuber produced (Nos.)	Minitubers <3g (%)
Modipuram	Microplants	47,237	89.86	2,70,708	1,52,146 (56.2)
	Microtubers	5,230	53.60	15,137	9,764 (64.5)
	Minitubers (< 3 g)	1,00,852	96.84	4,42,637	-
Jalandhar	Microplants	5,980	83.63	30,861	11,075 (35.88)
	Microtubers	5750	96.52	17,575	6,837 (38.90)
	Minitubers (< 3 g)	13390	100.00	53,932	-
Kufri	Microplants	14,464	78.14	55,001	20,401 (37.09)
	Minitubers (< 3 g)	1,032	83.6	2,578	-
Gwalior	Microplants	605	33.88	1,634	869 (53.18)
	Microtubers	3,602	33.09	4,188	3184 (76.03)
	Minitubers (< 3 g)	1,334	74.59	2,793	-
Patna	Microtubers	3,580	26.00	3,873	1676 (43.27)
Ooty	Microtubers	2,600	24.85	4,765	1686 (35.38)
	Minitubers (< 3 g)	3,245	66.56	7,802	-
Shillong	Microplants	5,170	41.20	3,891	2,224 (57.16)
	Microtubers	3,516	30.26	2,940	2,692 (91.56)
	Minitubers (< 3 g)	162	90.12	500	-
Total Microplants		**73,618**	**83.00**	**3,62,095**	**1,86,715 (51.57)**
Total Microtubers		**24,278**	**50.20**	**48,478**	**25,839 (53.30)**
Total Minitubers (< 3 g)		**1,19,853**	**96.13**	**5,10,242**	**-**
Total/Average		**2,17,749**	**86.56**	**9,20,815**	**2,12,554 (24.26)**

b) Generation.1: A total production of 1522.62 quintal was achieved in generation-1 in an area of 7.26 hectare both in hills and plains. In this generation 7.12 hectare was planted at all the four stations in the plains and a total production of 1476.77 quintal was achieved, whereas, in the hills the production obtained was 45.85 quintal in 0.14 hectare. The average production at Modipuram, Jalandhar, Gwalior, Patna, and Kufri was 206.93, 226.42, 166.75,

204.01 and 327.50 quintal per hectare, respectively (Table 8). Health status recorded in G-1 on the above centers was 99.8, 100.0, 99.2, 100.0 and 99.1 percent respectively.

D) Breeder Seed production through tissue culturally developed material: Generation 2: A total production of 5132.44 quintal was achieved in generation-2 in an area of 21.33 hectare both in hills and plains. In this generation 20.57 hectare was planted at all the four stations in the plains and a total production of 5045.04 quintal was achieved, whereas, in the hills the production obtained was 79.90 quintal in 0.73 hectare (Table 8). The average production at Modipuram, Jalandhar, Gwalior, Patna, and Kufri was 265.48, 249.00, 188.56, 216.87 and 109.45 quintal per hectare, respectively.

III) Production and supply of breeder seed before cold store during 2009-10:

A total production of 25010.89 quintal was achieved in stage-IV and generation-2 in an area of 100.76 hectare both in hills and plains. A total of 96.03 hectare was planted at all the four stations in the plains and a total production of 24241.04 quintal was achieved, whereas, in the hills the production obtained was 769.85 quintal in 4.73 hectare (Table 9).

A total of 26566.39 quintal seed was available for supply during 2009-10 which includes surplus nucleus seed of 1555.50 quintal. Out of which 23525.98 quintal seed was supplied to various agencies and about 2926.89 quintal was kept in cold store for the further supply during the crop season (Table 9).

IV) Production and supply of quality Seed:

At CPRS, Ooty, an area of 8.90 hectare was planted and 824.77 quintal quality seed was produced. Out of which, 533.73 quintal was disposed off to various agencies. At CPRS, Shillong an area of 5.47 hectare was planted and 375.37 quintal quality seed was produced. Out of which, 155.74 quintal was disposed off to various agencies.

V) Health status of nucleus seed crop.

Modipuram: The health status of all the varieties was high (92-100%), K. Frysona (69.1%) during tuber indexing. However, the healthy percentage of K. Frysona was substantially increased 91.7% in stage-I by adopting all the phytosanitary and plant protection practices (Table 2).

Table 2. Health status of tuber indexing and Nucleus seed at CPRS, Modipuram.

Variety	Tuber Indexing	Rouged out clones/plants (%)		Stage-I
	Healthy clones (%)	Mild mosaic	ELISA test	Healthy plants (%)
K. Anand	100.0	0.67	1.34	98.99
K. Badshah	96.0	0.35	1.39	98.26
K. Bahar	97.1	0.27	8.34	91.39
K. Himsona	100.0	0.33	12.0	87.67
K. Pukhraj	98.0	1.23	3.59	95.18
K. Sadabahar	96.9	0.30	8.42	91.28
K. Surya	98.0	0.41	2.66	96.93
K. Sutlej	100.0	0.68	13.51	85.81
K. Chipsona-1	92.0	2.41	9.09	88.50
K. Chipsona-3	97.3	2.05	2.74	95.21
K. Frysona	69.1	3.53	4.81	91.66
K. Chipsona-4	96.8	5.0	8.33	86.67

Jalandhar: The health standards of all the varieties were increased significantly from tuber indexing to stage-I and further in stage-II. Infected clones were rouged out in stage-I on the basis of ELISA (Table 3). In stage-II, 97.2% healthy plants were observed.

Table 3. Health status of potato tuber indexing and nucleus seed crop at CPRS, Jalandhar.

Variety	Healthy clones (%) (Indexing)	Rouged out clones/plants (%)		Healthy clones/plants (%)	
		Mosaic + PALCV	ELISA test	Stage-I	Stage-II
K. Chandramukhi	86.7	0	0	100.0	100
K. Jyoti	79.4	0	5.3	94.7	97.2
K. Badshah	86.7	0	0	100.0	96.0
K. Sutlej	100.0	0	0	100.0	96.0
K. Pukhraj	86.7	0	0	100.0	97.3

Gwalior: The percentage of healthy clones were comparatively high (98-100%) in tuber indexing and more or less similar to stage-I and stage-II (Table 4). All the plants grown in G-0 comprising microplants, microtubers and minitubers were free from all the test viruses. The plants of Kufri Chipsona-3 and Kufri Surya were 100% healthy, Kufri Lauvkar and Kufri Bahar were 99.4% healthy while Kufri Sindhuri and Kufri Chandramukhi were 88.2% healthy in G-1.

Table 4. Health status in tuber indexing and nucleus seed crop of potato at CPRS, Gwalior.

Varieties	Virus infected clones (%)					Healthy clones/plants (%)		
	PVX	PVS	PVY	PVM	PVA	Indexing	Stage-I	Stage-II
K. Chandramukhi	0 (2.4)	0 (0)	1.0 (0)	1.0 (0)	0 (0)	98.0	97.6	100
K. Jyoti	1.0 (0.1)	2.0 (0.4)	2.0 (0)	2.0 (0.1)	0 (0.1)	98.0	99.3	98.9
K. Sindhuri	0 (0)	0 (0.6)	0 (0)	0.0 (0)	0 (0)	100.0	99.4	96.7
K. Lauvkar	1.0 (0.6)	0 (0.4)	2.0 (0)	2.0 (0)	1.0 (0)	98.0	99.0	96.7
K. Chipsona-1	1.0 (0)	1.0 (0.6)	0.0 (0)	1.0 (0)	0 (0)	99.0	98.9	100.0
K. Chipsona-2	1.0 (0)	2.0 (0)	2.0 (0)	2.0 (0)	0 (0)	98.0	100.0	100.0
K. Arun	0 (0)	1.0 (1.3)	1.0 (0)	1.0 (0)	0 (0)	99.0	97.5	100.0

All the figures in parentheses are percent infected plants in stage-I.

Patna: The healthy clones were more than 92% in the varieties under test during tuber indexing and increased nearly to 98% in stage-I, which further increased to 100% in stage-II (Table 5). Kufri Pukhraj, Kufri Jyoti, Kufri Ashoka, Kufri Khyati, Kufri Kanchan, Kufri Sindhuri, Kufri Pushkar and Kufri Chipsona-3 were 100% healthy in G-0 and G-1 and free from X, S, Y, A and M.

Table 5: Health status in tuber indexing and nucleus seed crop of potato at CPRS, Patna.

Variety	Virus infected clones (%)					Healthy clones/samples (%)		
	PVX	PVS	PVY	PVA	PVM	Indexing	Stage-I	Stage-II
K. Pukhraj	0 (0.25)	0 (0)	5.43 (0)	0 (0.25)	2.17 (0.51)	93.6	98.97	100
K. Jyoti	0 (0)	2.6 (2.05)	0 (0)	0 (0)	3.9 (0)	93.5	97.95	100
K. Arun	0 (0.26)	0.8 (0.26)	2.4 (0.26)	2.4 (0.79)	2.4 (0.26)	92.0	98.15	100

All the figures in parentheses are percent infected plants in stage-I.

Kufri/Fagu: The incidence of PVX and PVS in Kufri Girdhari, Kufri Himalini, Kufri Jyoti and Kufri Giriraj indicated that contagious virus were prevalent in these varieties which can be

further minimized by strict phytosanitary precautions. Healthy clones were varied from 87.8 per cent to 100% in tuber indexing. Health status continuously increased in all the varieties from stage-I to stage-II and reached to maximum of 98.6%. It further increased to average of 99.1 % in stage-III. The visual observation of symptoms like Marginal Flavescence (MF) and Purple Top Roll (PTR) in stage-I and G-1 interesting result exhibited and requires a detailed study of the disease etiology (Table 6). All the samples of G-0 were 100% free from virus while more than 98.5% healthy plants were found in most of the varieties except Kufri Lauvkar (93.2%) in G-1.

Table 6. Health status in tuber indexing and potato nucleus seed at CPRS, Kufri/Fagu.

Variety	Healthy clones (%) (Indexing)	Rouged out plants (%)					Healthy plants (%)		
		MF	Mosaics	PTR	PLRV	ELISA	Stage -I	Stage -II	G-1
K. Jyoti	95.4	0.75	1.60	0.53	0.11	2.5	94.5	98.6	-
K. Giriraj	97.5	0.32 (0.3)	2.58 (0.26)	1.29 (0)	0 (0)	2.26 (0)	93.5	96.1	99.5
K. Kanchan	100.0	4.46 (0.66)	1.27 (0.41)	0 (0)	0 (0.07)	2.55 (0)	91.7	98.4	98.9
K. Shailja	100.0	2.02	2.02	0	0	0	96.0	96.5	-
K. Himalini	91.8	1.5 (0.66)	1.75 (0.18)	0 (0)	0 (0.04)	0 (0)	96.5	98.4	99.1
K. Girdhari	87.8	1.55 (1.08)	1.55 (0.42)	0 (0)	0 (0)	2.07 (0)	94.8	96.1	98.5
K. Himsona	91.0	7.45 (0.53)	2.84 (0.3)	0 (0)	0 (0.13)	0 (0)	87.9	91.1	99.1

All the figures in parenthesis are percent infected plants rouged out in G-I.

Seed Research

1. Study on effect of antibiotics on *in vitro* bacterial contaminant and morphology of Kufri Jyoti

In this study, the effect of three different antibiotics viz. carbenecillin, cefotaxime and kanamycin against bacterial contaminants and *in vitro* shoot growth of potato (*Solanum tuberosum* L.) cultivar Kufri Jyoti was evaluated. Different concentrations of antibiotics used were carbenicillin 50, 75, 100 and 125 mg l^{-1}, cefotaxime 100, 150, 200 and 250 mg l^{-1} and kanamycin 30, 40, 50 and 60 mg l^{-1}. Double nodes were cultured on MS medium with or without different concentrations of antibiotics. Each treatment was replicated ten times. Three antibiotics found to be differed in their capacity to eliminate bacterial contaminant. Cefotaxime and carbenicillin were found to be more effective as compared to the kanamycin. The media supplemented with kanamycin recorded 80% contamination. Results showed that antibiotics not only affected the bacterial contaminants but also the growth morphology of the culture. The medium containing carbenicillin 75 mg l^{-1} and cefotaxime 150 mg l^{-1} significantly accelerated the microplant height; number of leaves and roots; root and internodal length. Higher concentration beyond this level however, had detrimental effect on the morphology of culture. Therefore, for obtaining optimal growth without any bacterial contamination we can incorporate carbenicillin 75 mg l^{-1} and cefotaxime 150 mg l^{-1} into the culture media.

2. Effect of CCC on potato seed production and prolonging the shelf life of potato seed under normal storage:

In varieties Kufri Giriraj, Kufri Swarna and Kufri Jyoti soaking of tubers in 100 ppm CCC reduces the weight loss during storage to the tune of 1.2 to 3.8 % than control. In addition to this, CCC treatment increases the number of seed size tubers (25 to 75 gm). But soaking before storage and spraying with CCC in the field affected the plant growth more severely and resulted in reduction of tuber number and yield.

Table 7. Station wise, stage wise area planted and production obtained during 2009-2010

S. No	Variety	Stage-I		Stage-II		Stage-III		Stage-IV		Total	
		Area (ha)	Produc-tion (q)	Area (ha)	Produc-tion (q)	Area (ha)	Produc-tion (q)	Area (ha)	Produc-tion (q)	Area (ha)	Produc-tion (q)
Modipuram											
1	K. Anand	0.04	3.90	0.38	50.40	0.24	59.50	2.60	881.60	3.26	995.40
2	K Badshah	0.04	3.90	0.24	30.15	0.50	110.10	1.25	291.30	2.03	435.45
3	K Bahar	0.60	66.75	1.81	338.60	5.00	1206.80	24.50	6771.50	31.91	8383.65
4	K. Himsona	0.04	3.15	0.06	7.85	0.15	51.10	0.40	151.10	0.65	213.20
5	K. Pukhraj	0.13	13.20	0.62	81.25	1.00	279.50	3.00	904.90	4.75	1278.85
6	K. Sadabahar	0.13	13.30	0.22	36.65	0.10	37.10	0.00	0.00	0.45	87.05
7	K. Surya	0.25	26.45	0.80	129.10	0.50	133.10	2.25	613.45	3.80	902.10
8	K. Sutlej	0.02	1.60	0.25	32.30	0.00	0.00	0.00	0.00	0.27	33.90
9	K. Chipsona-1	0.05	3.90	0.38	56.25	0.25	77.90	2.65	709.70	3.33	847.75
10	K. Chipsona-3	0.02	2.05	0.48	77.85	0.50	111.10	1.00	274.90	2.00	465.90
11	K. Frysona	0.04	4.00	0.30	34.55	0.00	0.00	0.00	0.00	0.34	38.55
12	K. Chipsona-4	0.03	2.70	0.03	4.80	0.00	0.00	0.00	0.00	0.06	7.50
	Total	**1.39**	**144.90**	**5.57**	**879.75**	**8.24**	**2066.20**	**37.65**	**10598.45**	**52.85**	**13689.30**
	Jalandhar										
1	K. Badshah	0.0010	0.58	0.02	3.30	0.20	47.55	2.00	475.00	2.22	526.43
2	K. Chandramukhi	0.0008	0.55	0.02	3.30	0.50	115.00	1.50	345.00	2.02	463.85
3	K. Jyoti	0.2400	25.54	0.71	105.50	3.00	725.50	11.00	2634.90	14.95	3491.44
4	K. Pukhraj	0.0008	0.58	0.02	3.50	0.55	146.00	2.00	531.75	2.57	681.83
5	K. Pushkar	0.0000	0.00	0.00	0.00	0.00	0.00	2.00	682.25	2.00	682.25
6	K. Sutlej	0.0040	0.09	0.00	0.00	0.10	31.00	0.00	0.00	0.10	31.09
	Total	**0.2466**	**27.34**	**0.77**	**115.60**	**4.35**	**1065.05**	**18.50**	**4668.90**	**23.86**	**5876.89**
	Gwalior										
1	K. Arun	0.08	11.67	0.27	63.50	0.43	40.00	0.44	181.43	1.22	296.60
2	K. Bahar	0.00	0.00	0.00	0.00	0.00	0.00	0.08	8.00	0.08	8.00
3	K. Chandramukhi	0.12	9.45	0.50	89.50	0.42	80.00	2.29	493.03	3.33	671.98
4	K. Chipsona-1	0.22	23.79	0.64	118.16	1.00	182.50	1.97	438.41	3.83	762.86
5	K. Chipsona-2	0.03	3.84	0.50	90.29	0.60	101.50	2.65	409.67	3.78	605.30
6	K. Chipsona-3	0.00	0.00	0.00	0.00	0.00	0.00	1.19	259.67	1.19	259.67
7	K. Jyoti	0.39	34.16	0.94	165.55	0.86	186.80	2.72	468.82	4.91	855.33
8	K. Kanchan	0.00	0.00	0.00	0.00	0.00	0.00	0.08	8.50	0.08	8.50
9	K. Lauvkar	0.39	34.50	0.65	103.86	0.48	87.58	1.00	182.69	2.52	408.63
10	K. Pukhraj	0.00	0.00	0.00	0.00	0.00	0.00	0.11	21.00	0.11	21.00
11	K. Sindhuri	0.07	6.28	0.50	101.53	1.00	246.60	3.60	733.25	5.17	1087.66
12	K. Surya	0.00	0.00	0.00	0.00	0.00	0.00	0.08	12.94	0.08	12.94
	Total	**1.30**	**123.69**	**4.00**	**732.39**	**4.79**	**924.98**	**16.21**	**3217.41**	**26.30**	**4998.47**
	Patna										
1	K. Arun	0.05	4.25	0.11	13.80	0.00	0.00	1.10	182.72	1.26	200.77
2	K. Ashoka	0.00	0.00	0.00	0.00	0.10	19.00	0.00	0.00	0.10	19.00
3	K. Jyoti	0.04	4.60	0.08	14.10	0.50	132.13	2.00	528.52	2.62	679.35
4	K. Kanchan	0.00	0.00	0.00	0.00	0.20	40.50	0.00	0.00	0.20	40.50
5	K. Pukhraj	0.04	5.60	0.12	26.60	0.00	0.00	0.00	0.00	0.16	32.20
	Total	**0.13**	**14.45**	**0.31**	**54.50**	**0.80**	**191.63**	**3.10**	**711.24**	**4.34**	**971.82**
	G. Total Plains (A)	**3.07**	**310.38**	**10.65**	**1782.24**	**18.18**	**4247.86**	**75.46**	**19196.00**	**107.35**	**25536.48**
	Kufri										
1	K. Girdhari	0.0400	10.48	0.04	10.00	0.10	19.80	0.00	0.00	0.18	40.28
2	K. Giriraj	0.0300	5.55	0.11	11.25	0.12	31.90	0.00	0.00	0.26	48.70
3	K. Himalini	0.0400	10.00	0.08	12.10	0.12	27.55	0.30	39.00	0.54	88.65
4	K. Himsona	0.0300	3.85	0.04	4.90	0.16	22.70	0.00	0.00	0.23	31.45
5	K. Jyoti	0.1800	35.84	0.55	83.30	1.34	232.20	2.95	576.95	5.02	928.29
6	K. Kanchan	0.0200	2.10	0.01	4.45	0.12	28.80	0.30	40.00	0.45	75.35
7	K. Shailja	0.0200	3.90	0.02	6.00	0.12	26.25	0.45	34.00	0.61	70.15
	G. Total Hills (B)	**0.3600**	**71.72**	**0.85**	**132.00**	**2.08**	**389.20**	**4.00**	**689.95**	**7.29**	**1282.87**
	Grand total (A+B)	**3.43**	**382.10**	**11.50**	**1914.24**	**20.26**	**4637.06**	**79.46**	**19885.95**	**114.64**	**26819.35**

Table 8. Station wise, generation wise area planted and production obtained during 2009-2010

S. No	Variety	Generation-I		Generation -II		Total	
		Area (ha)	Production (q)	Area (ha)	Production (q)	Area (ha)	Production (q)
	Modipuram						
1	K. Anand	0.36	72.70	0.40	138.40	0.76	211.10
2	K. Badshah	0.02	7.20	0.25	59.00	0.27	66.20
3	K. Bahar	0.84	211.05	4.50	1155.00	5.34	1366.05
4	K. Himsona	0.25	63.10	0.20	75.00	0.45	138.10
5	K. Pukhraj	0.03	5.80	0.25	61.50	0.28	67.30
6	K. Sadabahar	0.20	35.80	0.00	0.00	0.20	35.80
7	K. Surya	0.72	138.30	0.75	215.75	1.47	354.05
8	K. Sutlej	0.02	4.30	1.60	325.00	1.62	329.30
9	K. Chipsona-1	0.06	11.20	0.50	136.40	0.56	147.60
10	K. Chipsona-2	0.01	3.55	0.25	60.00	0.26	63.55
11	K. Chipsona-3	1.60	297.50	3.00	880.10	4.60	1177.60
	Total	**4.11**	**850.50**	**11.70**	**3106.15**	**15.81**	**3956.65**
	Jalandhar						
1	K. Badshah	0.160	34.200	0.600	143.000	0.760	177.200
2	K. Chandramukhi	0.280	54.000	0.600	135.000	0.880	189.000
3	K. Jyoti	0.000	0.000	0.100	24.500	0.100	24.500
4	K. Pukhraj	0.210	53.500	0.700	186.000	0.910	239.500
5	K. Pushkar	0.000	0.000	0.000	0.000	0.000	0.000
6	K. Sutlej	0.074	20.800	0.150	46.850	0.224	67.650
7	K. Chipsona-1	0.001	2.900	0.000	0.000	0.001	2.900
8	K. Chipsona-2	0.005	1.200	0.000	0.000	0.005	1.200
9	K. Himsona	0.244	53.930	0.000	0.000	0.244	53.930
	Total	**0.974**	**220.530**	**2.150**	**535.350**	**3.124**	**755.880**
	Gwalior						
1	K. Arun	0.000	0.00	0.0001	0.35	0.0001	0.35
2	K. Bahar	0.106	16.58	0.37	80.87	0.48	97.45
3	K. Chandramukhi	0.059	10.20	0.53	36.80	0.59	47.00
4	K. Chipsona-1	0.000	0.00	0.02	4.00	0.02	4.00
5	K. Chipsona-3	0.003	0.76	0.00	0.00	0.00	0.76
6	K. Jyoti	0.000	0.00	0.27	55.00	0.27	55.00
7	K. Lauvkar	0.097	15.55	0.36	89.00	0.46	104.55
8	K. Sindhuri	0.013	3.30	0.22	63.50	0.23	66.80
9	K. Surya	0.002	0.30	0.00	0.00	0.00	0.30
	Total	**0.280**	**46.69**	**1.77**	**329.52**	**2.05**	**376.21**
	Patna						
1	K. Ashoka	0.04	7.90	0.60	159.25	0.64	167.15
2	K. Jyoti	0.05	17.55	0.00	0.00	0.05	17.55
3	K. Kanchan	0.13	26.15	1.50	361.55	1.63	387.20
4	K. Pukhraj	1.32	254.65	2.75	534.07	4.07	788.72
5	K. Chipsona-1	0.10	24.00	0.00	0.00	0.10	24.00
6	K. Chipsona-3	0.02	6.70	0.00	0.00	0.02	6.70
7	K. Surya	0.03	4.60	0.10	19.15	0.13	23.75
8	K. Himsona	0.08	17.50	0.00	0.00	0.08	17.50
	Total	**1.76**	**359.05**	**4.95**	**1074.02**	**6.71**	**1432.57**
	G. Total plains (A)	**7.124**	**1476.77**	**20.57**	**5045.04**	**27.694**	**6521.31**
	Kufri						
1	K. Girdhari	0.010	2.100	0.000	0.000	0.010	2.100
2	K. Giriraj	0.020	12.650	0.250	30.000	0.270	42.650
3	K. Himalini	0.050	18.850	0.300	36.000	0.350	54.850
4	K. Himsona	0.040	3.750	0.150	10.450	0.190	14.200
5	K. Jyoti	0.000	0.000	0.000	0.000	0.000	0.000
6	K. Kanchan	0.020	8.500	0.020	0.250	0.040	8.750
7	K. Shailja	0.000	0.000	0.010	3.200	0.010	3.200
	G. Total hills (B)	**0.140**	**45.850**	**0.730**	**79.900**	**0.870**	**125.750**
	Grand total (A+B)	**7.26**	**1522.62**	**21.30**	**5124.94**	**28.56**	**6647.06**

Table 9. Station wise breeder seed (Stage-IV and Generation-II) produced and supplied during 2009-2010

S. No	Variety	Total breeder seed		Surplus nucleus seed	Govt. agencies	Private agency	Farmers	Auctioned	Kept in Cold store	Free of cost/experiment
		Area (ha)	Production (q)							
	Modipuram									
1	K. Anand	3.00	1020.00	4.80	702.00	0.00	250.80	60.00	12.00	0.00
2	K. Badshah	1.50	350.30	17.70	315.00	0.00	27.70	24.50	0.00	0.80
3	K. Bahar	29.00	7926.50	56.80	4778.00	0.00	1953.80	794.50	450.00	7.00
4	K. Himsona	0.60	226.10	1.50	0.10	110.00	79.50	4.00	0.00	34.00
5	K. Pukhraj	3.25	966.40	17.00	509.00	0.00	262.00	183.50	20.00	8.90
6	K. Sadabahar	0.00	0.00	1.50	0.00	0.00	1.50	0.00	0.00	0.00
7	K. Surya	3.00	829.20	7.50	401.00	60.00	214.50	28.50	126.00	6.70
8	K. Sutlej	1.60	325.00	0.00	276.00	0.00	10.00	39.00	0.00	0.00
9	K. Chipsona-1	3.15	846.10	3.00	645.10	130.00	24.00	46.00	0.00	4.00
10	K. Chipsona-2	0.25	60.00	0.00	50.00	0.00	8.00	2.00	0.00	0.00
11	K. Chipsona-3	4.00	1155.00	32.70	699.80	50.00	190.70	60.00	177.00	10.20
	Total	**49.35**	**13704.60**	**142.50**	**8376.00**	**350.00**	**3022.50**	**1242.00**	**785.00**	**71.60**
	Jalandhar									
1	K. Badshah	2.60	618.00	47.55	430.00	30.00	88.00	0.25	116.00	1.30
2	K. Chandramukhi	2.10	480.00	115.00	342.00	3.00	148.00	0.20	100.50	1.30
3	K. Jyoti	11.10	2659.40	725.50	1952.50	50.00	405.00	0.55	974.50	2.35
4	K. Pukhraj	2.70	717.75	146.00	530.00	0.00	147.00	0.25	185.30	1.20
5	K. Pushkar	2.00	682.25	0.00	329.90	0.00	276.00	0.25	75.00	1.10
6	K. Sutlej	0.15	46.85	51.80	26.00	20.80	48.50	0.00	0.00	3.35
	Total	**20.65**	**5204.25**	**1085.85**	**3610.40**	**103.80**	**1112.50**	**1.50**	**1451.30**	**10.60**
	Gwalior									
1	K. Arun	0.44	181.78	0.00	77.50	66.75	34.40	0.00	3.00	0.13
2	K. Bahar	0.45	88.87	0.00	1.00	48.00	39.85	0.00	0.00	0.02
3	K. Chandramukhi	2.82	529.83	0.00	485.45	10.00	20.35	0.00	13.80	0.23
4	K. Chipsona-1	1.99	442.41	2.50	283.00	70.00	32.50	0.00	59.20	0.21
5	K. Chipsona-2	2.65	409.67	0.00	376.90	10.00	10.00	0.00	12.50	0.27
6	K. Chipsona-3	1.19	259.67	0.00	160.00	10.00	38.50	0.00	51.00	0.17
7	K. Jyoti	2.99	523.82	0.00	208.50	12.00	0.00	0.00	301.70	1.62
8	K. Kanchan	0.08	8.50	0.00	7.50	0.00	0.00	0.00	1.00	0.00
9	K. Lauvkar	1.36	271.69	0.00	158.50	3.00	38.00	0.00	72.00	0.19
10	K. Pukhraj	0.11	21.00	0.00	18.00	0.00	3.00	0.00	0.00	0.00
11	K. Sindhuri	3.82	796.75	40.50	628.86	48.50	156.25	0.00	3.35	0.29
12	K. Surya	0.08	12.94	0.00	0.00	0.00	10.00	0.00	2.85	0.09
	Total	**17.98**	**3546.93**	**43.00**	**2405.21**	**278.25**	**382.85**	**0.00**	**520.40**	**3.22**
	Patna									
1	K. Arun	1.10	182.72	0.00	161.50	0.00	3.50	5.00	12.72	0.00
2	K. Ashoka	0.60	159.25	0.00	148.50	5.00	0.00	5.40	0.35	0.00
3	K. Jyoti	2.00	528.52	0.00	118.00	324.00	1.00	9.00	76.52	0.00
4	K. Kanchan	1.50	361.55	0.00	347.00	0.00	4.50	9.05	1.00	0.00
5	K. Pukhraj	2.75	534.07	0.00	425.67	0.00	22.00	6.80	79.60	0.00
6	K. Surya	0.10	19.15	0.00	0.00	18.50	0.50	0.15	0.00	0.00
	Total	**8.05**	**1785.26**	**0.00**	**1200.67**	**347.50**	**31.50**	**35.40**	**170.19**	**0.00**
	G. Total plains (A)	**96.03**	**24241.04**	**1271.35**	**15592.28**	**1079.55**	**4549.35**	**1278.90**	**2926.89**	**85.42**
	Kufri									
1	K. Girdhari	0.00	0.00	14.65	3.00	0.00	9.25	0.00	0.00	2.40
2	K. Giriraj	0.25	30.00	41.20	52.00	0.00	15.55	0.00	0.00	3.65
3	K. Himalini	0.60	75.00	19.30	38.00	0.00	50.55	0.00	0.00	5.75
4	K. Himsona	0.15	10.45	24.90	20.00	0.00	14.20	0.00	0.00	1.15
5	K. Jyoti	2.95	576.95	133.30	479.00	0.00	219.35	0.00	0.00	11.90
6	K. Kanchan	0.32	40.25	29.75	63.00	0.00	5.20	0.00	0.00	1.80
7	K. Shailja	0.46	37.20	21.05	45.00	0.00	11.80	0.00	0.00	1.45
	G. Total hills (B)	**4.73**	**769.85**	**284.15**	**700.00**	**0.00**	**325.90**	**0.00**	**0.00**	**28.10**
	Grand total (A+B)	**100.76**	**25010.89**	**1555.50**	**16292.28**	**1079.55**	**4875.25**	**1278.90**	**2926.89**	**113.52**

Division of Social Sciences

Impact of Potato Production Technologies Developed by the Institute

Potato production has registered remarkable growth in the country over the years. The Institute has developed agro techniques for potato production in different regions of the Country. Many of these techniques have been well adopted by the farmers. However, some of the agro techniques have very low level of adoption at the farmers' field. The levels of technological change, impact of these technologies and various socio-economic constraints need to be assessed for the improved adoption of technologies for further development of potato crop and policy implications. Moreover, it is a right time for assessment of economic impact and adoption of selection potato production technologies such as table and processing varieties, seed plot technique, new late blight management molecules, storage at elevated temperature etc. Therefore, a hoistic study for above mentioned aspect, is pertinent to make suitable refinements in the future research agenda of the Institute.

Economic impact of new late blight control molecules in India

Severe late blight infestation coupled with high temperature during tuber formation and bulking stage characterised potato scenario during 2008-09 crop year. In order to study the impact of new late blight control molecules vis-à-vis the Mancozeb, Gujarat and West Bengal states were selected. Average potato yield in West Bengal was estimated 142.73 q/ ha while this figure was 258.49 in the state of Gujarat. In comparison to the previous year potato yields fell by 43.28% in West Bengal and 34.61% in Gujarat. In the state of West Bengal, farmers using new late blight control molecules harvested 31% higher potato yield than those who used comparable number of Mancozeb (only) sprays. Further, the farmers using new late blight control molecules got about 71% higher potato yield compared to those who applied two or less number of sprays of Mancozeb only. Similarly in Gujarat, farmers using new late blight control molecules harvested about 22% and 44% higher potato yield compared to those who applied Mancozeb only and ≤ 2 sprays of Mancozeb, respectively.

About 79 and 72% respondents in West Bengal and Gujarat, respectively, were not using new late blight control molecules. Nearly 9% respondents in West Bengal and 11.5% in Gujarat were not undertaking any late blight control measure. Among late new blight control molecules Metalaxyl combinations were more popular (7% respondents) than Cymoxanil combinations (5% respondents) followed by Dimethomorph combinations (2% respondents). Unaffordable price was reported as the main reason (69% non-adopters) for not using new late blight molecules. Other prominent reasons for not using new molecules were unawareness of such molecules (56% non adopters) followed by moderate effectiveness of Mancozeb (36% non adopters) and unavailability of new molecules (21% non adopters). Only 42% respondents had adequate knowledge of late blight control. The proportion of farmers having adequate late blight control knowledge was slightly more in Gujarat compared to the West Bengal. About one fifth of respondents reported bad quality of agro-chemicals and this proportion was higher West Bengal compared to Gujarat. Nearly one tenth respondents were not aware on the quality of agro-chemicals.

Spraying method determines efficacy of late blight management to a very high degree. Majority of the respondents sprayed only the top canopy of the crop (74%) while just 16%

applied chemical to the entire plant. Average yield on farms where late blight chemicals were applied on the entire plant was 37.21% higher in West Bengal and 20.30% higher in Gujarat.

Pesticide sellers were the main source of late blight knowledge (33%) for the potato farmers in the study area. Other important sources were such knowledge were government extension personnel (22%), fellow farmers (18%), agents of pesticide companies (14%) and exclusively personal knowledge and experience (13%). Among major suggestions on late blight management, 56% respondents want late blight control molecules to be more effective, followed by cheaper prices of new late blight control molecules through price control (49%), subsidy on new late blight control molecules (32%) and public control on seed potato supply (29%) so that inoculation through seed can be avoided.

Nearly three fourth respondents knew about crop insurance as tool to manage late blight risk. About two third respondents adopted this tool. Most of the respondents took crop insurance due to its compulsory adoption with crop loans. However, 15% adopters were not satisfied with the crop insurance mechanism and settlement of claims. Nearly 40% farmers had never staked their claim and no comments on this issue.

Application of new late blight molecules was indeed the costly affair. Cost A_1 in West Bengal was higher by about 9.6% for the adopters of new late blight molecules. This cost in Gujarat was higher by about 7.4%. However the net returns over cost A_1 in West Bengal was higher by about 2.4 times higher for the adopters of new late blight molecules. In Gujarat this proportion was 1.5 times higher. The respective benefit cost ratio of potato cultivation for non-adopters and adopters over cost A_1 was 1.2 and 1.44 in West Bengal and 1.42 and 1.59 in Gujarat.

Efficiency analysis of Potato Cultivation under different production system in Bihar (Only Potato)

The present study was conducted with the objectives of assessing inputs efficiency of potato growers in Muzaffarpur district of Bihar. Muzaffarpur one of the major producing district of Bihar. 142 farmers were selected randomly from district and interviewed in the seven blocks during crop season of 2008-09. The cost of cultivation was estimated, seed has highest component of cost in production system of potato. It was accounted around 30 % share in total cost followed by Fertilizer (22.49%), Machine labour (17.52%), Human labour (16.12%) and irrigation (3.40%). The BC ratio was 1.21, indicates the production system is traditional input based and there is need for intervention by extension system to enhance the productivity of district. Overall the farmers was made a net profit Rs 11594/ha from potato cultivation.

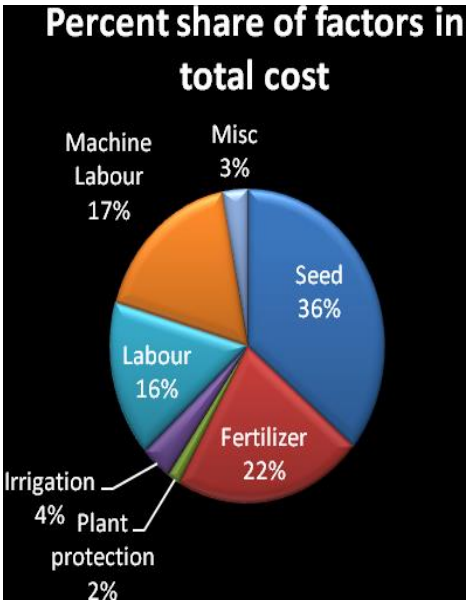
The majority of farmers purchase fresh seed from traders in limited quantity and multiplied the seed on own farm for next sowing season. It is major reasons for low productivity as compared to national and state average. 57% farmers incurred the loss in potato production system during 2008-09 in Muzaffarpur due either low quality seed or infestation of light blight. 43% farmers made profit by potato cultivation due higher price realisation at the time of harvest. The average cost of production was 413.5 per quintal which was very high. Productivity has to increase by creating awareness about quality seed and better management practices so income of farmers can be increase in the district which ultimately helps in reducing poverty and alleviating hunger in the area.

Table 1. Cost of cultivation of potato in Muzaffarpur district of Bihar

Item	Rs. /ha	% Share
Seed	19530	36.06
Fertilizer @	12183	22.49
Plant protection	772	1.42
Irrigation #	1841	3.40
Labour	8735	16.12
Machine Labour *	9488	17.52
Misc	1620	2.99
Total	**54168**	**100.00**
Yield	131	
Cost of production (Rs/Q)	413.5	
Harvest Price	502.0	
BC	1.21	

Note: @ included FYM and Micronutrient

 # Includes power and water charges
** includes depreciation also*
Misc expenditure includes expenditure on maintenance items used in cuitivatine on various items used in cultivation



Dependence on agriculture and due to small land holding their purchasing power was low which reflect in quality seed input purchase. Quality seed is main component in potato farming for good yield and higher productivity. 70 Percent of the framers in the study area were used local seed which main reason for low productivity. Around 20 percent farmers purchased the seed from traders and got good yield.

Factor share over the year

Table 2: Index of factor share in cost of production and Total Factor Productivity in potato

Year	Human Labour	Bullock labour	Machine labour	Seed	Fertilizer	FYM	TFP
1975-76	100	100	100	100	100	100	100
1980-81	134	64	350	105	167	46	131
1985-86	127	39	196	121	114	31	146
1990-91	117	28	196	129	108	43	109
1995-96	131	17	304	104	235	35	151
2000-01	153	15	631	89	223	47	140
2003-04	133	29	537	111	208	30	140
ACGR%	0.99	-7.40	5.88	0.59	2.83	-3.99	1.14

Farm level data on yield and input used and their prices collected under the "comprehensive Scheme For the study of Cost of Cultivation of Principle crops" of the Directorate of Economics and Statistics (DES) Government of India (GOI) have been used in the analysis to estimate factor share and total factor productivity. The growth rate of traditional input like bullock labour and FYM is negative in potato production and positive for modern input like machine labour, fertilizer and seed. The TFP growth of potato was 1.14 per cent from 1975-76 to 2003-04. It indicates that output growth is more than the input growth and technology developed by CPRI is responsible for higher output growth.

Value of output from potato

Per cent share of area, production and value of potato during 2007-08

Crop	Percent share			Gross returns per ha
	Area	Production	Value	
Rice	30.29	22.25	14.54	21713.05
Wheat	19.48	18.09	10.95	25427.71
Potato	1.07	6.57	2.48	104619.4

Note: Gross returns calculated using total area and value of output from crop

The contribution of potato in total value of agricultural output was 2.4 per cent from 1.07 per cent area during 2007-08. The gross returns per hectare from rice and wheat were Rs.21713 and Rs. 25427 respectively. Potato was giving highest gross returns per hectare as compared to rice and wheat.

Impact assessment of extension stretegies for potato technology dissemination

Technology gap at farmers field:

The data regarding the technological gap at farmers fields from Kharapathar in Shimla district revealed 40% gap in adoption of potato technologies with respect to cultural management, late blight, pest management and healthy seed potato production. Maximum technological gap of 65% was found in case of integrated pest management. Unavailability of good quality seed was amongst the major constraints for potato production. At Patna 64.28% technological gap was observed with respect to Seed Management, Planting Operation, Nutrient Management, Intercultural practices, Irrigation, Disease Management, Integrated Pest Management and Harvesting and Post Harvest Management. However lowest gap was found in Integrated Pest management (56.5%).

Assessment of selected potato technologies

Fifteen farm level demonstrations, 5 each on late blight management, white grub management, and healthy seed potato production were conducted on 200 sq.m area each in Kharapathar area of Shimla district in Himachal Pradesh during 2009-10. The demonstrations were laid using the institute's technology and were compared with farmers plots. With the adoption of institute technologies, farmers were able to harvest on an average yield of 225 q/ha from demonstration plot as against 198 q/ha obtained from farmers own practice. At Patna 15 demonstrations at farm level, 10 each on improved potato varieties like Kufri Kanchan, Kufri Ashoka and Kufri Pushkar were conducted on 200 sq. mts at Khakrandas village of Vaishali district of Bihar during 2009-10. The demonstration were laid using the Institute technology and were compared with farmer own varieties. Data revealed a significant increase in crop yield (16.66% to 24.66%) by use of high yielding potato varieties. Maximum increase in yield was recorded in potato varieties Kufri Ashoka (24.66%) followed by Kufri Kanchan (21.87%). Potato varieties Kufri Ashoka was found most remunerative with a net return of Rs.43,500/ha.

Impact of Extension Training

Eight days Model Training Course on "Techniques for Improved Quality Seed Potato Production" from 18-25 August, 2009 was organised at CPRI, Shimla. 14 participants from 7 states attended the training course. A variety of training methods were used to improve the knowledge and skill of extension officers working in state departments of agriculture/horticulture. These included lecture-cum-discussions, practical sessions, field visits and video film shows. To assess the impact of the training pre-and post training excavations were conducted. The results showed an overall improvement by 21%. Maximum gain in knowledge was in general information relating to potato cultivation (52%) followed by Plant Breeding, Biotechnology and Entomology (26%) and Physiology & PHT (25%).

TRANSFER OF TECHNOLOGY

Trainings

Training of Extension Officers

Model Training Course: The Division of Social Sciences organized 8 days Model Training Course on "Techniques for improved quality seed potato production" from 18-25 August, 2009 at Shimla sponsored by Directorate of Extension, Ministry of Agriculture, Govt. of India. A total 14 participants from 7 states attended the training course. The training included 24 lecure-cum-discussions, practical sessions, skill demonstrations, field visits and video film shows. The objective of the training course were to improve the knowledge of the trainee officers regarding seed potato production and to get the feedbacks from the trainee officers.

Master Trainers Training to KVK: 3 days training course on "Seed Potato Production" was organized during 26th to 28th May for the Master Trainers of Krishi Vigyan Kendra (KVK). This training course was attended by 10 officers from different KVKs of HP. During this training course the participants were exposed to a series of theory lectures comprising of disease and pest management, integrated nutrient management, quality seed production, post harvest handing, economics and marketing of potato. Besides this field visits to Kufri and Fagu farms was also organized.

Training of farmers at CPRI, Shimla: 2 days sponsored training programme was organized for the farmers of West Bengal in two batches each of 28 farmers during July 27 to 28, 2009 and August 6-7, 2009 on "Quality seed potato production and storage". During this training course farmers were given series of lectures consisting of healthy seed production, nutrient management, water management, fungal diseases, harvesting and transport management, cold storage management and viruses and their management. The objective of the training is to ensure that the technology developed by the Institute is adopted by the farming community.

Training to officers of Horticulture/Agriculture & Progressive farmers: A 4 days training course on "आलू उत्पादन तकनीक एवं विपणम प्रबन्धन" was organized during 4-7 November, 2009 at CPRI, Shimla. The training course was sponsored by the Director State Agriculture Management Institute, Rehmankhera, Lucknow (UP). This training course was attended by 35 officers of horticulture/agriculture and progressive farmers of UP. In all 18 lectures were delivered which consists of disease and pest management, nutrient management, organic potato production, potato storage, seed certification healthy seed production, marketing and export of potato and practical. A field visit to CPRS, Kufri and Fagu farms was also organized on this occasion.

CPRS, PATNA

Farmer's Training Programmes:

One day training programme on potato seed production; scientific potato cultivation and late blight management; and processing/ potato chip making were organized in collaboration with Bihar Agricultural Management and Extension Training Institute (BAMETI) and Agricultural Technology Management Agency (ATMA) at CPRS, Patna on 30-09-2009, 14-10-09, 28-10-09, 10-11-09, 18-11-09, 27-11-09, 16-12-09, 30-12-09, 23-01-09, 30-01-09, 15-02-10 and 26-02-10. A total of 466 farmers of Patna, Katihar, Rohtas, Bhagalpur, Nawada, Buxur, Bhojpur, Purnea, Nalanda, Begusarai, Gaya, E & W. Champaran, Vaishali, Jahanabad, Samastipur and Muzaffarpur districts of Bihar and Koderma district of Jharkhand participated in the programme. During the training programmes, lectures cum live demonstrations on different aspects of potato cultivation *viz*. use of HYV of potato, seed-bed preparation for TPS, plant protection, seed treatment and storages etc. were discussed in the programme. Farmers were also provided literature along with the field visit for adequate exposures on farm operations such as roguing and pesticides sprays etc. Agricultural implements used in potato cultivation were also shown to the farmers.

Training cum exposure visit for farmers sponsored by National Horticultural Research Foundation, Patna

One day training cum exposure visit was organized for the potato farmers sponsored by NHRDF, Patna on 29-12-09. A total of 26 farmers participated. During the programme, live demonstrations on potato cultivation technologies along with field visit for adequate exposures of farm operations, such as roguing and pesticides sprays/ use of agricultural implements in potato cultivation etc. were shown to the farmers.

Training for Self-help groups (Women) of adopted farmers of Women Development Corporation (WDC) , Dept. of Social Welfare Govt. of Bihar on potato production and processing at CPRS, Patna

One day training programmes sponsored by Women development Cooperation , Govt. of Bihar was organized on potato production utilization and processing on 21-01-10, 25-01-10, 18-02-10 and 20-02-10. Participants were trained on different aspects of potato production and also involved in live demonstrations on potato chip making at processing unit of CPRS, Patna. A total of 159 farmers including 97 women from districts of Purnea and Nawada of Bihar also participated in the programme.

Training under Sustainable livelihood improvement through need based integrated farming system models in disadvantaged district of Bihar NAIP (Component-3)

Six training programmes of one day duration each were organized on potato seed production, late blight management, true potato seed production (TPS), harvesting, grading and storage of potato on 30-09-09, 28-10-09, 18-11-09, 27-11-09, 16-12-09 and 19-02-10 at CPRS campus and also village- Chakramdas, Distt. Vaishali, under NAIP. A total of 159 potato farmers participated in the programme.

Training under Institute's project "Assessment of potato technology through farmers participatory approach"

Twenty five farmers were trained through lectures cum field visits at village Chakramdas, Vaishali district of Bihar.

Training cum exposure visit of District Horticultural Officers (DHO'S) of Bihar

One day training -cum -exposure visit was organized for the DHO's of Bihar on 23-12-2009. In this programme, latest potato technologies were demonstrated to the DHO' by the scientists of CPRS, Patna.

Exposure visit of farmers sponsored by Dept. of Soil Conservation Govt. of Jharkhand

A total of 533 farmers including 177 farmwomen sponsored by State Water Soil Conservation &Training Centre, Ranchi, Jharkhand were trained in potato cultivation and were given live demonstrations in sorting /grading/ seed treatment and potato chip making at CPRS campus on 15-03-10 & 19-03-2010.

Seed Production activity at National Research Centre for Litchi, Muzaffarpur, Bihar

Potato seed crop was raised in1.0 ha. at NRC for litchi, Mizaffarpur, Bihar. Potato varieties namely, Kufri Ashoka and Kufri Kanchan were planted during October,2009. All crop operations from planting to harvesting were closely monitored by the scientists and technical staff of CPRS, Patna by spot visits.

Activities of ATIC: A total of 617 farmers, 60 scientists, teaching staff, 705 students of UG and PG and 39 entrepreneurs visited the Institutes headquarters to get first hand information about potato technologies. These visitors were attended by ATIC staff by showing them potato film, museum and by delivering lectures. A number of technical and extension bulletins were supplied to the visiting farmers, students and extension officers. The Institute also sold bulletins worth Rs.63,200/= to the visitors through ATIC in this period.

Potato Exhibits: Exhibitions in Kisan Mela at Solan: An exhibition stall of potato technologies put up at the Kisan Mela organized by National Research Centre for Mushroom, Chambaghat, Solan on 10th September, 2009. It was visited by more than 300 farmers from different parts of the states. The interactions between the farmers and scientists proved worthy in getting first hand information from the farmers and transferring the potato technologies to them. Besides a number of priced publications of the Institute were sold to the farmers and scientists visiting the stall.

Exhibition in "Bharat Nirman" : CPRI Shimla put up an exhibition stall in "Bharat Nirman" Public Information campaign organised by Press Information Bureau at Ghumarwin, Bilaspur (HP) during 23-27 February, 2010. Latest technologies on potato production of the Institute were exhibited by CPRI. More than 500 farmers and scientists visited the stall and were given first hand information on technologies developed by CPRI. More than 30 organizations of National repute put up their stall to depict the latest trend in Agriculture and technology.

Live Phone-in-Programme on Doordarshan/AIR at Shimla: The Shimla Doordarshan telecasts live-phone-in programme of **"Krishi Darshan"** in collaboration with various organizations concerned with agricultural development. The programmes of various organizations are discussed in the monthly meetings and are telecast every Monday and Thursday as per schedule. In this programme burning issues related to crop, the studio-invited experts and the viewers can ask questions from the experts by dialling the phone number announced just before the start of the programme. Dr JS Minhas, Dr Brajesh Singh, Dr SK Pandey, Dr Vinod Kumar, Dr SS Lal, PM Govinda Krishnan, Dr Sanjeev Sharma, Dr VK Chandla, Dr Vinod Kumar and Dr. Aswani Kumar participated in the programmes during the year to discuss various aspects of potato production. Similarly Dr NK Pandey, Dr MC Sood, Dr Brajesh Singh, Dr JS Minhas, Dr Ashwani Kumar, Dr Vinod Kumar, Dr. Manoj Kumar, Dr Mukesh Jatav, & Dr SS Lal participated in Live Phone-in Programme on different aspects of potato on All India Radio, Shimla.

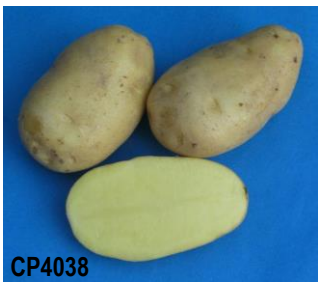
Doordarshan/TV/Radio Programme at Patna:

Live phone-in- programme and question/ answer session was organized jointly by Doordarshan Kendra, and CPRS, Patna for the benefits of the potato farmers of Bihar on 18-11-2009. Drs, R. P. Rai, Gulab Ram, Shambhu Kumar, S.K. Singh, and Barsati Lal participated in the programme. A total of 50 farmers from different potato growing districts of Bihar participated in the programme. In this programme, queries of farmers related to different aspects of potato cultivation storage and processing were answered face to face mode by the scientists. Dr. Shambhu Kumar Sr. Scientist participated in the programme on "*Aloo avam piyaj ki kheti*" and "*Aloo bhandaran ki desi taknik*" aired by AIR, Patna on 13-11-09 & 12-08-09 respectively. Dr. S.K. Singh delivered a talk on "A profitable potato based inter-cropping for Bihar" in krishidarshan programme of Doordarshan Kendra, Patna on 09-11-09. Dr. Barsati Lal, Sr. Scientist delivered a talk on "*Aloo fasal"* in Krishi Darshan programme telecast by Doordarshan Kendra, Patna on 20-11-2009.

EXTERNALLY FUNDED PROJECTS

1. Development and evaluation of potato germplasm and varieties with improved tolerance to abiotic stress and viruses (CIP-CPRI collaborative project)

1. **Seedling raising:** 21635 true seeds of 87 CIP x CPRI families produced at Kufri were used for seedling raising and 13943 seedlings were recovered and transplanted in the field. At harvest, 963 promising clones (6.91%) of 19 families were selected. The highest percent clones selected in the family were CP4176 x K. Arun and CP4175 x K. Ashoka (27%), K. Pukhraj x CP4049 (21%), CP4175 x K. Badshah (20%), CP4173 x Norchip (17%), CP4178 x K. Pukhraj (16%), CP4176 x K. Himalini, CP4181 x K. Badshah (15%), K. Pukhraj x 4 CP049 (14%), K. Pukhraj x CP4177, CP4175 x K. Jyoti, K. Sutlej x CP4212, CP4180 x K. Sutlej, K. Alankar x CP4192, CP4172 x K. Pukhraj, K. Alankar x CP4170, CP4180 x K. Pukhraj (13%), CP4175 x K. Pukhraj, 83-P-47 x CP4203 (12%) and 83-P-47 x CP4186(11%).
2. **Evaluation of clones in F_1C_1 generations**: 840 clones of CIP families were evaluated in short row of five tuber trial at 90 days crop duration and at harvest, 23 promising clones of 9 families were selected.
3. **Evaluation and multiplication of CIP late blight/virus resistant clones:** Twenty CIP clones (LBVR) were evaluated along with eight control varieties (K Anand, K Badshah, K Bahar, K Jyoti, K Lauvkar, K Pukhraj, K Sadabahar, K Surya). CIP clone CP4047 produced significantly high marketable and total tuber yield (478 and 509 q/ha) than the best control Kufri Pukhraj (415 and 443 q/ha) and recently released variety Kufri Sadabahar (400 q/ha and 420 q/ha). CIP clone CP4038 (378 q/ha & 412 q/ha) produced at par marketable & total tuber yield with control Kufri Pukhraj & Kufri Sadabahar. Nine CIP clones namely CP 4042 (394611.112), CP 4043 (395017.229), CP 4045 (395112.6), CP 4048 (395195.7), CP 4049 (396029.205), CP 4050 (396037.215), CP 4051 (396244.12), CP 4055 (397069.11) and CP 4058 (397099.6) were rejected on account of poor performance and undesirable tuber characters.



4. **Evaluation/Multiplication of CIP parental lines in net house (SK Luthra):** Seventeen CIP parental lines were evaluated at 90 DAP along with nine varieties (K Anand, K Badshah, K Bahar, K Jyoti, K Khyati, K Lauvkar, K Pukhraj, K Surya and K Sadabahar). CIP parental lines namely CP4175 (301 g/plant), CP4176 (349 g/plant) and CP4180 (466 g/plant) were found promising. Seven CIP parents namely CP4164 (388615.22), CP4169 (392820.1), CP4170 (394034.7), CP4171 (395192.1), CP4172 (395193.4), CP4173 (395194.9) and CP4174 (395195.7 were rejected on account of poor performance and undesirable tuber characters

2. Enhanced food and income security in SWCA through potato varieties with improved tolerance to abiotic stress (CIP-CPRI collaborative project funded by GTZ Germany)

Evaluation/multiplication of CIP advance clones in net house: Thirty one CIP clones were evaluated along with nine varieties (K Anand, K Badshah, K Bahar, K Jyoti, K Khyati, K Lauvkar, K Pukhraj, K Surya and K Sadabahar). CIP clones namely CP4189 (307g/plant), CP4196 (280), CP4199 (276), CP4200 (302), CP4206 (292) and CP4210 (303) were found promising. Thirteen CIP clones namely CP4183 (301024.14), CP4185 (301040.63), CP4187 (376181.5), CP4190 (380606.6), CP4191 (381379.9), CP4194 (382171.10), CP4195 (386292.3), CP4201 (392785.15), CP4203 (393381.4), CP4211 (396311.1), CP4213 (709003), CP4214 (709004), CP4215 (720118) were rejected on account of poor performance and undesirable tuber characters.

Evaluation of CIP genotyoes for drought tolerance: Twenty three CIP clones were tested in two field experiments under three irrigation regimes (normal irrigation, moderate water deficit and severe water deficit). In first experiment, CIP genotypes CP4048 and CP4055 performed better under sever water deficit which were also corroborated by higher drought tolerance index (DTI) and lower drought susceptibility index (DSI). In second experiment five CIP clones namely CP4176, CP4192, CP4193, CP4202 and CP4206 produced higher tuber yield (total as well as marketable) than control cultivar Kufri Bahar under sever water deficit. These clones also had higher DTI and lower DSI than Kufri Bahar.

3. Development of transgenic potato with resistance to major viruses (ICAR network project on transgenics in crops).

The internodal stem explants of the early variety Kufri Pukhraj were co-cultivated with EHA-105 containing the binary vectors containing PVY CP gene in sense, antisense, and non-translatable orientations. The regenerants were checked for rooting in MS medium containing 50 mg/L kanamycin and the rooting positive lines were further tested for gene integration by PCR (Fig. 1); 15, 4, and 10 positive lines have been identified so far for CP sense, antisense and non-translatable constructs, respectively.

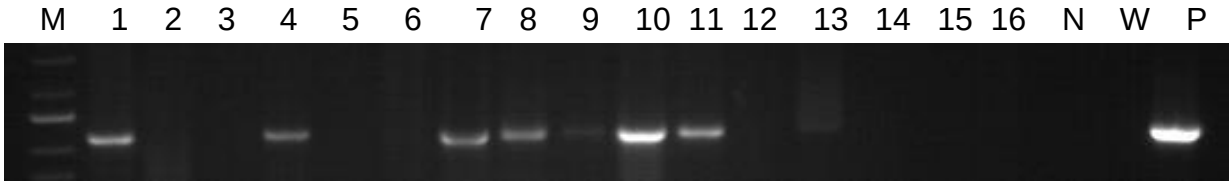


Fig.1. PCR of the genomic DNA of transgenic lines containing CP gene (sense orientation), amplified with the specific primers (showing 1100bp band): M = Gene rule 1Kb marker (MBI Fermentas), W = Water control, N = Negative control, P = Positive control, Lanes 1 to 16: transgenic lines.

For development of transgenic potato resistant to potato apical leaf curl virus, the early variety Kufri Pukhraj and Kufri Badshah were selected. The replicase gene of the potato apical leaf curl virus was inserted in antisense and hairpin loop orientations using *Agrobacterium*-mediated genetic transformation. The putative regenerants were checked for rooting in MS medium containing 50 mg/L kanamycin and by PCR. In case of Kufri Badshah, 11 and 35 regenerants were positive for gene integration in antisense and hp orientation (Fig. 2). Similarly, 16 and 6 positive lines of Pukhraj were identified for antisense and hp constructs of replicase gene, respectively. A few transgenic lines of Kufri Pukhraj were grown inside the glass house and inoculated with PALCV through white flies. Virus acquisition by the white flies was confirmed by print capture PCR. Two transgenic lines were resistant to the apical leaf curl virus.

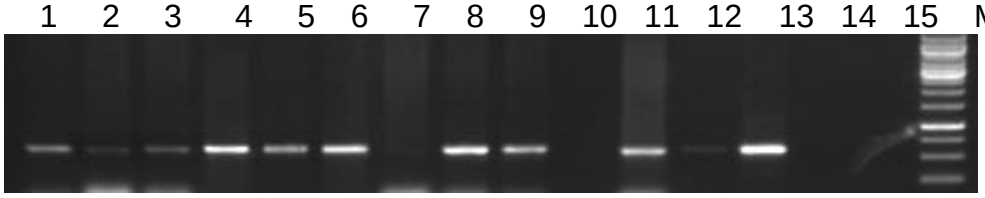


Fig. 2. PCR amplification of the PALCV replicase gene (hairpin loop) in putative transgenic lines of Kufri Badshah. Lane-1,2,3,4,5,6,7,8 9 11,12 - Putative transgenics, 13 - Positive control, 14 – Non transgenic control, 15 - Negative control, M – Marker.

4. Engineering late blight resistance in susceptible Indian potato cultivars (ICAR/ABSP II collaboration)

A confined field trial for event selection with 11 selected F_1C_5 clones from the cross Kufri Bahar x SP904/951, 11 selected F_1C_3 clones from the cross Kufri Bahar x SP951 and 50 selected F_1C_3 clones from the cross Kufri Jyoti X SP951 was conducted at CPRI, Shimla (Fig. 1). One line of each genotype with 5 tubers was planted along with non-transgenic Kufri Jyoti and Kufri Bahar. Planting was done 15th May 2009 and the trial was harvested on 29th September. Late blight appeared late in the season and its progress was recorded on 17th, 27th August and 4th September and RAUDPC values were calculated. All the 50 hybrids obtained from the cross Kufri Jyoti x SP951 performed better than Kufri Jyoti. Based on late blight resistance and tuber characters, 11 F_1C_4 clones have been selected for further evaluation at Modipuram. The hybrids of Kufri Bahar also performed better than non-transgenic Kufri Bahar control. However, the level of resistance was inferior to those of Kufri Jyoti hybrids. Only one line out of 22 selected hybrids showed good tuber characters under Shimla condition. Total RNA from all the selected hybrids was extracted and checked for the RB gene expression by RT-PCR and all were positive for RB expression. Similarly, 11 F_1C_4 hybrids of Kufri Bahar and 26 of Kufri Jyoti were evaluated at Modipuram during winter season. Two hybrids of Kufri Bahar and 12 of Kufri Jyoti were selected for further trial.

The RB gene has also been transferred to Kufri Jyoti and Kufri Bahar by *Agrobacterium*-mediated genetic transformation and six promising transgenic lines have been identified for each variety. The selected lines were multiplied *in vitro*.

Fig. 1. Photographs of the confined field trial with RB-transgenic hybrids at CPRI, Shimla.

5. Central Sector Scheme for Protection of Plant Varieties and Farmers' rights

Conservation of reference varieties: Reference collection of 158 varieties/numbers was maintained; 121 *in-vitro* and 104 in fields. These included 44 CPRI released varieties, 3 state varieties, 5 Indian number released elsewhere, 20 exotic varieties in cultivation in India, 57 indigenous varieties/numbers and 29 UPOV example varieties.

Testing and Meristem-tip culture for virus freedom:During the year 85 reference varieties were sub-cultured for testing their freedom from viruses and have been supplied for testing. The results of 48 varieties/clones supplied last year showed that only 9 were free of viruses. This may be because these varieteis/samples were from farmers' fields. The virus positive varieties are being subjected to chemo-cum-thermotherapy and meristem tip culture. Fifteen of these have been made free of the most difficult viruses PVX and PVS.

Characterization of reference varieties: Trial with all CPRI released varieties were conducted at Kufri and Modipuram and data recorded for various descriptors including the quantitative ones.

Finalization of descriptors: The descriptors of potato developed by the CPRI were finalized in consultation with PPV & FR authority and the final version has been hosted on the web site of the authority.

6. Artficial microRNA-mediated silencing of UDP-glucose pyrophosphorylase and vacuolar acid invertase gene for reduction of cold-induced sweetening in potato.

Three Indian processing potato cultivars, Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Surya, were transformed with twelve different artificial microRNA (amiRNA) gene constructs (Fig. 1) by *Agrobacterium*-mediated genetic transformation using internodal stem explants for reduction of cold-induced sweetening. A total of about six hundred putative transformants were obtained, which were screened for *NPTII* expression by RT-PCR. A total of 141 *NPTII* positive amiRNA transgenic lines were obtained. In addition, the three Indian potato cultivars were also transformed with transcriptional gene silencing construct under the control of tuber-specific promoter. The putative transformants were screened for *NPTII* expression by RT-PCR, and 38 transgenic lines were obtained. All the 179 transgenic lines were multiplied *in vitro* and about 3000 plantlets were planted in soil in the glasshouse of Central Potato Research Station, Jalandhar for evaluation of cold-chipping attributes.

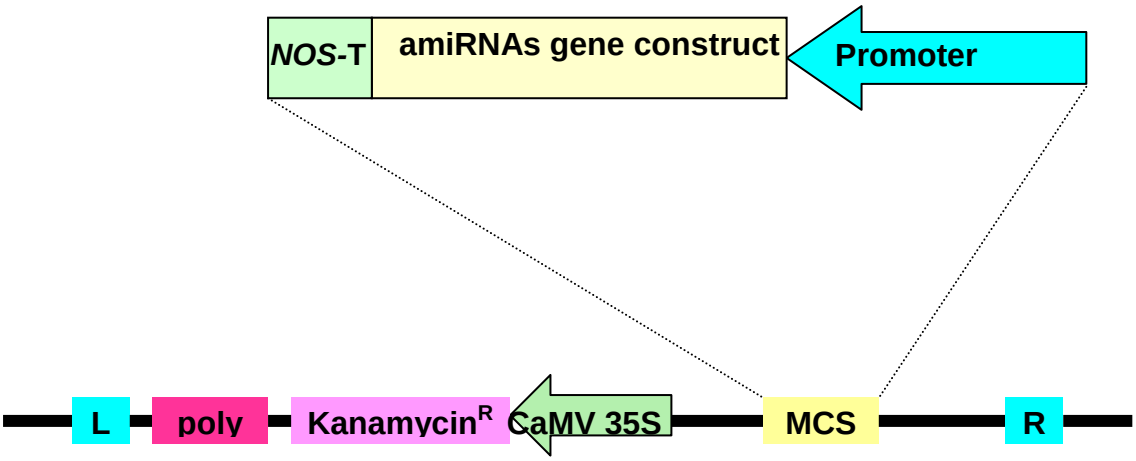


Fig. 1: Map of T-DNA region of binary vector cassette of pCAMBIA2300 harbouring amiRNA gene constructs.

7. Biotechnological approaches for reduction of cold-induced sweetening in potato

Cold-induced sweetening is a complex physiological phenomenon and success of any attempt for reduction of cold-induced sweetening requires robust and durable approaches. Therefore, attempt has been made for integration of both approaches of post-transcriptional silencing of invertase expression by introduction of invertase inverted repeat gene construct under constitutive promoter, and overexpression of tobacco invertase inhibitor gene under the control of tuber specific promoter for inactivation of any residual invertase enzyme. The purpose of integration of both RNAi and overexpression of tobacco invertase inhibitor is to get robust and durable level of reduction of cold-induced sweetening so that industrially desired level of chip colour is obtained.

Binary vector cassette harbouring both *Nt-Inhh* and invertase RNAi gene constructs were developed for potato transformation for reduction of cold-induced sweetening. Three Indian potato cultivars, Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Surya, were transformed with the vector cassette and 1000 putative transgenic lines were developed. So far 900 putative lines were screened and 20 lines were found to be positive.

8. Impact, adaptation and vulnerability of potato to climate change (ICAR Sponsored Network Project on Climate Change)

Most inexpensive adaptation option is changing date of planting according to the emerging agro-climatic conditions, which can be easily done at the farmers' level. In potato the optimum date of planting (DOP) is highly location specific even within small states and varies appreciably according to local weather conditions, soil and cropping systems. Therefore, a general recommendation to advance or delay in future climate scenarios is impractical. However, adaptation studies on change in DOP indicate possibility and extent of sustainable potato production in future climate scenarios by modification in DOP. Simulation studies were conducted by INFOCROP-POTATO model for several locations to assess the effectiveness of change in DOP from currently recommended dates in the current and future climates (2020 and 2050). In Punjab

and Western UP the delayed planting by 5-10 days generally increased or sustained the tuber yield in warmer 2020 and 2050. In these frost prone areas in the current climate the prime concern was to escape the frosting period in late December and early January by selecting an optimum planting date (OPT) allowing at least 75-90 days of growing period. Even in the current climate during frost free years delayed planting was found beneficial but is not recommended due to enhanced risk of frost damage. In Eastern UP and Bihar the delayed DOP by 5 to 10 days might sustain the potato production with only minor losses (0-10%) in tuber yield in future climate scenarios. In West Bengal (WB) there is no advantage from delayed planting and recommended DOP is the best option with a loss of 4-8% only. In WB, other adaptation measures like heat tolerant varieties, mulching *etc.* may prove beneficial. Similar was the situation in plateau and South India with yield losses of 4-49.1% depending upon the location. Results indicate that for states of WB, plateau region and south India development of heat tolerant varieties and other adaptation measures need to be developed as change in DOP might not be very effective.

9. Understanding vermicompost technology: Analysis, experimentations and standardization of practices (Department of Science and Technology, GOI funded)

The main aim of the project was to standardize practices for production of vermicompost and their documentation. The vermicompost (Table….)was producecd through locally unidentified earthworm and a commercially used *Eisenia fetida species* reared in plastic tray having 4.5 and 0.5 kg fresh dung and neem leaves, respectively (Fig.-1). Survey was also conducted to collect more number of local species of earthworm in different tehsils of Meerut district. When these species were reared artificially in soil and dung their population did not increase and finally all except one died in soil as well as in dung.

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Fig. 1. Pot study on vernicomposting with local new unidentified/*Eisenia foetida*

Table .1 Composition of vermicompost prepared from *Eisenia fetida and* local unidentified species of earthworm

Property	*Eisenia fetida prepared vermicompost*		Local unidentified species prepared vermicompost	
	Fresh wt. basis	Dry wt. basis	Fresh wt. basis	Dry wt. basis
Moisture (%)	64.4	-	66.2	-
pH	7.5	-	7.66	-
EC (ms/cm)	5.49		5.72	-
OC (%)	16.02	39.83	17.16	43.14
N (%)	0.67	1.6	0.82	2.05
P (%)	0.72	1.8	0.75	1.87
K (%)	1.28	3.2	1.28	3.2
Ca (%)	1.53	3.82	1.45	3.62
Mg	Traces	-	Traces	-
Fe (%)	0.24	0.60	0.27	0.67
Zn (%)	0.007	0.0175	0.006	0.015

10. Potassium and nitrogen nutrition management in Kufri Pukhraj (funded by Potash Research Institute of India, Gurgaon)

Two field experiments were conducted under the project at two sites, one at CPRS Farm and second at farmers fields in villages Janpara and Nasiriganj in the Patna district during 2009-10. The results revealed that the tuber yield increased with increasing N and K application. Potato yield was 250, 322, 381 and 397 q ha $^{-1}$ due to main effect of 0,75,150 and 225 Kg N ha^{-1} respectively and 277, 334, 361 and 377 q ha $^{-1}$ due to main effect of 0, 50, 100 and 150 kg K_2O ha^{-1} , respectively. The large (>75 g), medium (50-75 g) and total aggregate tuber yield and tuber number enhanced markedly with each increment in nitrogen levels from 0 to 225 kg/ha. Potassium and N application also improved tuber size by increasing the large and medium grades yield and decreasing the small and very small sized tubers. At farmer's field also the total tuber yield increased significantly with each increment of potassium dose. The tuber yield increased from 212 q ha $^{-1}$ (0 Kg K_2O ha^{-1}) to 311.9 q ha $^{-1}$ (150 Kg K_2O ha^{-1}). The increase in tuber yield was 19, 28 and 32 percent at 50, 100 and 150 kg K_2O ha^{-1} respectively.

11. National project on organic farming (funded by Ministry of Agriculture, Govt. of India)

The work on national project on organic farming was initiated during November, 2009-10. Ten farmers trainings on low external input farming system were given on concept of organic farming, its importance, management of plant nutrition through organic sources of nutrients, use of biofertilizers and incorporation of leguminous crop in soil. Bio control of insect-pests, diseases, preparation of vermicompost technology was demonstrated to 270 farmers from Shimla, Solan and

Bilaspur districts of Himachal Pradesh. Ten demonstrations (five for potato and five for ginger) were conducted during this period. The organic potato yield varied from 150 to 450 q/ha depending on organic matter status of soil and land aspect. Ginger yield also varied from 20 to 100 q/ha under different farmer's trials. The field experiment conducted under CPRI organic farm showed significantly higher potato yield with application of vermicompost and biofertilizers.

12. "Sustainable Livelihood Improvement through need based Integrated farming system models in disadvantaged districts of Bihar"

Sub-Project: Scientific cultivation of seed and processing potatoes

During the current crop season three major activities namely; 1) Production of quality seed of predominant variety, Kufri Pukhraj, 2) Improved cultivation of processing variety, Kufri Chipsona-1, 3) Training to farmers on seed plot technique and cultivation of processing variety were undertaken at the village Chakaramdas of Vaishali district. Under seed production programme a total of two ha area was planted involving 30 farmers. Similarly under cultivation of processing variety, another 2.0 ha area was planted involving 42 farmers. A total of 72 farmers were covered during the year under this project. Details of activities were as under:

I. Seed production activity: Breeder seed of Kufri Pukhraj @ 40 q/ha was used for multiplication and production of foundation seed covering an area of two hectares involving 30 farmers with variable cultivable area (table-1). Planting of seed crop was done by farmers after imparting them training on a) Seed preparation b) Application of

judicious doses of NPK @ 150:60:80 alongwith Thimet @18 Kg/ha and c) Furrow-ridge method of planting. Planting of crop was done from 30-10-2009 to 06-11-2009. For the control of weeds, herbicide oxyflurofen (Goal) was applied @500ml/ha just after planting the crop. First irrigation was given at the 4-5 days after planting. To protect the crop from cutworm, which is common in the area, Lethal (Chloropyriphos) was applied @ 2.0 lit/ha after emergence. Application of remaining half dose of nitrogen with urea was carried out at earthing operation. Roguing of diseased and undesirable plants was carried out thrice at 25-30 days, 50-60 days and before dehaulming. First prophylactic spray of fungicide (Moximate) was done on 15th December followed by 2nd and 3rd spray of Dithane-M-45 after 12 days intervals. Dehaulming of crop was done on 10- 20th January to avoid infestation with aphids. Irrigation was also stopped at this stage. Growers were registered with state seed certification agency for certification of crop. Crop was harvested after 12-15 days of dehaulming to allow skin maturity. Harvested produce was kept in heap for 12-15 days for skin-curing. Sorting/ grading was done before seed treatment. Seed treatment with 2.5% boric acid was also carried out.

The agronomic practices were supervised at farmer's fields by scientists and technical staff at regular intervals. A total of 465.50q seed of Kufri Pukhraj was produced. The details of farmers, area planted, production achieved, produce sold and produce retained in cold store are given in table-1.

II. Use of improved agronomic practices for cultivation of processing potatoes : A total of 42 farmers were selected. These farmers were given the breeder seed of variety Kufri Chipsona-1 for planting in 2.0 ha. The farmers were imparted the know-how of growing ware crop for processing through live demonstrations and made aware of the following points:

- Planting can be done by 3rd week of November after harvesting of main crop paddy
- No insecticide is required to be applied at planting or at any stage of plant growth
- Higher doses of fertilizers need to be applied for increasing the longevity of the crop and also to increase the size of the tuber
- The optimum dose of nitrogen to be applied was 270 kg/ha and potash 150kg/ha
- Roguing is not required
- Dehaulming is not required
- The crop need to be protected against late blight.
- The crop need to be harvested at maturity only to get maximum yield and bigger size of tubers suitable for processing

In the farmers fields, the crop was fully protected against late blight and the maximum yield achieved was 625.00q with an average yield of 300.60q/ha.

III) HRD/ Training Programmes: All farmers were trained at CPRS, Patna campus on potato production under four training schedules. A total of six training programmes of one day duration each were organized on Potato seed production, Late blight management, true Potato seed (TPS) production and harvesting, grading and storage of potato on 30-09-09, 28-10-09, 18-11-09, 27-11-09, 16-12-09 and 19-02-10 at CPRS campus and village Chakramdas. A total of 159 potato farmers participated in the programme.

Table.1. Details of farmers and area planted under seed potato production Variety- Kufri Pukhraj

Sl. No.	Name of Farmer	Area (Katha)	Area (ha)	Production (in q)	Yield (in q/ha)
1.	Sh. Umesh Shukla	4	0.064	16	250
2.	Sh. Jaganth Singh (East)	6	0.096	35	365
3.	Sh. Harendra Singh (East)	4	0.064	15	234
4.	Sh. Kameshawar Pd. Singh	4	0.064	24	375
5.	Sh. Baidyanath Singh	4	0.064	18	281
6.	Sh. Ram Pukar Sahani	3	0.048	10	208
7.	Sh. Pukar Sahani	4	0.064	15	234
8.	Sh. Mohan Singh	4	0.064	08	125
9.	Sh. Sudhir Singh	5	0.080	17	213
10.	Sh. Lalbundel Baitha	4	0.064	08	125
11.	Sh. Sandeep Kumar (R. N. Singh)	4	0.064	18	281
12.	Sh. Shailendra Singh	4	0.064	12	188
13.	Sh. Ayodhya Sah	4	0.064	14	219
14.	Sh. Bharat Singh	4	0.064	16	250
15.	Sh. Sukhlal Sahni	4	0.064	14	219
16.	Sh. Puneet Sahni	4	0.064	15	234
17.	Sh. Baiju Sahni	4	0.064	15	234
18.	Sh. Dashrath Sahni	4	0.064	17	266
19.	Sh. Parwal Sahni	4	0.064	16	250
20.	Sh. Chandeshawar Rai	4	0.064	12	188
21.	Sh. Muneshawar Rai	4	0.064	12	188
22.	Sh. Sita Ram Rai	4	0.064	12	188
23.	Sh. Rameshawar Rai	4	0.064	15	234
24.	Sh. Dev Narayan Sah/ Awdhesh Sah	6	0.096	18.5	193
25.	Sh. Mewalal Sah	4	0.064	08	125
26.	Sh. Chandrashekhar Rai	4	0.064	20	313
27.	Sh. Paras Rai	4	0.064	15	234
28.	Sh. Jagannath Rai	4	0.064	15	234
29.	Sh. Rameshawar Sah	5	0.080	20	250
30.	Sh. Mahesh Singh	4	0.064	15	234
	Total =	**125**	**2.0**	**465.50**	**6932.00**
	Avg. yield (q/ha)				**231.07**

Monitoring of seed crop by the scientists of CPRS, Patna

at Chakramdas, Vaishali

Advice being given by the scientists for seed potato production at field level

Training Programme organized for the farmers of NAIP, Vaishali

Training on potato planting and late blight management at Chakramdas, Viashali

Demo on potato planting at Chakramdas, Viashali

13. Standardization of conventional storage technology for potato using CIPC (funded by UPCAR, Lucknow)

Experiment No. I: Effect of Ca fertilization on quality of potatoes stored at 10-12 ^{o}C with CIPC

- Application of calcium improved the Hunter chip colour and maintained lower glucose content during storage of potatoes at 12^{o}C with CIPC.
- There is no effect of calcium application on sucrose, phenols & total free amino acid contents of potato tubers stored at 12^{o}C with CIPC treatment

Experiment 2: To find out the effect of organic nutrition and homeopathic product on quality of potatoes during storage

- Organically fertilized potatoes have lesser dry matter content as compared to inorganically fertilized ones.
- Organically fertilized potatoes have better chip colour & lesser glucose content as compared to inorganically fertilized during storage at 12^{o}C.
- Total free amino acid content and phenol content is more in inorganically fertilized potatoes as compared to organic ones.

14. **Value Chain on Potato and Potato Products (funded by NAIP, ICAR, New Delhi)**

- Dipstick kits for detection of PVX, PVS, PVM, PVY viruses has been developed.
- 13,000 minitubers were produced and supplied to chain partners.
- Kufri Frysona has been rated as the best variety for fries, on the basis of higher total tuber yield, higher dry matter, acceptable fry colour and superior texture of fries.
- Crop geometry of 67.5 × 25 cm has been found optimum for getting higher proportion of French fry grade tuber yield (54.4%) in variety Kufri Frysona.
- Depth of planting at 10 cm for higher French fry grade and total tuber yield has been standardized for variety Kufri Frysona.
- Ca nutrition (100 kg at planting) through zypsum increased the French fry grade and total tuber yield substantially in variety Kufri Frysona.
- Identified padding materials for safe heaping of potatoes, 10 cm thick paddy straw can be used for long term (2-3 months) heaping while perforated rubber mat can be used for short term (2-3 weeks) heaping.
- The variety Kufri Frysona has been found suitable for getting acceptable colour fries after long term storage at 12-14^{0}C with two CIPC treatments.
- Profiling of 20 Indian potato varieties for Acrylamide content in French fries completed.
- Two/three row automatic and semi-automatic planters have been developed for high density planting of potato for raising special purpose crop for baby potatoes.
- Kufri Himsona has been identified as a variety for baby potatoes with dry matter content of 17.2- 17.7% (<18%) and better yields (8.9 t/ha).
- Micro- irrigation systems lead to better tuber productivity (10.2-38.5%) over flood irrigation system.
- Two row or three row bed planting is better in comparison to conventional ridge-furrow system under drip and sprinkler irrigation system.
- Kufri Surya with maximum content of phenols, ascorbic acid and total carotenoids (54.0 mg/100gFW, 26.8 mg/100gFW and 100.7 µg/100g FW, respectively) has been identified as a nutritionally rich variety.
- Antioxidants namely ascorbic acid and carotenoids decreased during storage at 10^{0}C & room temperature with more pronounced decrease at room temperature.
- Animal feed pellets were prepared from unmarketable potato, barley and maize. Feed pellets were prepared by incorporating 10- 22 % unmarketable potatoes as an ingredient.
- The process for the extraction of dietary fiber from potato peel was developed and it is being standardized. The process involves treatment of peel with acid, enzyme and hydrogen peroxide.

- Base line survey has been completed and final report submitted.

Pic.1. Colour developed in virus detection dip stick

15. OUTREACH PROJECT ON *PHYTOPHTHORA, FUSARIUM* AND *RALSTONIA* DISEASES OF HORTICULTURAL AND FIELD CROPS

- Isolated and maintained sixty isolates of *Phytophthora infestans*
- Extraction of DNA from 40 isolates
- *Phytophthora* Avr3a avirulence gene having *RXLR* motif was identified for RNAi and amiRNA-mediated gene silencing for resistance development
- Devised strategies for RNAi and amiRNA-mediated silencing of *Avr3a* gene
- 21 late blight differential and 44 Indian potato varieties maintained
- DNA was extraction from late blight differentials and potato varieties; its qualitative and quantities analysis was done
- Synthesized primers for markers SPUD 237 and R1AS(R1gene) and cLET5E4 and GP 185 (R3a gene)
- Validation of above mentioned marker in late blight differentials
- All the 126 F1 offspring of the cross *S. spegazzinii x S. chacoense* were maintained *in vitro* as micro plants
- The population was genotyped using 4 AFLP primer combinations and 1 SSR primer set
- A molecular map of S. chacoense developed using 134 markers
- Twenty five bacterial isolates have been isolated and Some of them showed >33% emulsification activity and others showed <33% emulsification activity

- In dual culture test one bacterial isolate showed positive effect on *P. infestans*, it was identified as *Pseudomonas sp*
- To study the effect of temperature on efficacy of fungicide, four fungicide viz, Acrobat, Curzate (Cymoxanil + Mancozeb) Mancozeb, Ridomyl (Metalaxyl + Mancozeb) were tested at 25^0c
- JHULCAST model has been validated

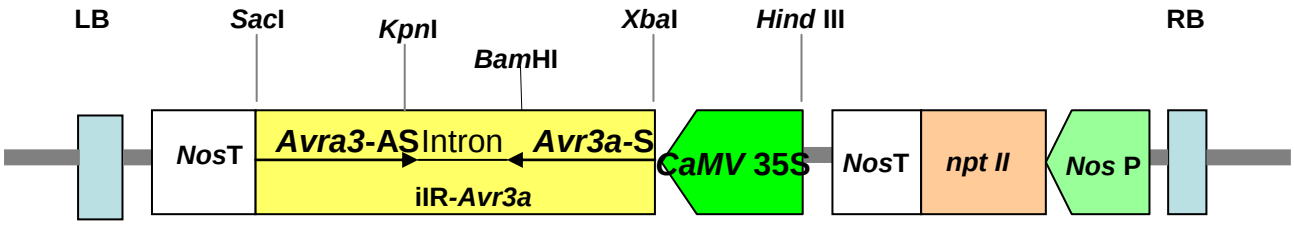


Fig. 3: Map of T-DNA region of binary vector cassette, pBI121:iIR-*Avr3a*

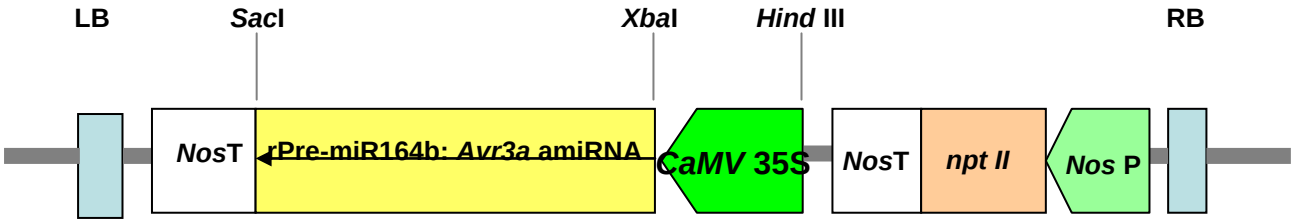
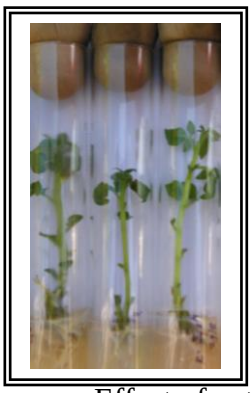


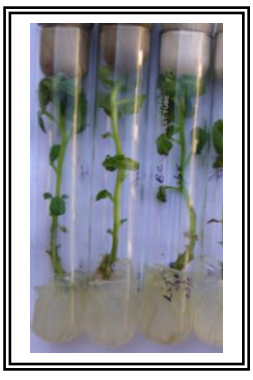
Fig. 6: **Map of T-DNA region of binary vector cassette pBI121:*Avr3a*-amiRNA**.

16. *In vitro* mass micropropagation and protected production of micro/minitubers of processing and common potato varieties suitable for hills (Under MM-I)

A total of 18307 microplants, 11552 microtubers and 74429 minitubers of eight varieties viz., Kufri Chandramukhi, Kufri Giriraj, Kufri Jyoti, Kufri Kanchan, Kufri Shailja, Kufri Himalini, Kufri Himsona and Kufri Girdhari suitable for hills were produced. In addition to this, standardization of media for mass multiplication of recalcitrant variety Kufri Jyoti, studies on effect of antibiotics on bacterial contamination and *in vitro* growth of Kufri Jyoti and studies on reducing the lenticels busting during microtuber production were under taken.

Growth of Kufri Jyoti on





Effect of antibiotics on bacterial

New multiplication media	contamination and growth of Kufri Jyoti

17. Integrated Development of Horticulture in NEH Region (funded by Technology Mission on Horticulture, Mini-Mission–I)

Quality seed production through potato micropropagation

A total of Potato 18360 microplants of different varieties viz., K. Giriraj (3230), K. Jyoti (940), K.Himsona (2990), K. Himalini (7800) and K. Giridhari (3400) were produced through micro-propagation during the period April, 2009 to March 2010 (Table 18). 9940 microplants (K Giriraj-2650, K Himsona-1160, K Girdhari-900, K Himalini-5230) were transferred to polyhouse from April 2009 to March 2010 for minituber production. At present 4800 microplants (K.Jyoti- 640, K.Himalini-1300, K.Giriraj-360, K.Girdhari- 1530, K.Himsona-950) are available in the laboratory and 4200 microplants of the variety K.Himalini has been transferred to the polyhouse for minituber production. During the same year 29 Kg minitubers of different varieties were produced in the polyhouse. A total of 127.52 q quality seed from various field generations were obtained and out of total quantity 17.5 q seed was given for demonstrations to farmers in Meghalaya. Remaining quantity will be multiplied during 2010-11.

Table 18. Status of micro plants/mini-tubers production and different field generations during 2009-10

Cultivars	Microplant produced (No.)	Microplant transferred to polyhouse (No.)	Minituber production (kg)	Field Generation III (q)	Field Generation IV (q)	Field generation V (q)	Total of all field generations (q)
K.Himalini	7800	5230*	9.2	-	-	-	-
K.Himsona	2990	1160	7.9	-	-	-	-
K.Girdhari	3400	900	1.5	-	-	-	-
K.Giriraj	3230	2650	10.4	34.65	23.88	43.62	102.15
K Kanchan	-	-	-	25.37	-	-	25.37
K.Jyoti	940	-	-	-	-	-	-
TOTAL	**18360**	**9940**	**29.0**	**60.02**	**23.88**	**43.62**	**127.52**

*4200 microplants of K. Himalini variety transplanted in polyhouse at present
4800 microplants presently available in the laboratory

Evaluation of growth potential of different nodal sections on microplants

An experiment was planned to evaluate growth potential of top, middle and lower portion of nodal cuttings of microplants of four potato varieties namely K.Giriraj, K.Girdhari, K.Himalini and K.Himsona. The present study shows that there is no clear cut distinction between top, middle and lower stem segment of microplants for subsequent sub-culturing. The top segment showed vigorous rooting and better leaf size while the lower segment produced maximum number of nodes. The middle segment exhibited highest growth rate. Thus, all the stem segments can be used for micropropagation through subculturing of nodal segments in potato microplants.

Standardization of Production and Protection

Under this programme, the effect of different dates of sowing on late blight incidence and yield in potato was studied. The experiment was laid using four varieties K Giriraj, K Girdhari, K Jyoti and K Megha, three dates of sowing viz. early (D1), normal (D2) and late planting (D3), two spraying schedules against late blight (sprayed and non sprayed) and two dates of harvest (90 DAP & 105 DAP).

In 90 days crop duration, the marketable and total yield increased linearly with advancement in date of planting in all the varieties. Among varieties, K Giriraj gave higher yield in 90 days duration at normal planting date. For early planting, K Megha and K Giriraj were the best yielders in 90 days. For longer crop duration (110 days), total yield was highest at normal planting date (Table 21). In late planted crop, K Giriraj, K Megha and K Girdhari performed equally irrespective of spraying schedule. When crop duration was extended to 110 days K Megha yielded well at all three planting dates. K Jyoti, the most preferred variety in the North-eastern region performed significantly poor in all the treatment combinations. Thus, K Megha seems to be the best variety at different planting dates and duration of crop.

On-farm demonstration and training on improved potato technologies

105 on- farm demonstrations were conducted in the farmers' field in East Khasi hills district of Meghalaya on potato through seed tuber (K. Jyoti & K. Giriraj). Kufri Giriraj and Kufri Jyoti used for the demonstration recorded an average yield of 15 t/ha and 13.5 t/ha respectively while the local variety used by the farmers recorded only 3.5 t/ha. An average 328 % and 285% yield increase was achieved in Kufri Giriraj and Kufri Jyoti respectively as compared

to local varieties. The farmers expressed their desire to adopt the improved varieties and methods of potato cultivation.

Four demonstrations were conducted in the farmers' field on potato through seed tuber (K. Jyoti, K. Giriraj and K. Giridhari).

The average yield obtained from K. Jyoti, K. Giriraj and K. Giridhari was 20.5t/ha, 20.4t/ha and 21.4t/ha respectively, which showed that yield advantage from K. Giridhari was significantly higher in comparison to K. Jyoti and K. Giriraj.

Six demonstrations of TPS technology were conducted at the farmers' field in Mylliem (2) and Mawkriah (4) circles. Each of the farmers were supplied with TPS- C-3 for demonstration along with the technical know- how of TPS technology.

Table 24. Demonstration with TPS population TPS C3

Name of the farmer	Village	Crop duration	Total Yield (t/ha)
Misalan. Lyndogh	Mawkriah West	120 days	8.0
Surmalang Nongbri	-do-	120 days	4.3
Klenselin N.	-do-	110 days	5.8
Marshes Syiemong	-do-	110 days	4.0
Battri.Kharkongor	Mylliem	60 days*	2.1
Meitis .Langstieh	-do-	60 days*	1.3

* Crop harvested early due to frost injury

The average yield obtained from six TPS demonstrations was 4.29t/ha (Table 24). Five demonstrations were conducted at different location of Mawklot village in order to undertake a comparison study in yield difference by adopting both scientific as well as nur and bun method of planting through potato seed tuber (K .Jyoti and K. Giriraj).

S. No	Name of the farmer	Village	Type of land	Method of planting	Yield (t/ha) K. Jyoti	Yield (t/ha) K. Giriraj
1.	Neltimai Kurkalang	Mawklot	Plane	Nur & Bun	10.5	9.0
2.	Cibilian Kharir	-do-	-do-	Scientific	1.0*	0.25*
3.	Lioris Kharir	-do-	Slope	Scientific	14	11
4.	Biolinda Nongsiej	-do-	-do-	-do-	6.2	6.1
5.	Daplin Suiting	-do-	-do-	Nur & Bun	5.1	7.5

Table 25. Demonstration with scientific and Nur (raised bed) method of potato cultivation.

*Crop severely infested with late blight

K .Jyoti and K. Giriraj sown in plain area under nur and scientific method recorded an average yield of 10.5t/ha, 9.0t/ha,1.0t/ha and 0.25t/ha, respectively (Table 25). Similarly K .Jyoti and K. Giriraj planted in slope area under nur and scientific method recorded an average yield of 5.1t/ha, 7.5t/ha,10.1t/ha and 8.55t/ha, respectively. The crop sown on plain land under scientific method of sowing was severely affected by late blight and hence yield comparision with Nur method is not valid. Under slopy land, the scientific method gave higher yield over nur method.

Nur-Bun Method of planting Potato

Standing crop at demonstration field

18. Popularizing of low cost storage technology for table potato seed (funded by NABARD RIF)

Household level storage for table potatoes

In the previous year there were 16 farmers from four villages, while this year a total number of 15 farmers were selected five from Mylliem, two from Mawklot, two from Myrkhan four from Mawnianglah one from and two from Lmsohriew. All the fifteen farmers in the project kept 2 -10 q table potato as well as part of their seed in the household storage structure depending on their volume of harvest. The market rate of table potato was monitored at fortnightly interval up to 15th December 2009.

The farmers who sold their produce in the month of November they received a better price after 3 months of storage .The farmers received a profit of Rs 75-625.

Potato tubers in all the household storage structure did not have greening which is useful for table potatoes marketability. The average tuber sprouting in 30DAS is 23.35%, 24.8% in 60DAS and 27.9% in 90DAS.The total loss in household structure (i.e. rottage and weight loss) ranged between 1.01%- 4.0%. The disease infestation was also less. Hence farmers can keep their produce for the sufficient period of time till the market rate is suitable for sale and earn a good profit.

Community Level Seed Storage Structures

The seed in the storage structure had less sprouting with medium shrinkage (Table 28). There was less infestation of diseases with dry rot between 1-2%, soft rot between 1-2% with no infestation of PTM.

Table 28. Seed quality in the community level storage structure at the end of storage period

Village	No. of farmers	Sprouting %	Greening %	Rottage	Weight loss	Disease
Mylliem	12	100%	0%	2%	500g	2%
Mawklot	2	100%	2%	0%	120g	0%
Nongpyiur	1	100%	2%	0%	100g	0%

19. Survey of virus vectors and pathogen pressures in potato production regions of North-East India (CIP-CPRI collaborative project)

Survey on virus vectors and pathogen pressures in potato production regions of North-East India viz. 6 sites each in Meghalaya and Sikkim and 5 sites each in Arunachal Pradesh and Nagaland was done during the crop season 2009-10**.** In all the above selected sites work was undertaken to monitor the vector populations through a simple aphid-leaf count in the crop. In addition to the simple aphid-leaf count a survey was conducted during the cropping period at all sites in all the four states of NE- India to monitor the population dynamics of the potato aphids by placing yellow trays filled with water with some detergent to trap the alate aphids. Yellow sticky traps applied with the petroleum jelly as an adhesive to trap the aphids was also used. Weekly data of aphid population in each tray and traps were counted and recorded from all the sites from different locations.

Meghalaya

In Meghalaya the highest number of aphid catch in water trap was 10 at Tyrsad during second week of May where as during mid April the highest population of winged aphids was around 50 at the same location (Tyrsad) as well as at Laitlyngkot during third week of April. Aphid count between 20-30 was recorded weekly from almost all the locations irrespective of the different altitudes.

Viruses like PVX and PLRV were altogether absent from the samples tested for ELISA last year but in 2009, these viruses showed the positive reaction from few samples collected from Laitlyngkot and Mowkodok. More over PVY also showed the positive reaction from the samples collected from almost all the locations in 2009 .

Sikkim

During the weekly survey in Sikkim the aphid population was recorded using yellow water trap and yellow sticky trap. The number of aphids counted ranged from 40 in the last week of April and continue to increase till 80 aphids in the first week of May in both the traps from almost all locations but the highest aphid count was recorded in the sticky trap i.e. around 430 in the last week of April. Samples collected from Bakhim, Rawangla and New Sada showed the positive reaction of PLRV, PVA, PVS, PVX and PVY.

Arunachal Pradesh

The aphid data collected this year showed that the aphid population was found to be slightly higher than that of critical level at almost all the locations (last week of May to first week of June). If we compare the current data from last year we found that aphid abundance at both lower as well as higher altitudes and aphid build up is slightly shifted from end of April to the end of May and early June.

Graph showed the aphid population increase soon after the plants emergence and continue to increase till second week of June. More than 20 aphids were counted in water as well as sticky traps 40 days after planting till 76 days after planting at all the locations irrespective of the altitude.

Nagaland

Weekly survey of Aphid population and virus incidence was done at different sites in Nagaland viz. Kigwema Vill, Ukule Kigwema, Khuzama, Khuzama Vill. NH 39 and Lower Ukule Kigwema from April 9 to May 30, 2009. It was found that the Aphid population was below the critical level at almost all the locations except one with slightly higher i.e Khuzama village NH-39 (last week of April)

In 2009 the samples collected from Nagaland showed the presence of viruses like PVA, PVX, PVS and PVM and few samples which were collected from the Kigwema and Khuzama gave the positive results of PLRV but PLRV.

20. Bio-intensive management of white grubs

Eight species of scarabid beetles were recorded in Shimla. Eighteen plant extracts and some bacterial and fungal isolates were evaluated under laboratory conditions for their efficacy against these beetles. The multilocational trials were conducted at Shimla, Kheradhar and Shilaroo with the botanical extracts and microbes isolated from soil and dead insects, proved effective under laboratory conditions revealed that Neem seed karnel and Jatropha karnel extracts remitted minimum damage, whereas *Bacillus* species were found effective amongst different isolates of bacteria and fungi. IPM schedule was developed which comprises of light trap in vicinity with

soil application of locally isolated bacterial strain *Bacillus* spp. at the time of planting and application of neem seed kernel extract in cattle urine @5ml/l on the appearance of the beetles or soon after the first monsoon showers.

Brahmina coriacea *B. flavoserica* *B. crinicollis* *H. longipennis* *Holotrichia* spp

A. lineatopennis *A. dimidiata* *Lepidiota stigma*

Scarabid beetles infesting potato in Himachal Pradesh

22. *In vitro* mass micropropagation and protected production of micro/ minitubers of processing and table potato varieties suitable for hills

The microplants, microtubers and mini tubers of eight varieties of processing and table potato, suitable for hills were developed/ multiplied

under protected conditions. A total of 18307 microplants (670 Kufri Chandramukhi, 1405 Kufri Giriraj, 4554 Kufri Jyoti, 2900 Kufri Kanchan, 3233 Kufri Shailja, 3760 Kufri Himani, 1170 Kufri Himsona and 615 Kufri Girdhari), 11552 microtubers (1873 K. Chandramukhi, 5500 K. Giriraj, 2400 K. Kanchan, 124 K. Himsona and 1655 K. Girdhari and 74429 minitubers (7728 K. Chandramukhi, 3344 K. Giriraj, 12797 K. Jyoti, 13697 K. Kanchan, 8075 K. Shailja, 12987 K. Himani, 7961 K. Himsona and 7840 K. Girdhari) were produced.

Production of micro tubers

Micro plants in net house

Micro tubers

Mini tubers

(Library and Documentation Services)

Sub: Annual Report for the period April 2009 to March 2010

Introduction: In accordance of one of the CPRI mandate ***"To act as national repository of scientific information relevant to potato"*** CPRI Library and Documentation Services unit was established in 1956 with a modest collection of 256 documents. Presently this library stacked more than 60 thousands documents and has attained the position of most sought-after library on potato R & D in India. Since its inception this library has acted as repository and clearinghouse of potato literature and information. It continually provided scientific and technical information supports and services towards attainment of research mission of the institute. Efforts were made for strengthening and developing the information resources and services through undertaking various activities given here below:

Resource Development

At the headquarter (Shimla), a total of 364 documents were purchased, procured and added to library resources. The total collection at Shimla stand at 35164 documents comprised of 13545 books, 14368 back volume of journals, 2446 serials, 2125 annual reports, 582 theses, 251 standards, 41 maps/atlases, 1663 reprints and 143 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 26714 books; journals back volumes and other documents i.e. AR/Reprints and Bulletins etc as per the details below (Table-1).

Table-1: Library Collection of CPRIC & CPRS

Regional Stations		Books	Back vols. of Journals	Other Documents (AR/Rpr/Bull)	Total	Current Journals subscribed (Indian)
1	CPRIC, Modipuram	4042	5526	2200	11768	23
2	CPRS, Jalandhar	2906	1401	1137	5444	30
3	CPRS, Patna	1854	1256	13	3123	18
4	CPRS, Gwalior	665	4	326	995	1
5	CPRS, Ooty	1427	1851	540	3818	13
6	CPRS, Shillong *	1289	-	133	1422	-
7	CPRS, Kufri	144	-	-	144	-
	TOTAL	12327	10038	4349	26714	85

Note: * *Figure shown for CPRS, Shillong is for the year 2008-09*

Periodicals and Serials Management

Sixteen serials title i.e. advances, annual reviews, reference annuals, yearbooks and statistical data publications etc. were purchased. A total of 213 current journals comprising of 60 foreign and 152 Indian have been subscribed at Shimla. Out of which 46 foreign and 134 Indian journals were subscribed on payment basis and rest on exchange or gratis. In all 1189 issues of such journals were received, marked and kept in library for use. Besides 85 titles of different journals were subscribed at

CPRS libraries. 116 entries of library documents were made in Library Automation Software and 191 books were classified, catalogued, labeled, pasted and transcribed for use. The library has the complete series of CABCD, AGRICOLA (NAL), AGRIS (FAO), Current Contents – AB&ES, Derwent Biotech Abstracts, FSTA (IFIS), ISA on CD, and Nucssi on CD, CDROM databases for retrospective and current scientific literature search and use of scientists.

Computerized & Net Based Services

The institute scientists were facilitated with online full text access to 33 foreign subscribed journals and more than 2000+ journals through ICAR's e-resources consortia (Consortia for E-Resources in Agriculture). The library resources e.g. library catalogue (OPAC), foreign journals, CD Net searching, and other services like Recent Articles on Potato (RAP) and Current Journals Received Last Week were regularly updated and maintained on library web page. Now scientists are making use of mostly library resources online from their desktop. Many relevant web sites were visited and information and data were downloaded therefrom for scientists' use.

Readers and Reference Service

A total of 812 documents were circulated (borrowed and returned) for home studies and 5916 readers consulted 11081 documents within the library. Besides 56 outside scientists and research scholars of various research organizations consulted the library resources. A total of 854 job requests were received for 2,46,1330 copies of photocopying and printing work of different official documents. 6 new members were enrolled and 11 old members withdrew their library membership due to their transfer or retirement. At present 149 readers are active members of library excluding RAs/SRAs. Library received 8511 reference queries from the users of the library and responded to them satisfactorily.

Documentation and Information Services

1189 issues of journals (758 issues of national and 431 issues of international journals) were scanned for potato literature. Besides, the in-house documentation services in the form of Current Periodicals Received Last Week (Weekly) and Recent Articles on Potato (Monthly) were brought out regularly and updated on the library website for users of library.

Resource Generation and utilization

The library has generated the revenue of Rs. 1,29,102.00 which include the amount charged on account of rendering CDROM searching & photocopying services (Rs. 6,830.00), IGNOU computer practical (Rs. 21,900.00) and library discount (Rs. 1.00.342.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 19,68,569.00 was spent (under Plan Rs. 15,96,422.00; Non-Plan Rs. 1,81,030.00 and Rs 191117.00 under XIth Plan IPR Scheme) on library resources and developments like purchase of books (Rs. 5,38,037.00), and subscription of journals (Rs. 10,50,655.00) at HQ library Shimla and Rs 1,88, 760.00 on CPRS libraries..

CDS/ISIS Practical Training

As per MOU between CPRI and IGNOU, New Delhi, 17days computer, IT, and database creation and operation practical session was organized during 19-31 July, 2009 and 1-4 August, 2009 for 11 MLIS and 21 BLIS students of IGNOU Study Center, Shimla.

Infrastructure Development

One Digital Photocopier cum network printer has been procured and installed to facilitate photocopying and printing of scientific documents.

Institute Research Council Meeting

The Institute Research Council (IRC) Meeting, 2009 was held at CPRI, Shimla on 5th – 7th June, 2009. It was attended by 52 scientists from the Headquarters, Institute's Campus at Modipuram and regional stations. The basic objective of this meeting was to review the achievements of 2008-09 and formulate future plan of work for 2009-2010 of different research programmes.

Dr. SS Lal, Secretary, IRC welcomed the participants. After the opening remarks by Dr. SK Pandey, Director, CPRI and Chairman, IRC, Heads of Divisions presented action taken report on the decisions and recommendations taken in the last IRC Meeting. All Programme Leaders and participating scientists highlighted the major activities and achievements during 2008-09. Thorough discussions were held on each of the above items and various recommendations have been included in the IRC Proceedings of the Institute. The important recommendations of IRC Meeting, 2009 are:

1. The data collection on andigena germplasm should be completed this year and the core collection should be identified. This core collection should be freed from all viruses by meristem culture and conserved *in-vitro* at Shimla.

2. Hybrids K-22, G-4 and control varieties Kufri Khyati, Kufri Sadabahar and Kufri Surya will be evaluated at Modipuram, Patna and West Bengal.

3. Work on germplasm screening for Vitamin-C content at Jalandhar shall be taken up on priority.

4. Andigena hybrids A-98-98 and A-97-29 should be introduced in AICRP (P) multi-location trials to be conducted at Pantnagar, Modipuram, Jalandhar and Hissar during spring season.

5. All the available data for screening against stem necrosis should be compiled and highly resistant accessions should be evaluated again in a single trial. Based on the results, recommendation should emanate from this programme.

6. A trial will be conducted with varieties Kufri Sadabahar, Kufri Surya, Kufri Frysona and one more variety in Gujarat for French Fries. The treatments will be as per farmer's practices and package of practices recommended for the region by CPRI.

7. The advanced stage hybrid, MP/01-916 will be considered for release in the Karnataka state based on its performance in the coming crop season in different multi location trials being conducted in *Kharif* season.

8. In the experiment on effect of high temperature priming, efforts should be made to explore new chemicals for dormancy breaking in shorter period of time.

9. Work on Marker Assisted Selection (MAS) and mapping will be undertaken under respective breeding Programmes/Projects. For this, facilities developed in Biotechnology programme will be used by respective breeders.

10. Transgenics of Kufri Surya should also be developed for bacterial wilt tolerance in addition to Kufri Giriraj.

11. Possibilities should be explored to find the alternative gene to EBD for tolerance against bacterial wilt.

12. The germplasm accessions with known resistance to hopper burn and stem necrosis should be used as parents in developing varieties for heat tolerance.

13. In experiments on Potato Cyst Nematodes (PCN) management through cropping system, chemical control treatment may also be added to compare different PCN management strategies.

14. Hybrid JX-576 is to be multiplied and be included in the experiments for identification of nutrient efficient cultivars.

15. Potato cultivars Kufri Himalini and Kufri Girdhari should be included in root studies.

16. A video film of approximately 20 minutes should be made covering all the farm equipments developed/used in running/working condition at Jalandhar and Modipuram.

17. The scenario of traditional storage practices in Malwa region of MP has to be assessed again to find out the present status of potato storage by traditional methods.

18. Development of high starch yielding varieties may be taken up in the breeding programme on processing.

19. The fertilizer trials of Kufri Surya at two locations of Punjab, six locations in UP and two locations in Bihar should be completed to find out the optimum fertilizer dose for this variety.

20. Selected hybrids with combined resistance to late blight and PVY (LBY series) may be multiplied on priority by tissue culture.

21. A video CD for the management of late blight may be prepared for the use by the potato growers and create awareness in mission mode manner.

22. Research work may be initiated to reduce the lenticels bursting in microtuber to reduce the driage losses during storage.

23. Economic impact assessment of two potato production/storage technologies, viz. Seed Plot Technique and Potato storage at elevated temperature should be completed.

24. Knowledge dissemination on late blight management should be emphasized through trainings and other extension methods.

PUBLICATIONS

A. Books :

Annual Report – 2008-09
Annual Report Mini Mission-I (2008)
MM-I Consolidated Report 2004-05 to 2007-08
CPRI Diary 2010
Newsletter Vol. No. 40
Newsletter Vol. No. 401
Samahit Hindi Patrika Allo fasal Calender
Souvineir of " Golden Jubilee Celebrations of Seminar on potato in North East"
CPRI Profile

B. Folders:

C. Technical Bulletions:

AICRP-POTATO (Bulletin No. 3)
Information technology in Horticultural Crops.

D. Extension Bulletin :

Extension Bulletin No. 41 – Paharti Khashetron main alloo ki unnat kheti
Extension Bulletin No. 42 – Uttari Pashchimi pahari ilakon main alloo ki fasal main paushak tatvon ka prabandhan.

F. PAPERS PUBLISHED IN REFERRED JOURNALS:

1. Anupam Sharma, D. R Thakur and V. K. Chandla. (2009). Use of *Steinernema* and *Heterorhabditis* Nematodes for Control of White grubs, *Brahmina coriacea* Hope (*Coleoptera: Scarabaeidae*) in Potato Crop. Potato J 36 (3-4):160-165.
2. Arora, R.K. 2009. Rational use of fungicides in management of late blight of potato. Invited Lecture IMSPP (NZ) Symposium on “Rational use of fungicides in the management of horticultural crop diseases” July 8-9, 2009. Souvenir and Abstracts P. 8.

3. Arora, R.K. 2009. Response of major Indian commercial potato varieties to early blight in north-western plains. National Conference on Production of Quality seeds and Planting material- health management in Horticultural Crops, March 11-14, 2010, New Delhi. Abstracts pp.127.
4. Arora, R.K. 2009. Utility of hyperspectral data for potato late blight disease detection through remote sensing. Invited lecture. 5th International Conference on Plant Pathology in the Globalized Era, Nov. 10-13, 2009, New Delhi. Souvenir and Abstracts P. 13
5. Bhatnagar, A. 2009. Efficacy and economics of insecticides, neem product and biopersticide against Thrips (*Thrips palmi* Karny) on potato (*Solanum tuberosum*) crop. *Annals of Plant Protection Sciences* 15 (1):101-105.
6. Bhatnagar, A. 2009. Effect of two pesticides and nitrogen application on insect vectors population of potato (*Solanum tuberosum*) crop. *Potato J*, 36 (1-2):75-77.
7. Bhatnagar, A . 2009 . Alu ke hanikarak kito ka jaivik karko se saurakshan. Krishi chainika. April – June ank, 28-29.
8. Bhatnagar, A and Somani , A.K. 2009. Bharat ke hrudaystal Madhya Pradesh me alu ke badhate kadam. A Potato News Letter, CPRI, Shimla. Page 18-20

9. Chakrabarti, S.K. 2010. Advances in diagnostic research on potato. Oral presentation in the "National Consultative Meeting on Disease Diagnostics for Horticulture Crops", 22-24 January, 2010, Tiruchirapalli, Tamil Nadu.
10. Chakrabarti, S.K., Bradeen, J.M., Singh, B.P., Austin-Phillips, S., Raman, K.V., and Pandey, S.K. A major gene with typical R protein structure confers genotype dependent quantitative resistance to late blight. Oral presentation in "The 6th Solanaceae Genome Workshop 2009", 8-13 November, 2009, New Delhi, India.
11. Dua, VK, SS Lal and PM Govindakrishnan. 2009. Nutrient requirement of Frenchbean (*Phaseolus vulgaris*) in potato (*Solanum tuberosum*) – Frenchbean intercropping system. *Indian Jounral of Agricultural Sciences* **79** (5):329-33.
12. Gopal J, ID Garg and SK Pandey 2010. An efficient protocol of chemo-cum-thermotherapy fpr elimination of potato viruses by meristem-tip culture. Abst. National Conference on Production of Quality Seeds and

Planting Material. 11-14 March, 2010. National Agriculture Science Complex, Pusa, New Delhi. pp.176.

13. Gopal J, V Bhardwaj, P Manivel, PH Singh and V Kumar. 2008. Screening of wild species for late blight resistance in potato. Proc. Internatl. Conf. Biodiv. Conserv. & Mgt. 327-331
14. Gopal J, V Kumar and SK Pandey. 2009. Potato genetic resources in India. Abst. 6th Solanaceae Genome Workshop, 8-13 November, 2009. Le meridian, New Delhi. pp. 98.
15. Gopal J. 2009. Evolution of potato breeding in India. Abst. 7th World Potato Congress, 22-25 March, 2009. Christchurch, New Zealand. pp.58.
16. Gopal J. 2009. Slow-growth in vitro conservation of potato germplasm. Abst. 7th World Potato Congress, 22-25 March, 2009. Christchurch, New Zealand. pp.58.
17. Gopal J. 2010. Scope of potato production through TPS technology. Abst. National Conference on Production of Quality Seeds and Planting Material. 11-14 March, 2010. National Agriculture Science Complex, Pusa, New Delhi. pp 117-118.
18. Grover, A., Azmi, W., Paul Khurana, S.M., and Chakrabarti, S.K. 2009. Multiple displacement amplification as a pre-polymerase chain reaction (pre-PCR) to detect ultra-low population of Ralstonia solanacearum (Smith 1896) Yabuchi et al. (1996). Letter in Applied Microbiology 49 (5): 539-543.
19. Gupta VK, K Malik, SK Luthra, JS Minhas, J Gopal and BP Singh. 2010. Identification of heat tolerant planting materials in potatoes. National Conference on production of quality seeds and planting material-health management in horticultural crops. 11-14 March, 2010, NASC Complex, New Delhi, SPH, IIHR, CHAI. Abstracts: p30.
20. Gupta VK, KD Bipul and SK Pandey. 2009. Performance of local potato varieties In Meghalaya hills. *Potato J*. 36 (1 - 2): 65-67.
21. Gupta, R.; Modgil, M.; and Chakrabarti, S.K. 2009. Assessment of genetic fidelity of micropropagated apple root stock plants EMLA111 using RAPD markers. Indian Journal of Experimental Biology 47: 925-928.
22. Gupta, VK, Kamlesh Malik, SK Luthra, JS Minhas, Jai Gopal and BP Singh.2010. Identification of heat tolerant planting materials in potatoes. National Conference on production of quality seeds and planting material-health management in

horticultural crops.11-14 March, 2010. NASC Complex. New Delhi, SPH, IIHR,CHAI,Abatracts : p30.

23. Kumar P, MS Kadian, C Carli, M Bonierbale, R Schafleitner, J Gopal, SV Singh, SK Luthra, BP Singh, N Sharma, E Chujoy and SK Pandey. 2008. Evaluation of advanced and early generation germplasm from CIP and CPRI for abiotic stress tolerance. Abst. 7th World Potato Congress, 22-25 March, 2009. Christchurch, New Zealand. pp.61.
24. Kumar R, GS Kang, J Gopal and SK Pandey. 2009. Kufri Khyati-A new early maturing potato variety for Indian plaines. *Potato J.* 36 (1-2):14-19.
25. Kumar R, GS Kang, SK Pandey and J Gopal. 2009. A new germplasm JX 90 registered. *Central Potato Research Institute Newsletter* 40:5-6.
26. Kumar R, RS Marwaha, J Gopal and SK Pandey. 2009. Relationship between chip colour and compositional characters in potato (*Solanum tuberosum*). *Indian Journal of Agricultural Sciences* 79 (8):679-683
27. Kumar V, J Gopal and SK Luthra. 2010. Studies on flowering traits and foliage maturity in potato under field and glasshouse conditions. Identification of superior parents for developing potato varieties for warm climate with tolerance to mite and leafhopper damage. National Symposium on conservation horticulture-2010. 21-23 March, 2010. ONGC auditorium, Dehradun. GBPU Ag & Tec. Pantnagar and ISH&D, Uttarakhand. Abstracts: p171.
28. Kumar, M, MK Jatav, SP Trehan and SS Lal. 2009. Integrated nutrient management.
29. Kumar, M, SP Trehan, MK Jatav and SS Lal. 2009. Efficacy of potato (*Solanum tuberosum*) cultivars under varying levels of nitrogen and growth duration in eastern Indo-Gangetic plains. *Indian J. Agronomy* **54**: 63-68.
30. Kumar, M. Chimote, V., Singh, R., Mishra, G.P., Naik, P.S., Pandey, S.K., Chakrabarti, S.K. 2009. Development of Bt transgenic potatoes for effective control of potato tuber moth by using cry1Ab gene regulated by GBSS promoter. Crop Protection 29: 121-127.
31. Kumar, Parveen, S Rawal and SS Lal. 2009. Evaluation of weed management options for potato. *Potato Journal* **36**: 72-74.

32. Kumar, Parveen, SP Trehan, BP Singh, S Rawal and MA Khan. 2008. Precising nitrogen requirement of table potato (*Solanum tuberosum*) cultivars for different growth periods. *Indian Journal of Agronomy* **53**: 314-317.
33. Luthra SK, J Gopal, BP Singh and SK Pandey.2009. Stability of tuber yield and its components in potato (*Solanum tuberosum* L.). *Potato J.* 36 (1-2): 20-24.
34. Luthra SK, J Gopal, D Kumar, BP Singh and SK Pandey. 2009. *Solanum* wild species as source of resistance to cold induced sweetening. *Potato J.* 36 (3-4):115-120.
35. Somani, A.K. 2009. Stem necrosis disease resistant in exotic potato germplasm. *Potato J*. 36 (1-2): 57-60.
36. Somani, A.K. 2009. Management of black scurf(*Rhizoctonia solani*) of potato through seed treatment. with botanicals. *Potato J*. 36 (3-4): 155-159

Abstracts / papers presented :

37. Luthra SK, K Malik, J Gopal, V Kumar, VK Gupta, SK Pandey and BP Singh. 2010. Identification of superior parents for developing potato varieties for warm climate with tolerance to mite and leafhopper damage. National Symposium on conservation horticulture-2010. 21-23 March, 2010. ONGC auditorium, Dehradun. GBPU Ag & Tec. Pantnagar and ISH&D, Uttarakhand. Abstracts: p212-213.
38. Luthra SK, SV Singh, SK Pandey, J Gopal, VK Gupta, and BP Singh. 2010. Mini-tuber production of indigenous potato varieties through nodal cutting derived from *in-vitro* plants under net house conditions. National Conference on production of quality seeds and planting material-health management in horticultural crops. 11-14 March, 2010, NASC Complex, New Delhi, SPH, IIHR, CHAI. Abstracts: p126-127.
39. Luthra SK. 2009. Genetic divergence of germplasm accessions in potato (*Solanum tuberosum* subsp. *tuberosum*). *Indian Journal of Plant Genetic Resources.* 22 (2):98-101.
40. Luthra, SK, Kamlesh Malik, Jai Gopal, Vinod Kumar, VK Gupta, SK Pandey and BP Singh.2010.Identification of superior parents for developing potato varieties for warm climate with tolerance to mite and leafhopper damage. National Symposium on conservation horticulture - 2010. 21-23 March, 2010. ONGC

Auditorium,Dehradun. GBPU Ag & Tech. Pantnagar and ISH &D, Uttrakhand. Abstracts: p212-213.

41. Malik K, SK Luthra, VK Gupta, J Gopal and BP Singh. 2010. Selection of quality planting material of potato against mite and hopperburn. National Conference on production of quality seeds and planting material-health management in horticultural crops. 11-14 March, 2010, NASC Complex, New Delhi, SPH, IIHR, CHAI. Abstracts: p29.
42. Malik, Kamlesh and BP Singh. 2010. Management of virus vectors for quality potato seed production. National Conference on production of quality seeds and planting material-health management in horticultural crops.11-14 March, 2010. NASC Complex. New Delhi, SPH, IIHR,CHAI,Abatracts: p 122-123.
43. Malik, Kamlesh, SK Luthra, VK Gupta, Jai Gopal and BP Singh.2010. Selection of quality planting material of potato against mite and hopperburn.National Conference on production of quality seeds and planting material - health management in horticultural crops.11-14 March, 2010. NASC Complex. New Delhi, SPH,IIHR,CHAI,Abatracts : p 29.
44. Marwaha RS, SV Singh, SK Pandey, D Kumar and VK Gupta. 2009. Evaluation of advanced potato hybrid MP/97-644 and processing varieties for yield and chipping quality in north-eastern hills. *Indian j. Hort*. 66(3): 363-366.
45. Pandey SK, SV Singh , RS Marwaha and D Pattanayak . 2009. Indian potato processing varieties: Their impact and future priorities. *Potato J.* 36: 95-114.
46. Puja Rani, Yogeeta Thakur, Anupam Sharma, Ashwani Sharma and V. K. Chandla, 2009. Management of white grubs, *Brahmina coriace*a (Hope) with botanical extracts in cattle urine. Pot J. 36(1-2): 61-64.
47. Somani AK. 2009. Stem necrosis disease resistance in exotic potato germplasm. *Potato J.* 36(1-2):57-60.
48. Trehan, S.P. 2009. Improving nutrient use efficiency by exploiting genetic diversity of potato. *Potato J.* **36**: 121-135.
49. Trehan, SP 2009. Mechanism of high nitrogen efficiency in potato cultivars. *Advances in Horticultural Science* **23**: 179-184.
50. Visser, R.G.F., Bachem, C.W.B., de Boer, J. M., & Bryan, G.J., Chakrabati, S.K., Feingold, S., Gromadka, R., van Ham, R.C.H.J., Huang, S., Jacobs, J.M.E., Kuznetsov, B., de Melo, P.E., Milbourne, D., Orjeda, G., Sagredo, B., Tang, X. 2009. Sequencing the Potato Genome: Outline and First Results to Come from the Elucidation of the Sequence of the World's Third Most Important Food Crop. Am. J. Pot Res. 86: 417-429.

CONFERENCES/SYMPOSIA AND WORKSHOP

SL. No	Name	Title of Conference/Symposia/Workshop	Dates & Venue
1.	Dr. Shashi Rawat, Scientist (Sr, Scale) ARIS Cell, CPRI, Shimla	Workshop on "Expert System in Agriculture"	IASRI, ICAR, New Delhi on June 12,2009
2.	Dr. R. K. Arora, PS, CPRS, Jalandhar & Dr. SK Kaushik, Sr. Scientist, CPRI, Shimla	National Symposium on "Rational use of fungicides in management of horticultural crop diseases"	Dr. YS Parnar University of Forestry, Nauni, Solan from 8-9 July, 2009
3.	Dr. JP Singh, PS, CPRS, Jalandhar & Dr. Brajesh Singh, Sr. Scientist CPRI, Shimla	Agronomy conference	July 13-14,2009 at Chandigarh.
4.	Dr. NC Upadhyay, PS, CPRIC, Modipuram	Conference on "Organic Farming"	July 24-25, 2009 at Chandigarh
5.	Dr. Dhruv Kumar, Sr. Scientist, CPRIC, Modipuram & Dr. SP Trehan, PS, CPRS, Jalandhar.	"IPI-OUAT-IPNI-International Symposium"	November 5-7,2009 at OUAT Bhubaneshwer
6.	Dr. D. Pattanayak, Sr. Scientist & Dr. VU Patil, Scientist CPRI, Shimla.	Workshop "Functional and Structural Proteomics An *In Silico* Approach"	October 26-30, 2009 at HP University, Summer Hill, Shimla.
7.	Dr. R. K. Arora, PS, CPRS, Jalandhar & Dr. A. Jeevalatha, Scientist, CPRI, Shimla	5th International conference "Plant Pathology in the Globalized Era"	November 10-13, 2009 at IARI, New Delhi.
8.	Dr. MA Khan, Sr. Scientist, CPRIC, Modipuram.	"Platinum Jubilee Symposium and 74th Annual Convention of ISSS"	22-25 December, 2009 at New Delhi
9.	Dr. Anuj Bhatnagar, Sr. Scientist, CPRS, Gwalior.	8th National Symposium on problems and perspectives in eco-friendly innovtives to plant protection	9-11 December, 2009 at Sardar Vallabh Bhai Patel University of Agriculture &

			Technology, Modipuram, Merrut
10.	Dr. NC Upadhayay, PS, CPRIC, Modipuram,Dr. MC Sood, PS, Dr. MK Jatav, & Dr, Manoj Kumar Scientist, CPRI, Shimla	Platinum Jubilee symposium on Indian Society of Soil Science	22-25 December, 2009 at IARI, New Delhi.
11.	Dr. R. Ezekiel, Head, CPB & PHT, CPRI, Shimla.	National Conference "Frontiers in Plant Physiology towards Sustainable Agriculture"	5-7 November, 2009 at Assam Agricultural University, Johrat, Assam.
12.	Dr. Devendra Kumar, PS, CPRIC, Modipuram.	Zonal seminar on *"abiotic stress tolerance in plants:Physiological and molecular approaches"*	05.12.2009 at Indian Society for Plant Physiology, New Delhi.
13.	Dr. SS Lal, Head, Div. of Crop Production, CPRI, Shimla.	Symposium on "Diversification of cropping system for sustaining productivity and rural upliftment"	3-4 January, 2010 at Kerala University, Thiruvanathapuram.
14.	Dr. SV Singh, PS, Dr. Dinesh Kumar, Sr. Scientist, CPRIC, Modipuram	International conference on Horticulture	Organized by Dr. Prem Nath Agricultural Science Foundation, Bangalore during 9-12 November, 2009
15.	Dr, VK Dua, Sr. Scientist & Dr. Shashi Rawat, Sr. Scientist CPRI, Shimla.	International Conference on "Himalayan Environment: Issues & Challenges"	March 22-24,2010 at Institute of Integrated Himalayan Studies, HP University, Summer Hill, Shimla.
16.	Dr. RM Sharma, Librarian, CPRI, Shimla	International conference on Digital Libraries (UCDL 2010)	23-26 February, 2010 at New Delhi.
17.	Dr. VU Patil, Scientist, CPRI, Shimla.	Workshop on "Plant Genomics in Crop improvement with reference to biotic and abiotic stresses "	25-27 February, 2010 at CCS Haryana Agricultural University, Hisar, Haryana.
18.	Dr. SK Chakrabarti, Head, Plant Protection, CPRI, Shimla.	National Conference on "CPSEA"	15th January, 2010 at New Delhi.
19.	Dr. Vinod Kumar, Head, CPRS, Kufri, Dr. SK Luthra, Sr.	National Symposium on "Conservation Horticulture"	21-23 March, 2010 at Dehradun.

	Scientist, CPRIC, Modipuram & Dr. Manoj Kumar, Sr. Scientist, CPRI, Shimla.		
20.	Dr. PM Govindakrishnan, PS & In-Charge, ARIS Cell, CPRI, Shimla.	National workshop for the sensitization of the ARIS Incharges about the uniformity guidelines for websites	19 March, 2010 at NBPGR, Pusa Campus, New Delhi.
21	Dr. TA Joseph, PS & Acting Head, CPRS, Muthorai & Dr. R. Umamaheswari, Scientist, CPRS, Muthorai.	National conference on "Innovations in Nematological Research for Agricultural Sustainability- Challenges and A Roadmap Ahead"	23-25 February, 2010 at TNAU Coimbatore.
22	Dr. SK Pandey, Director, CPRI, Shimla, Dr. SK Chakrabarti, Head, Div. of Plant Protection & Dr, NK Pandey, Head, Div. of Social Sciences, CPRI, Shimla.	Seminar on "Potential& Road Map for Promoting Agri-Horti Exports from Himachal Pradesh"	19th March, 2010 at Peterhof, Shimla.
23.	Dr. Anuj Bhatnagar, Sr. Scientist, CPRS, Gwalior.	8th National Symposium on "Problems and Perspectives in Eco-friendly "	24-25 January, 2010 at C.S.A. University of Agriculture and Technology, Kanpur, (UP).
24.	Dr. SK Pandey, Director, CPRI, Shimla, Dr. SK Chakrabarti, Head, Div. of Plant Protection & Dr. VU Patil, Scientist, CPRI, Shimla.	SOL 2009 Conference	8-14 November, 2009 at New Delhi.
25.	Dr. SK Pandey, Director, CPRI, Shimla, Dr. Jai Gopal, Head, Div. of Crop Improvement, CPRI, Shimla, Dr. Ashwani Kumar, Sci, SG, CPRS, Kufri, Dr. RK Arora, PS, CPRS, Jalandhar, Dr. R. Muthuraj, Sr. Sci. CPRS, Muthorai, Dr. AK Somani, PS & Head, CPRS, Gwalior, Dr. Anuj Bhatnagar, Sr. Sci. CPRS, Gwalior, Dr. Kamlesh Malik, Sr. Sci./ Dr. Sanjay Rawal, Sr. Sci./ Dr. VK Gupta, Sr. Sci./ Dr. Parveen Kumar, Sr. Sci./ Dr. Vinay Singh, Sr. Sci./ Er. Sukhwinder Singh, Sci. SG/ Dr. Dhruv Kumar, Sr. Sci./ Dr. SK Luthra, Sr. Sci. & Dr. Dinesh Kumar, Sr. Sci., CPRIC, Modipuram, Miss. Jyoti, Sr. Research Fellow, Div. of Seed Technology, CPRI, Shimla		Attended/Participated inNational Conf-erence on "Produ-ction of quality seeds and planting material – Health Management in Horticultural Crops" from 11-14 March , 2010 at New Delhi.

PROMOTIONS / RETIREMENTS / TRANSFERS / DEATHS FROM 01.04.2009 TO 31.3.2010 IN RESPECT OF SCIENTIFIC CATEGORY

TRANSFERS /PROMOTIONS	
1.	Dr. M Naryan Butt, Sr. Scientist relieved w.e.f. 12.05.2009 to join his new assignment as PS at NCIPM, New Delhi.
2.	Dr. Anil Kumar, Sr. Scientist relieved w.e.f. 17.08.2009 to join his new assignment as PS at PDCSR, Meerut.
3.	Dr. Med Ram Verma, Scientist (SS) relieved w.e.f. 19.12.2009 to join his new assignment as Sr. Scientist at IVRI, Izatnagar.
4.	Dr. S Ramani, PS & Head, CPRS,Shillong relieved w.e.f. 26.02.2010 to join his new assignment as PC (Honeybees & Pollinators) AICRP on HB & P CCS, HAU, Hisar with Hqr. at ICAR. Krishi Bhawan, New Dehli.
APPOINTMENTS / JOINING	
1.	Dr. Virupakshagouda, Scientist, Biotechnology CPRI, Shimla w.e.f 20.06.2009
2.	Dr. Mehi Lal, Scientist, Plant Pathology CPRIC, Modipuram w.e.f 19.06.2009
3.	Dr. Sanjeev Sharma, Sr. Scientist, Plant Pathology CPRI, Shimla w.e.f 02.07.2009
4.	Dr. Vinay Sagar. Sr. Scientist, Plant Pathology CPRI, Shimla w.e.f 28.07.2009
5.	Dr. Med Ram Verma, Scientist, (SS) Agri. Stat. CPRI, Shimla w.e.f. 05.08.2009.
6.	Dr. (Ms) Jeevalatha A. Scientist, Plant Pathology, CPRI, Shimla w.e.f. 29.08.2009.
7.	Dr. Prem Chand Meena, Scientist, Agri. Eco., CPRI, Shimla w.e.f. 31.10.2009
8.	Sh. Baswaraj R, Scientist, Plant Pathology, CPRI, Shimla w.e.f. 15.3.2010
9.	Sh. Chandersekar V, Scientist, Agril Economics, Shimla w.e.f. 15.3.2010
10.	Dr. KK Pandey, Head, Division of Seed Technology, CPRI, Shimla w.e.f. 23.3.2010
RETIREMENTS	
1.	Dr. ID Garg, PS w.e.f. 31.5.2009
2.	Dr. PH Singh, PS, w.e.f. 30.11.2009
3.	Dr. VK Chandla, PS w.e.f. 28.2.2010
Death	
1.	Dr. RS Marwaha, PS expired on 01.09.2009

List of Scientific staff at CPRI, Shimla & its Regional Stations as on 31.03.2010

HQ CPRI, Shimla

Director: Dr. SK Pandey

AICPIP Unit

1. Dr. PS Naik, PS & Project Coordinator

Divn. of Crop Improvement

1. Dr. Jai Gopal, PS & Head
2. Dr. SK Kaushik, Sr. Scientist
3. Dr. D. Pattanayak, Sr. Scientist
4. Dr. Vinay Bhardwaj, Sr. Scientist
5. Sh. A.Chanemougasoundharam, Scientist
6. Dr. Virupakshagauda U Patil, Scientist
7. Dr. Jagesh Kumar, Scientist

Division of Seed Technology

1. Dr. KK Pandey, PS & Head
2. Dr. EP Venkatasalam, Scientist (SS)

Division of Crop Production

1. Dr. S.S. Lal, PS & Head
2. Dr. M.C. Sood, PS
3. Dr. PM Govindakrishnan, PS
4. Dr. VK Dua, Sr. Scientist
5. Dr. Manoj Kumar. Sr. Scientist
6. Sh. MK Jatav, Scientist

Division of Social Sciences

1. Dr. NK Pandey,PS & Head
2. Dr. Rajesh Kumar Rana, Sr. Scientist
3. Dr. Prem Chand Meena, Scientist
4. Sh. Chandrasekar V., Scientist

Division of Plant Protection

1. Dr. SK Chakrabarti, Head
2. Dr. Sanjeev Sharma, Sr. Scientist

3. Dr. Vinay Sagar, Sr. Scientist
4. Dr.(Ms) Jeevalatha A, Scientist
5. Sh. Baswaraj R., Scientist

Division of Crop Phy. & PHT

1. Dr. R. Ezekiel, PS & Head
2. Dr. JS Minhas, PS
3. Dr. Brajesh Singh, Sr. Scientist

ARIS Cell

1. DR. Shashi Rawat, Sr. Scientist

CPRI Campus, Modipuram

1. Dr. Birpal Singh, PS & Joint Director
2. Dr. OP Singh, PS
3. Dr. NC Upadhayay, PS
4. Dr. Satya Vir Singh, PS
5. Dr. Raj Pal Singh, PS
6. Dr. Devendra Kumar, PS
7. Sh. Rambir, Sr. Scientist
8. Dr. (Mrs.) Kamlesh Malik, Sr. Scientist
9. Dr. SK Luthra, Sr. Scientist
10. Dr. Name Singh, Sr. Scientist
11. Dr. Dinesh Kumar, Sr. Scientist
12. Dr. Vinay Singh, Sr. Scientist
13. Dr. RK Verma, Sr. Scientist (Presently working with CITH, RS, Mukteshwar)
14. Dr. Praveen Kumar, Sr. Scientist
15. Dr. MA Khan, Sr. Scientist
16. Er. Sukhwinder Singh, Scientist (SG)
17. Dr. Sanjay Rawal, Sr. Scientist
18. Sh. Dhruv Kumar, Scientist (SG)
19. Dr. Vijai Kishore Gupta, Sr. Scientist
20. Dr. Mehi Lal, Scientist

CPRS, Jalandhar

1. Dr. RK Arora, PS
2. Dr. JP Singh, PS
3. Dr. (Mrs.) Ashiv Mehta, PS
4. Er. Manjit Singh, PS
5. Dr. SP Trehan, PS
6. Dr. Raj Kumar, Sr. Scientist

7. Er. Sunil Gulati, Scientist (SG)

CPRS, Gwalior

1. Dr. AK Somani, PS
2. Dr. Anuj Bhatnagar, Sr. Scientist
3. Dr. Shiv Pratap Singh, Sr. Scientist
4. Dr. Murlidhar .J.Sadawarti, Scientist

CPRS, Shillong

1. Dr. KM Nagaraj, Scientist
2. Dr. AK Srivastava, Scientist

CPRS, Muthorai

1. Dr. TA Joseph, Sr. Scientist & Acting Head
2. Dr. (Mrs.) K. Manorama, Sr. Scientist
3. Dr. G. Ravichandran, Sr. Scientist
4. Dr. R. Muthu Raj, Sr. Scientist
5. Dr. Uma Maheshwari, Scientist

CPRS, Kufri

1. Dr. KR Dhiman, PS & Head
2. Dr. YK Sharma, Sr. Scientist
3. Sh. Ashwani Kumar Sharma, Scientist (SG)
4. Dr. Vinod Kumar, Sr. Scientist

CPRS, Patna

1. Dr. RP Rai, PS Head
2. Dr. Gulab Ram, PS
3. Dr. Shambhu Kumar, Sr. Scientist
4. Dr. SK Singh, Sr. Scientist
5. Dr. Barsati Lal, Sr. Scientist
6. Sh. Eradassapa. E, Scientist

Staff Position at CPRI & its Regional Stations

Scientific Category

Scientfic Category	**Sanctioned**	**Shimla**	**Modi.**	**Jal.**	**Patna**	**Shill.**	**Gwlr.**	**Ooty**	**Kufri**	**Total**
Director	**01**	**01**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**01**
PC	**01**	**01**								**01**
Prin. Sci.	**10**	**06**	**01**	**00**	**01**	**00**	**00**	**00**	**01**	**09**
Sr. Scientist	**19**	**05**	**02**	**00**	**01**	**00**	**01**	**00**	**00**	**09**
Scientist	**79**	**17**	**17**	**07**	**04**	**02**	**03**	**05**	**03**	**58**
Total	**110**	**30**	**20**	**07**	**06**	**02**	**04**	**05**	**04**	**78**

Administrative Category

Name of the post	Shimla	Mod.	Jal.	Patna	Shillong	Gwalior	Ooty	Kufri	Total
Sr. Admn.Officer	1	-	-	-	-	-	-	-	01
F&AO	1	-	-	-	-	-	-	-	01
AO	-	-	-	-	-	-	-	-	-
AAO	5	-	1	1	-	1	-	1	09
AFACO	1	-	-	-	-	-	-	-	01
AD(OL)	1	-	-	-	-	-	-	-	01
Asstt.	15	2	2	1	1	1	1	1	24
Sr.Clerk	17	3	5	-	2	-	1	1	29
LDC	15	4	2	3	-	4	-	1	29
Private Secy.	1	-	1	-	-	-	-	-	02
Sr.Steno.	1	-	-	-	-	-	-	-	01
PA	6	1	-	1	-	-	1	-	09
Steno. Grade-III	3	1	-	-	-	-	-	-	04
Total	67	11	11	6	3	6	3	4	111

Technical Category.

Grade	Shimla	Mod.	Jal	Patna	Gwlr.	Shillong	Ooty	Kufri	Total
T-9	1	1	-	-	-	-	-	-	**2**
TO T(7-8)	1	1	1	1	1	-	-	-	**5**
TO (T-6)	1	7	3	2	-	-	-	-	**13**
TO (T-5)	16	13	11	3	3	-	1	2	**49**
Techn. T-4	5	13	4	4	4	2	2	3	**37**
Techn. (T-3)/T-I-3	9	4	2	5	2	1	-	1	**24**
Techn. T-2	22	3	4	7	3	4	2	3	**48**
Techn. T-1	5	2	1	-	-	1	-	1	**10**
Total	**60**	**44**	**26**	**22**	**13**	**8**	**5**	**10**	**188**

Supporting Staff

Grade	Sanctioned	Filled	Vacant
SS Grade-I	86	55	31
SS Grade-II	65	60	05
SS Grade-III	39	39	-
SS Grade-IV	18	16	01
Sub Total	**208**	**170**	**37**
Canteen Staff			
Cook	1	1	0
Tea Maker	1	1	0
Wash Boy	1	1	0
Grand Total	**211**	**173**	**37**

Station-wise/Grade-wise list of the Supporting Staff

Station	Grade-IV	Grade-III	Grade-II	Grade-I	Total
Shimla	04	13	06	13	36+3* canteen staff
Kufri	02	05	03	05	15
Patna	03	02	09	06	20
Jalandhar	01	02	15	08	26
Modipuram	01	07	07	04	19
Shillong	04	06	-	-	10
Muthorai	-	02	-	05	07
Gwalior	01	02	20	14	37
Total	**16**	**39**	**60**	**55**	**170+3=173**

***3 Posts of Canteen Staff**

Staff position as on 01.4.2009 of CPRI showing number of SCs, STs, OBCs & Women

Category	Sanctioned	Total Filled	SC	ST	OBC	Women
Scientific	109*	77*	11	02	05	06
Administrative	121	111	25	08	06	28
Technical	207	188	43	08	12	11
Supporting	211	170+*3	52	09	12	23
Total	**648**	**548**	**131**	**27**	**35**	**68**

*** Excluding 1 RMP**
***3 post of Canteen staff**