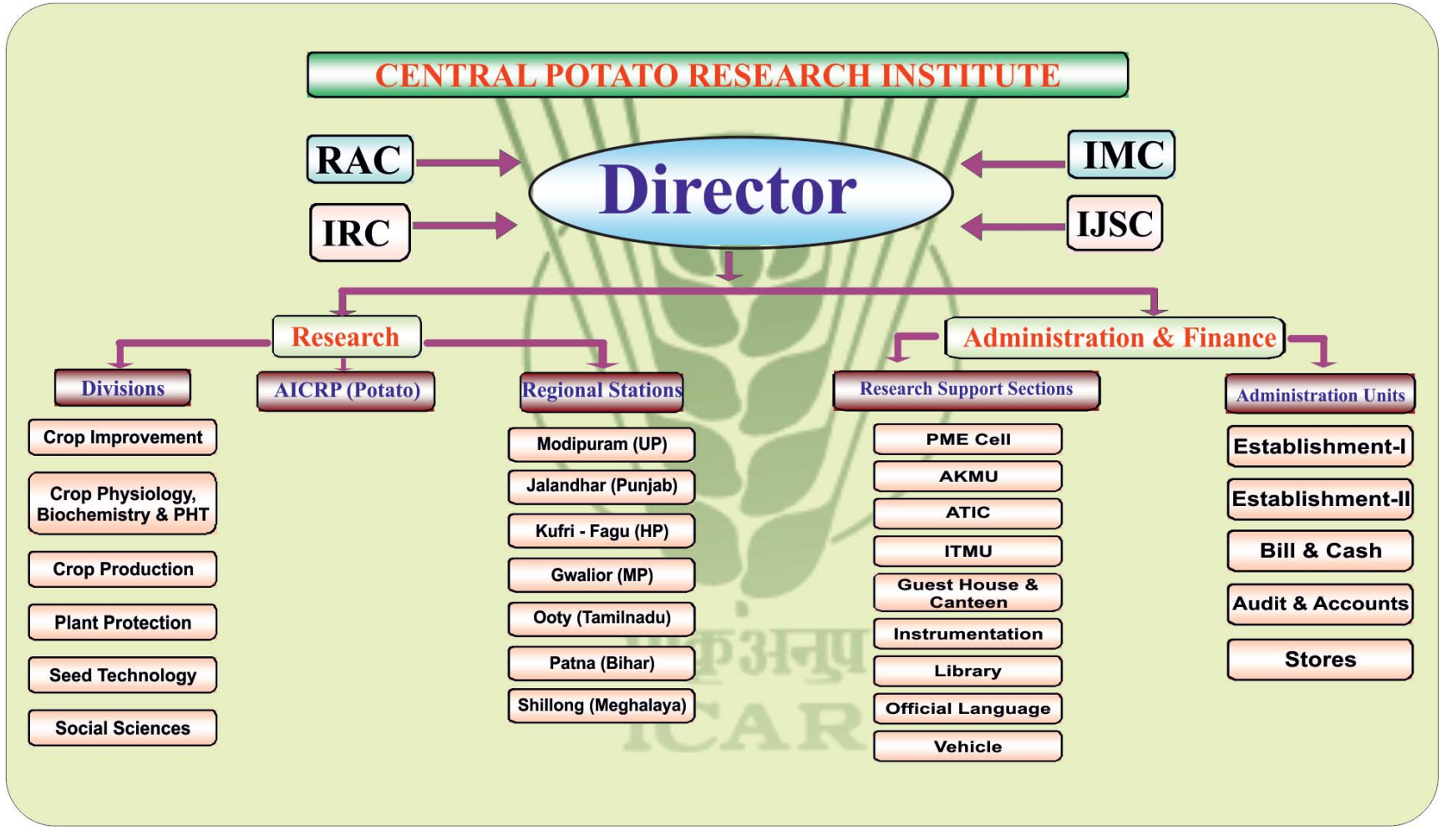
CPRI-An Introduction

The Central Potato Research Institute was established under the Ministry of Agriculture, Government of India in August 1949 at Patna (Bihar) on the recommendation of the then Agricultural Advisor to the Government of India, Sir Herbert Steward. The institute was shifted to Shimla in the year 1956 in order to facilitate hybridization work in potato and maintain seed potato health. It was transferred to the Indian Council of Agricultural Research (ICAR) in April 1966.

The Research and Development Activities of the institute is carried out under the six divisions namely, Division of Crop Improvement, Crop Production, Plant protection, Seed technology, Crop Physiology, Biochemistry and Post Harvest Technology and Social Sciences. The institute headquarters is located in the heart of Shimla city, 4 kilometer from Shimla bus stand near Bemloe. It is located at an altitude of 2000 metres above mean sea level and has a wet temperate climate. It has one campus at Modipuram (UP) and six regional stations located across the country viz. Kufri Fagu (HP), Jalandhar (Punjab), Gwalior (MP), Patna (Bihar), Shillong (Meghalaya) and Ooty (Tamil Nadu) to cater the need for location specific research and extension activities.

The institute created the state-of-the-art laboratories for conducting basic and strategic research in different areas of potato. The All India Coordinated Research Project on potato (AICRP-Potato) is also located in the institute and has been functioning since 1971. It has 25 regional centers located in nearly all agro climatic zones of the country to test the performance of new potato varieties and technologies in different locations. An Agricultural Technology Information Centre (ATIC) is also functioning in the institute which looks after the transfer of technology activities of the institute. The institute develops new varieties and production technologies for potato growers of the country and also takes care of dissemination of these technologies to the ultimate consumers through various trainings, demonstrations, farmers fair, exhibitions *etc*. Every year, a large number of publications on modern potato technologies are being brought out by the institute which includes technical bulletins, extension bulletins, newsletter, folders and annual reports. These publications also help in transfer of potato Research and Development to different stakeholders. The Institute has bagged the **Best Annual Report Award of ICAR** for the year 2012-13 under large institute category. Currently the institute


CENTRAL POTATO RESEARCH INSTITUTE
RAC
IRC
Director
IMC
IJSC
Research
Administration & Finance
Divisions
AICRP (Potato)
Regional Stations
Research Support Sections
Administration Units
Crop Improvement
Crop Physiology, Biochemistry & PHT
Crop Production
Plant Protection
Seed Technology
Social Sciences
Modipuram (UP)
Jalandhar (Punjab)
Kufri - Fagu (HP)
Gwalior (MP)
Ooty (Tamilnadu)
Patna (Bihar)
Shillong (Meghalaya)
PME Cell
AKMU
ATIC
ITMU
Guest House & Canteen
Instrumentation
Library
Official Language
Vehicle
Establishment-I
Establishment-II
Bill & Cash
Audit & Accounts
Stores

has a dedicated team of 66 scientists, 163 technical staffs and 100 administrative staffs working on potato crop.

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 non profit 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 agro-ecosystem. 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 coordinate network research with State Agricultural Universities (SAUs) 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 technologies 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 *viz.* Crop Improvement; Plant Protection; Crop Production, Crop Physiology, Biochemistry & Post Harvest Technology; Seed Technology and Social Sciences under 18 well defined research programmes. In addition to regular research programme, 14 externally funded research projects sponsored by various national and international organizations are also under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

Staff & Finance

The institute has 595 sanctioned staff strength comprising of 108 scientific, 178 technical, 102 administrative and 207 supporting staff. The staff position as on 31. 03.2014 was 455 including 67 scientific, 163 technical, 100 administrative and 125 supporting staff. The expenditure of the institute for the year (Plan & Non Plan) was Rs 49.50 crores and receipts Rs. 6.65 crores including RFS. The CPRI generated some parts of its total budget from its own resources i.e. from the sale of seed, farm produce, Revolving fund scheme, consultancy, etc. The revolving fund scheme sanctioned in 1991 by the ICAR with seed money of Rs. 40.0 lakhs generated revenue to the tune of Rs 424.98 lakhs this year and the scheme has been very successful and widely acclaimed. During the year, Dr. R. Eziekel, Head, CPB&PHT has assumed the charge to the post of National Coordinator, NAIP, ICAR, New Delhi. Three scientists were retired and four were transferred from the institute. In technical category, 13 technicals were promoted, 6 retired and 4 were transferred within institute. In administrative category, 13 persons were promoted, 5 retired and 1 transferred within the institute. In skilled supporting staff, 2 were promoted under 33.33% departmental promotion quota from SSS to technical posts and 4 retired.

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 institute 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, the Government of India has notified this laboratory as 'Accredited Test Laboratory' for testing and certification of tissue culture raised potato micro plants and minitubers.

The biotechnology laboratory of the institute, created in 1992, presently houses all the facilities for transgenic research, DNA fingerprinting, molecular breeding, micro propagation 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. Recently, Aeroponic facility was created in CPRI, Shimla, CPRIC, Modipuram, CPRS, Patna and CPRS, Shillong for soil less disease free seed potato production. A BPD Unit has been established at CPRS, Jalandhar for commercialization of potato technologies developed by the institute. The institute library is the second largest library in the world. Besides, the institute has well-equipped AKMU cell, ATIC, museum, auditorium, conference hall, committee room at the hqrs. and similar facilities have been provided at the regional stations. The institute is well equipped to organize training programmes with the facilities like audio-visual aids, projector, Guest house, farmers' hostels etc.

Research Highlights

Crop Improvement

- Twenty six accessions were added to cultivated germplasm collection, besides TPS of 282 accessions belonging to 43 species were also imported from USA. Indigenous samples were collected from plains of Assam, Lahul-Spiti, Manipur, West Bengal and Leh & Ladhakh regions.
- Based on superior performance hybrids MS/7-645 and MP/4-816 were introduced into AICRP, while 4 advanced stage hybrids for table purpose *viz*., J/6-18), MS/8-1148, MS/8-1565, PS/7-7 & 5 processing hybrids viz., MP/9-91, MP/6-39, MP/6-595, MP/8-62 and MP/8-1900 were indentified for introduction in AICRP for multi-location testing. Seventeen parental lines were identified with early maturity & processing traits.
- Whole genomes of *Ralstonia solanacearum* (4 strains) causing bacterial wilt in potato and *Fusarium sambucinum*, causing dry rot in potato were sequenced using massive-parallel pyrosequencing technology (Roche 454).
- Developed transgenic lines of potato cvt. Kufri Chandermukhi expressing 17.6 HSP gene for heat stress tolerance and Kufri Jyoti expressing F-Box gene isolated from wild *Solanum spegazinii* for its role in defence against late blight disease.
- Transcriptional expression analysis was done for potato tuberisation in response to heat stress in Kufri Surya (heat tolerant) and Kufri Chandermukhi (heat sensitive). In total 2432 genes upregulated in Kufri Surya on 14 day and 448 genes on 21 day of heat stress.
- Interspecific somatic hybridization was carried out between the androgenic dihaploid (C-13) of *S. tuberosum* and 6 wild *Solanum* species seperately. Among them *S. cardiophyllum* derived 4 regenerants were confirmed for true somatic hybrids possessing both parent and specific bands.
- Gene expression analysis for nitrogen use efficiency showed the wide variation of N efficiency in three cultivars Kufri Gaurav (highest N use efficient) followed by Kufri Pukhraj and Kufri Jyoti (least N efficient).

Plant Protection

- Developed JHULSACAST late blight forecasting model for plains of West Bengal and developed web based decision support system for management of late blight in western Uttar Pradesh. Besides, Indo-Blightcast- a web based forecasting model, which is applicable pan India, has also been developed.
- Clones (18) possessing stacked *R1* and *R3a* genes evaluated for late blight resistance and advanced to F_1C_2 generation. Moreover, 14 genotypes possessing multiple disease resistance to late blight, PVY and PCN have been identified through MAS.
- Developed triplex lateral flow immune assay (LFIA) for simultaneous detection of PVX, PVA and PVM, duplex RT-PCR for CMV & TMV and multiplex RT-PCR for simultaneous detection of PAMV, PVS, PVM, PLRV and PVX.
- Bacterial wilt in Meghalaya is caused by highly diverse group of *Ralstonia solanacearum* comprising strains of phylotype I/45, I/47, II/1, IV/8 and IV/unknown.
- Identified seven aphid species namely *Myzus persicae, Aphis gossypii*, *Aphis fabae Aphis spiraecola*, *Aphis nerii, Hydaphis coriandri* and *Rhophalosiphumru fiabdominalis* from various potato growing regions of India using universal COI specific primers.
- Trap cropping for all three seasons with susceptible variety Kufri Jyoti recorded maximum yield of potato and minimum cyst nematode population. Besides, intercropping of radish and marigold with potato was also found effective in reducing the population of nematode.

Seed Technology

- A total production 452.28 quintals breeder seed produced in 3.56 ha area and 447.18 quintals was supplied from Kufri hills.
- A total number of 13,325 *in vitro* culture tubes, 1,750 bottles and 17,109 microtubers were produced at Shimla.

- A total number of 58,796 minitubers were produced through aeroponics at Shimla, 71,247 minitubers at Modipuram and 23,349 at Patna.
- A total of 23,955.37 quintals breeder seed were supplied to various government and private agencies during 2012-13 from plains and hills.
- About 80 individual tubers of 20 varieties of virus free, true to type, uniform in size and genetically pure tubers were selected and aseptically maintained at 4ºC as basic material.
- The highest percent vigour increase in 6 mm grade of microtubers was 171.4% by priming of carbendazim, pencycuron as well as tracel over control.
- Sodium alginate 2 and 3% resulted very good encapsulation in all grades and without any cracking in comparison of 5-9% concentration. Calcium alginate failed for encapsulation.
- Maximum reduction of black scurf was observed in *T. viride,*mancozeb, monecron and boric acid+ *T. viride* while common scurf incidence was minimum in *P. florescence,* boric acid and *T. viride*.

Crop Production

- The impact of climate change on potato productivity in Uttar Pradesh was assessed using WOFOST crop growth model. The model has projected a decline in productivity of Kufri Badshah, Kufri Bahar and Kufri Pukhraj to the tune of 5.5, 6.1 and 7.0%, respectively in 2020 and 9.4, 10.9 and 13.4%, respectively in 2055 without adaptation.
- Climate change impact on late blight in Punjab and western Uttar Pradesh was assessed using JHULSACAST model. The model has predicted a 0 to 6 days delay in 2020 and 12 to 14 days in 2055 in late blight appearance in Punjab. The comparative figures for western Uttar Pradesh are 0 to 8 and 10-21 days.
- At Hassan, Karnataka potato variety Kufri Himalini performed better in plateau areas during Kharif season. In front line demonstrations potato variety Kufri Surya performed better over Kufri Jyoti and recorded higher yields (17.4%).
- In the long term manurial/fertilizers trial at Modipuram rice-potato-wheat system recorded higher productivity by 9.7 and 18.5% over maize-potato-onion and groundnut-potato-Moong bean cropping system.
- At Shimla, it is shown that after basal application of N in potato, crop should be applied at 90% RCI (Relative Chlorophyll Index) @ 25kg/ha. 20% recommended N applied at 90% of the reference SPAD value at Patna and at 95% of the reference SPAD value at Gwalior gave similar yield as compared to the recommended N level.
- Germplasm J-93-58 and J-92-159 were found more N efficient than previously identified most N efficient cultivar, Kufri Gaurav based on nitrogen requirement for getting equivalent yield.
- A small, compact and low cost prototype of 2-row tractor operated potato combine harvester for collection of dug tubers in bags or crates was designed and fabricated.
- The grader has been designed to grade the material in four different size grades. Fabrication work of the grading sieves (three numbers) having 20, 32 & 52 mm size square openings, was carried out.
- A portable aeroponic system was developed for conducting experiments on potato and other crops. A 25 kg capacity machine was designed for grading experimental produce.

Crop Physiology, Biochemistry and Post Harvest Technology

- A method was standardized through High Performance Liquid Chromatograph (HPLC) for the evaluation of the concentration of flavouring compound 5'-nucleotides (AMP+GMP)
- Microwave cooking was found to increase the concentration of flavouring compounds in all the tested cultivars.
- For making bio-degradable films, mixing of starch and PVA in 1:3 ratio showed good results, with soft, flexible and semi-transparent film.
- Resistant starch content increased in French fries prepared from all the cultivars with increase in storage duration (at -20°C) from 24h to 180d.
- Osmotically dehydrated fries had low oil content compared to normal fries (4.32% v/s 16.75%).

- In terms of anti-oxidative potential, Kufri Chipsona-1 was superior to Kufri Jyoti and Kufri Pukhraj during storage.
- In Kufri Jyoti and Kufri Girdhari, GA content was low in dormant and sprouted tubers and high in chitted tubers i.e at the end of dormancy.
- Dip treatment of potatoes with paclobutrazol (500-1500 ppm) reduced the sprouting and weight loss in potatoes up to 60 days of storage in heap.
- An organic compound named AF1 recorded complete sprout inhibition at 100 and 200 ppm concentration up to 90 days of storage at 12°C.
- Six hundred twenty four selections were made from the seedlings raised from these seeds in the glass house and field.
- Heat tolerance in advanced hybrids was quantified by leaf bud tuberization test under controlled conditions and hybrid HT/07-1105 and HT/07-804 showed good heat tolerance.
- Slow release formulations PS10 and PP10 of growth retardant Paclobutrazole at 5 ppm spray 30 days after planting improved tuber yield under heat stress conditions.
- At Jalandhar, Kufri Surya was found to be suitable for planting during first week of September for yield advantage over Kufri Pukhraj.

Social Sciences

- Survey in West Bengal and Bihar revealed that Kufri Jyoti was the predominant potato variety occupying more than two third areain West Bengal and more than half in Bihar. Kufri Pukhraj was the next popular variety in both states.
- It was also found that seed potato purchased from traders was the most commonly used source of seed (53% farmers) in West Bengal while in Bihar, own farm production retained as seed potato (49% farmers) was the most commonly used seed source.
- Seed replacement rate was as low as 15% in the state of Bihar while this rate was 48% in West Bengal.
- In Bihar, due to lower rate of adoption of recommended package of practices in Muzaffarpur, average yield of potato in the district was only 20.6 t/ha while it was 33.6 t/ha in Nalanda and 28.8 t/ha in Patna.
- Expensive seed was found to be the severest problem for potato farmers in the state of West Bengal while unavailability of healthy seed potato was the number one constraint in the state of Bihar.
- Altogether 25 potato technology demonstrations were laid out in Bihar and UP. Observations from these demonstration revealed that new varieties of CPRI like Kufri Khyati and Kufri Garima are having high yield advantage over local varieties. Moreover, with recommended dose of pesticides there was lesser incidence of pest and diseases.
- The impact of 21-day Summer School revealed that average increase in knowledge of trainees before and after training was estimated at 25.7%. A majority (46.2%) of the trainees graded the training as excellent while 53.8% graded it as very good quality.

Executive Summary

Crop Improvement

The division of crop improvement has three research programmes aimed at genetic improvement of the potato. 'Management and Enhancement of Potato Germplasm' is basic programme of the division which aims at collection, conservation, evaluation and documentation of germplasm. During the year, 26 accessions were added to cultivated germplasm collection, besides TPS of 282 accessions belonging to 43 species were also imported from the USA. Indigenous samples were collected from plains of Assam, Lahul & Spiti, Manipur, West Bengal and Leh & Ladhakh regions and thus at present CPRI maintains more than 4,100 accessions of cultivated, semi-cultivated and wild species of potato. A large number of accessions were evaluated for various biotic and abiotic stresses, adaptability and physcio-biochemical qualities and promising accessions were identified. Information generated have been maintained in the electronic databases.

The second programme is on 'Breeding for Improved Varieties' which aims at developing improved varieties for table and processing purposes having resistance to important diseases and pests. A number of new breeding populations were generated during the years by conventional hybridization and new clonal materials were evaluated in early as well as advanced generations. Based on consistent performance over the years 4 advanced stage hybrids for table purpose *viz*., J/6-18), MS/8-1148, MS/8-1565, PS/7-7 & 5 processing hybrids viz., MP/9-91, MP/6-39, MP/6-595, MP/8-62 and MP/8-1900 were indentified for introduction in AICRP for multi-location testing. Seventeen parental lines were identified with early maturity & processing traits.

The third programme is on 'Biotechnology in Potato Improvement' which aims at use of molecular biology tools for genetic improvement of the potato. During the year whole genomes of *Ralstonia solanacearum* (4 strains) causing bacterial wilt in potato and *Fusarium sambucinum*, causing dry rot in potato were sequenced using massive-parallel pyrosequencing technology (Roche 454 GS FLX Titanium). Developed transgenic lines of potato cvt. Kufri Chandermukhi expressing 17.6 HSP gene for heat stress tolerance and Kufri Jyoti expressing F-Box gene isolated from wild *Solanum spegazinii* for its role in defence against late blight disease. Transcriptional expression analysis was done through micro assay for potato tuberisation in response to heat stress in Kufri Surya (heat tolerant) and Kufri Chandermukhi (heat sensitive). In total 2432 genes upregulated in Kufri Surya on 14 day and 448 genes on 21 day of heat stress. Interspecific symmetric somatic hybridization was carried out between the androgenic dihaploid (C-13) of common potato *S. tuberosum* and 6 wild *Solanum* species. Among them *S. cardiophyllum* derived 4 regenerants were confirmed for the true somatic hybrids possessing parent specific bands. Gene expression analysisfor nitrogen use efficiency was done in potato cultivars by real-time PCR for ammonium transporter, asparagine synthetase, nitrate reductase and nitrite reductase genes. Results showed the variation of N efficiency in three cultivars Kufri Gaurav (highest N efficient), Kufri Pukhraj and Kufri Jyoti (least N efficient) which differ widely in N efficiency.

Plant Protection

Late blight incidence in the sub-tropical plains was significant this year and losses varied from region to region. No change in race spectrum, mating types,metalaxyl tolerance and mitochondrial haplotyping was observed in *Phytophthora infestans* over last year. Attempts were made to purify cell wall based protein from *P. infestans* to develop polyclonal antibody for development of dipsticks. Southern blot analysis of selected Avr3a-siRNA transgenic lines was carried out and copy number was determined. In order to silence transposable elements in *P. infestans,* retro-transposon element encoding 1 kb fragment GYPSY-1a was retrieved and sense and antisense primers were designed to develop RNAi construct. Microarray analysis of mycelium, sporangia and zoospores of *P. infestans* revealed differential gene expression where 43 and 61 genes were upregulated>10 and 15 fold, respectively in sporangia and zoospores. JHULSACAST model successfully forecasted late blight appearance in north west Indo-Gangetic plains of Uttar Pradesh and Punjab. An INDO-BLIGHTCAST- a web based forecasting model, which is applicable pan India, has been developed to predict the first appearance of late blight disease. Treatment combination - *Bacillus subtilis* (B5) + *Trichoderma viride* (before disease appearance) – Cymoxanil-based (at disease appearance) and subsequently *Bacillus*

subtilis (B5) +*Trichoderma viride* spray was found highly effective.

For development of late blight resistant cultivars, 12800 seedlings were screened out of which 1489 resistant seedlings were retained for further studies. Early generation (F_1C_1-F_1C_5) hybrids (1259) were evaluated and 568 hybrids were retained for further evaluation. In advanced generation, 16 hybrids were evaluated and 6 were retained for further evaluation. Hybrid SM/00-42 has been identified for introduction into AICRP (Potato) for multilocation trials. Out of 78 accessions screened for presence of *R1* and *R3* genes, 10 accessions possessed *R1* while 7 accessions possessed both genes. Eighteen clones possessing stacked *R1* and *R3a* genes were evaluated for late blight resistance and have been advanced to F_1C_2 generation. Fourteen elite genotypes possessing multiple disease resistance to late blight, PVY and PCN have been identified through MAS.

The viruses (PVY & PVS) were mass propagated and the purified virus particles were used to raise antisera. Sixty four germplasm accessions were tested for PVY and PVX resistance through mechanical inoculation and 14 CP nos. were found having combined resistance to both PVX and PVY, 24 CP Nos. to PVY and 6 CP Nos. to PVX, respectively. Two hundred and twenty leaf samples were tested under Accredited Test Laboratory (NCS-TCP) while 15 samples were tested under post entry quarantine.ToLCNDV-potato was transmitted through whiteflies to *N. benthamiana* plants and confirmed through PCR and EM. Triplex lateral flow immune assay (LFIA) for simultaneous detection of PVX, PVA and PVM was standardized and validated. RT-PCR assay for detection of potato viruses CMV and TMV and multiplex RT-PCR assay for simultaneous detection of PAMV, PVS, PVM, PLRV and PVX was standardized and validated. Real Time PCR protocols based on SYBR green chemistry have been standardized for *Potato virus X* and *Potato virus A*. Southern blot analysis was carried out for ToLCNDV-potato transgenic lines and copy number was determined. Studies on prevalence of PVY isolates showed the existence of PVY^O, PVY^C, $PVY^N$and PVY^{NTN} in many of the states. Helper component gene, P1 protein and coat protein gene of PVA were amplified, sequenced and assembled.

Isolates (47) of *Ralstonia solanacearum* collected from Meghalaya were characterized into biovars (based on a physiological test) and phylotypes (based on phylotype specific multiples PCR). Phylogenetic analysis of *egl* gene sequences of 114 *R. solanacearum* isolates was determined and strains characterised to sequevars. Of the thirty three pathogenic *Streptomyces* strains tested by PCR using specific primers TxtAB1 and TxtAB2 to the txtAB operon, only twelve were found positive as revealed by the presence of expected 385bp txtABamplicons. The phylogenetic analysis of 26 *Rhizoctonia solani* isolates collected from Himachal Pradesh, Madhya Pradesh, Arunachal Pradesh, and Bihar grouped all *R. solani* isolates with AG-3 (potato) group.Four strains of *Streptomyces* spp. were evaluated for development of the disease under three different soil moisture levels at Jalandhar revealed development of maximum disease incidence under high moisture regime. Application of *Trichoderma viride* @ 150 kg/ha over the seed tubers in furrows at planting significantly reduced incidence and severity of common scab in the fields affected by the disease. Application of *T. viride* and boric acid seed treatment was effective for the management of both common scab and black scurf diseases of potato. A combined spray of 0.2% Bavistin + 100 ppm of Krosin AG on the seed tubers significantly reduced rotting in seed tubers already predisposed to rotting.

Seven aphid samples were collected from various locations and were identified from various potato growing regions of India using universal COI specific primers. However, *M. persicae* and *A. gossypii* were found in all regions probably because of their ability to tolerate fluctuations in the abiotic factors. Regarding white flies, *Bemisia tabaci* was identified from both Modipuram and Jalandhar while *Trialeurodes vaporariorum* from glasshouse population of Shimla. The transmission studies of whiteflies transmitted *ToLCNDV-Potato* revealed that even a single viruliferous white fly can transmit virus to healthy potato plants. Among the various botanical extracts studied, dalchini was found to be very effective against whiteflies and aphids under field conditions. Among various non-edible seed oils, Neem oil was found to be most effective against whiteflies and leafhoppers. The screening of potato cultivars against leafhoppers revealed that red cultivars, Kufri Arun and Kufri Sinduri, were least preferred as compared to other cultivars. The Potato tuber moth incidence was below threshold levels at five locations (stores) in Kangra valley (Himachal Pradesh) during June and July (2013). The PTM population monitoring using pheromone traps under field conditions indicated that it was below the critical levels at four locations in Kangra valley while no infestation was reported on seven potato varieties in Indore/Malva region of Madhya Pradesh at the time of harvest.

For breeding cyst nematodes and late blight resistant varieties, 53,000 hybrid TPS were produced from 49 bi-parental crosses. Nine thousand four hundred seedlings were screened for late blight and 567 selections were made. In early generations, 1423 hybrids were evaluated and 777 hybrids were selected. Out of 55 advance generation hybrids evaluated, 52 were selected on the basis of agronomic traits, resistance to late blight and cyst nematodes. Out of sixty three advanced generation material and varieties screened for presence of genes conferring resistance to *Globodera* spp., 38 found positive for H1 gene. Trap cropping for all three seasons with susceptible variety KufriJyoti recorded highest reduction in cyst population. Among the non-solanaceous crops, radish resulted in highest reduction in number of cysts and number of eggs/cyst. Moreover, intercropping of radish and marigold with potato was also effective in reducing the population of nematode.

Seed Technology

A total production of 653.93 quintals of nucleus and breeder seed was achieved in both conventional and hi-tech seed production system from an area of 5 hectares in hills. This provided 452.28 quintals breeder seed produced in 3.56 ha area. A total quantity 447.18 quintals of breeder seed was supplied from Kufri hills during the current season. A total number of 13,325 *in vitro* culture tubes of 23 varieties and 1,750 bottles were produced while 900 flask of liquid culture were transferred for microtuber induction and 17,109 microtubers produced at Shimla. A total of 1,173 *in vitro* culture tubes of 10 varieties and 12,810 microtubersof 21 varieties were supplied to different regional stations for further multiplication. A total number of 58,796 minitubers were produced through aeroponics at Shimla, 71,247 minitubers at Modipuram and 23,349 at Patna. A total of 23,955.37 quintals breeder seed were supplied to various government and private agencies during 2012-13 from plains and hills which include both pre-cold store (21,646.79 quintal) and post-cold storage (1,898.36 quintal). About 80 individual tubers of 20 varieties of virus free, true to type, uniform in size and genetically pure tubers were selected and aseptically maintained at 4ºC as basic material and 21 nodal cutting from virus-free basic plants for 17 varieties were aseptically used for microplant generation and further multiplication. A total of 1360 indexed tubers of four hill varieties were supplied under MoU for further multiplication in subsequent cycles to augment seed potato production in Manipur and supply chain in NE regions.

The vigour was tremendously increased in most of the treatments in both the grade of microtubers. The highest percent vigour increase was 171.4% in carbendazim, pencycuron as well as tracel over control in 6 mm grade of microtubers. Sodium alginate 2 and 3% resulted very good encapsulation in all grades without any cracking in comparison of 5-9%. Among the varieties, the best coating without any cracking was noticed in Kufri Surya, Kufri Girdhari and Kufri Bahar after 50 days of storage at 4ºC temperature.

The mode of primary infection of *Sclerotinia sclerotiorum* on potato is only through ascospores which are short lived and falls on flowers to cause infection only on petals. In absence of potato flowers it infects flower of weeds available in vicinity of potato plant and the infected flower of weeds leads to infection in potato plant. Colony characters of potato endophytes were highly variable with maximum frequency of red bacteria in Kufri Chandramukhi which was tentatively identified as *Methylobacterium* species. Maximum reduction of black scurf was observed in *T. viride,*mancozeb, monecron and boric acid + *T. viride* and statistically at par to each other while common scurf incidence was minimum in *P. florescence,* boric acid and *T. viride*. In G2 of Kufri Jyoti produced 72.13% oblong shape tuber while in G1 of Kufri Girdhari produced 51.51% phenotypic changes oblong shape tuber. In Kufri Jyoti, round shaped tuber planted material produced 69.50% round shape tuber and 30.45% oblong shape tubers while oblong shape tuber planted material produced 67.76% rounded shaped tuber and 32.23% oblong shape tubers. The increase in number and weight of aeroponic minituber was recorded in all types of varieties irrespective of long day, short day and day neutral. The maximum 275% increase in yield by weight was recorded in Kufri Jyoti, 260.3% in Kufri Badshah under bower system of planting over normal planting. Microplants of six potato cultivars planted in April resulted minituber per plant production from 5.60 in Kufri Lauvkar to 13.77 in Kufri Sindhuri. Planting in second week of July resulted minituber production per plant from 7.17 in Kufri Chandramukhi to 31.34 in Kufri Chipsona-3. Average tuber number and weight per plot was higher in >3-10 g tubers in almost all the dates of harvest than <3 g tubers. Days taken for first harvest were minimum (38 days) in Kufri Bahar whereas Kufri Chipsona-3 took 57 days to attain the desired size of minitubers for first harvest. In vector monitoring system, funnel based water trap was very effective for intact catch of vectors for identification purpose and four different types of aphid were identified in the seed crop. Vermiculite+pearlite were observed best in terms of

all characters under study for photo-autotrophic growth of microplnts.

Crop Production

Studies were carried out to evaluate and select productive, resource use efficient and remunerative potato based crop sequences. At Patna (Bihar), potato-bottle gourd–rice was found most productive system in terms of rice equivalent yield followed by early potato-potato-sponge gourd-green manuring, potato-onion-rice and early potato–wheat-green gram-maize sequence. At Shimla, with the adoption of improved production technologies developed by CPRI for hill farmers, the productivity can be improved by over 40%, *i.e.* the current gap between farmers' and research farm yields. At Shillong in NEH region, the planting of radish as an intercrop with potato in the ratio of 1:1 was found more remunerative.

Studies were conducted at Madenur, Hassan, Karnataka to develop production technology for *Kharif* potato in plateau areas. Potato variety Kufri Himalini (19.0 t/ha) performed better among the hybrids/varieties and recorded 15.1% extra tuber productivity over second best popular variety of the region Kufri Jyoti (16.4 t/ha). The prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% followed by fenamidon + mancozeb @ 0.3% and one more spray with mancozeb recorded significantly lower late blight disease intensity (28.75%) and higher yield (43.04 t/ha).

Developed a decision support system (DSS) on potato weed management "Potato Weed Manager" hosted on institute's website. (http://cpri.ernet.in).

The impact of climate change on potato productivity in Uttar Pradesh under A1FI scenario was assessed using WOFOST crop growth model. The mean productivity of Kufri Badshah, Kufri Bahar and Kufri Pukhraj was 46.0, 46.8 and 45.3 t/ha, respectively, under baseline scenario. In a study on impact of climate change on late blight in Punjab and western Uttar Pradesh using JHULSACAST model, it was predicted that under the favourable relative humidity in Punjab, the earliest late blight appearance is during 13th to 25th October in baseline scenario (2000) which is expected to be delayed by 0 to 6 days in 2020 and 12 to 14 days in 2055 scenarios. A subset of *P. infestans* isolates was found to grow well at 30ºC, which was grown well earlier upto 28ºC only at Modipuram. It can be concluded that *P. infestans* could grow at higher temperature. At Shimla, the four different *R. solanacearum* strains *viz*., RS-2 (phylotype II bv 2), RS-25 (phylotype I bv 4), RS-50 (phylotype I bv 3) and RS-75 (phylotype IV bv 2T) survived up to seventeen months of storage in distilled water at 20ºC. However, none of the strain survived after one month of incubation at 37 and 40ºC. At Modipuram, due to high temperature, effect of mite feeding was more (upto 60% burn) and hopper burn percentage was low. Whitefly was highest in first week of November in 5th October planted crop and in second week of November in 10th October planted crop. At Gwalior, high temperature (30-35ºC) and low humidity (55-60%) observed during the potato season this year were not favorable for insect growth and also inhibited the tuber formation.

In the long term manurial and fertilizer trials at Modipuram, the mean system productivity was maximum in rice-potato-wheat cropping system followed by maize-potato-onion and groundnut-potato-Moong bean system (48.9 t/ha). Inorganic, secondary and micro nutrients application recorded highest and markedly better system productivity in maize-potato-onion and groundnut-potato-Moong bean system. The varieties Kufri Anand and Kufri Chipsona-1 recorded 30.5 and 26.9% decline in total tuber productivity with 100% substitution of inorganic nutrients with vermi-compost. Tuber yields were not affected distinctly upto 50% substitution of inorganic nutrients with vermi-compost. Long term impact of nutrition on soil properties was studied after seven crop cycles. Organic carbon content increased in all treatments except control. Potato fields applied with organic source exhibited less damage due to potato pests as compared to inorganic nutrition or part of both. Thrips and leaf folder population was also less in groundnut and rice, respectively, which received organic treatments.

At Shimla, CCI (chlorophyll content index) increased after application of second dose of N and declined thereafter continuously till last observation in the over fertilize plot. All the treatments produced statistically similar tuber yields (14.4-14.8 t/ha). At Patna, 20% recommended N applied at 90% of the reference SPAD value gave similar yield as compared to the recommended N level and was significantly better than the treatments where N was top dressed at 80% of the reference SPAD value. Among varieties Kufri Khyati and Kufri Pukhraj gave better response and yielded significantly better than Kufri Jyoti. At Gwalior, highest total tuber yield was recorded with neem coated urea at recommended fertilizer level which was significantly higher over control. At Shillong, application of 75%

recommended dose of fertilizers and remaining recommended dose of N substituted through FYM along with inoculation of *Azotobacter* and phosphate solubilizing bacteria brought about the significant improvement in total yield of potato thereby saving 25% fertilizers. Nutrient efficient germplasm J-93-58 (30.8 t/ha) and J-92-159 (31.4 t/ha) produced significantly higher tuber yield than Kufri Gaurav (27.3 t/ha) at lower dose of N (160 kg/ha). Tuber yield produced by germplasm J-93-58 (30.8 t/ha) and J-92-159 (31.4 t/ha) at 160 kg N/ha was statistically equal to that produced by Kufri Gaurav (30.2 t/ha) at higher dose of N of 240 kg/ha.

At Modipuram six promising genotypes/hybrids *viz.* J 93-58, J 92-164, 83-P-142, JN-2207, MS/82-279, J 92-167 gave higher potato yield than popular *var.* Kufri Bahar and Kufri Pukhraj at all three soil moisture levels (Wet regimes,0.20-0.25 bars; moist regimes, 0.40-0.45 bars and semi-dry regimes, 0.60-0.65 bars). At Patna different root parameters such as fresh root weight, root length, root surface area and root volume in general increased with increasing NO_3^- level in hydroponics (solution culture studies). At Modipuram, fertigation through drip and mulching improved yield as well as nutrient and water use efficiency. The best results were obtained (39.0 t/ha) when 75% of recommended NPK was applied as fertigation through drip using liquid fertilizer in eight equal splits after 25% of basal application. At Shimla, soil moisture contents remained 8-12% higher in poly-mulch condition during drought in comparison to no mulch condition. Black polythene mulch increased surface soil temperature by 1.4-2.7ºC at 10 cm depth compared to 5 cm depth and 1.2 to 1.4ºC at 10 cm depth compared to bare soil condition. On the other hand silver poly mulch and pine needle mulch reduced soil temperature by 0.5 to 1.0ºC at 5 cm depth and 0.2 to 0.4ºC at 10 cm depth and 1.2-2.2ºC at 5 cm depth and 0.9-1.1ºC at 10 cm depth, respectively, relative to no mulch condition.

A small, compact and low cost prototype of 2-row tractor operated potato combine harvester for collection of dug tubers in bags or crates was designed and fabricated.

Fabrication work of the main frame and three numbers of the grading sieves of the grader was carried out. Major systems of the grader are the main frame, grading mechanism and power transmission system. This grader has been designed to grade the material in four different size grades.

A portable aeroponic system was developed for conducting experiments on potato and other crops. A 25 kg capacity machine was designed for grading experimental produce. Parameterization was done for another machine for grading minitubers produced through aeroponics technology.

Crop Physiology, Biochemistry and Post Harvest Technology

A method was standardized through High Performance Liquid Chromatograph System (HPLC) for the evaluation of the concentration of flavouring compound 5'-nucleotides (AMP+GMP). The concentration was low in raw tubers of 44 Indian potato cultivars ranging from 1.70µg/ g FW (Kufri Jawahar) to 6.68 µg/ g FW (Kufri Muthu). Microwave cooking increased the concentration of flavouring compounds as well as flavour in all the tested cultivars and the 5'-nucleotide contents ranged from 2.97 µg/g FW (Kufri Jawahar) to 9.54 µg/g FW (Kufri Himalini), showing an increase of up to 272%. Potato starch based bio-degradable films were made with starch and PVA. Starch and PVA in 1:3 ratio showed good results, with soft, flexible and semi-transparent films. Resistant starch (RS) content increased in French fries prepared from all the cultivars with increase in storage duration (at -20°C) from 24h to 180d. Increase in RS content was significant after 60 DOS. French fries prepared after 180 DOS contained highest RS content and the increase was 9.49, 9.66 and 8.25 % in Kufri Frysona, Kufri Chipsona-1 and Kufri Chipsona-3, respectively. Osmotically dehydrated (OD) French fries with acceptable colour and taste recorded sodium contents (up to 1.24%) which were within the tolerable upper intake levels for adults (2.3 mg/day).These fries had low oil content (4.32% v/s 16.75%) and were enriched with Vitamin -C (48-128 mg/100g fresh weight) as compared to normal French fries (14.75 mg/100g fresh weight).

The antioxidative properties related to keeping quality of potatoes was studied. Peroxidase activity increased during storage up to 180 days at two temperatures (4ºC and 12ºC) and remained high in Kufri Chipsona-1 and low in Kufri Pukhraj. DPPH inhibition decreased during storage at 4°C and remained high in Kufri Chipsona-1 (33.88%) and least in Kufri Pukhraj (14.69%) up to 180 days of storage. Hydrogen peroxide scavenging activity remained high in Kufri Chipsona-1 and low in Kufri Pukhraj throughout storage with higher activity recorded at 12°C compared to 4°C. In terms of antioxidative potential, Kufri Chipsona-1 was

superior to Kufri Jyoti and Kufri Pukhraj during storage. Higher ascorbate peroxidase activity, higher ascorbic acid contents and low sugar accumulation was recorded in cvs. Kufri Chipsona-1 and Kufri Chipsona-3 during storage up to 180 days as compared to Kufri Pukhraj. Gibberellic acid (GA) content was estimated in dormant, chitted and sprouted potato tubers of three varieties differing in dormancy duration through DAS-ELISA. In Kufri Jyoti and Kufri Girdhari, GA content was low in dormant and sprouted tubers and high in chitted tubers. Dip treatment of potatoes with paclobutrazol (500-1500 ppm) reduced the sprouting and weight loss in potatoes up to 60 days of storage in heap. In studies to find alternative to CIPC, an organic compound named AF1 (developed at IARI) recorded complete sprout inhibition at 100 and 200 ppm concentration up to 90 days of storage at 12°C. Vapour treatment with Dill seed (*Anethum sowa*) oil (500-1250 ìl/l) also recorded complete sprout inhibition without any increase in rotting in potatoes up to 65 days of storage at 24°C.

Out of 91 successful crosses for heat tolerance, 1,84,289 seeds were extracted. 624 selections were made from the seedlings raised from these seeds in the glass house and field. In the field selection at Modipuram, 128 clones were selected from F_1C_1-F_1C_4 stage for further evaluation. Heat tolerance in advanced hybrids was quantified by leaf bud tuberization test under controlled conditions and hybrid HT/07-1105 and HT/07-804 showed good heat tolerance. Slow release formulations PS10 and PP10 of growth retardant Paclobutrazole at 5 ppm spray 30 days after planting improved tuber yield under heat stress conditions. At Jalandhar, Kufri Surya was found to be suitable for planting during first week of September for yield advantage over Kufri Pukhraj. For drought tolerance 6 hybrids were selected from 2005 - 2008 series, 10 from 2009, 20 from 2010 and 69 from 2011 series. Two hybrids WS/2005-108 and WS/2005-146 showed good keeping quality at room temperature.

Social Sciences

During this year, a survey was conducted in West Bengal and Bihar to find out real problems and seed potato utilization pattern of the potato growers. Variety wise potato area was assessed and it was found that in both the states Kufri Jyoti was the predominant potato variety occupying more than two third area in West Bengal and more than half in Bihar. Kufri Pukhraj, Kufri Sindhuri and Kufri Chandramukhi were the other popular varieties of these states. It was also found that seed potato purchased from traders was the most commonly used source of seed (53% farmers) followed by own farm production retained as seed (24%) in West Bengal. However, in Bihar, own farm production retained as seed potato (49% farmers) was the most commonly used seed source followed by the seed purchased from traders (24%). Seed replacement rate was as low as 15% in the state of Bihar while this rate was 48% in West Bengal. It was found that 50% respondents with higher seed potato expenditure invariably had higher potato yield, cost of cultivation, net income and benefit-cost ratio compared to the 50% respondents with lower expenditure on seed potato in both the states. Expensive seed was found to be the severest problem for potato farmers in the state of West Bengal followed by wide fluctuation of potato prices over the year. However, unavailability of healthy seed potato was the number one constraint in the state of Bihar followed by expensive cold storage.

Another survey of 120 potato growers was carried out in three districts of Bihar namely Patna, Nalanda and Muzaffarpur. The varietal adoption pattern was observed in these three district and it was found that Kufri Pukhraj was the most popular variety in Patna as well as Nalanda district while Kufri Jyoti predominant variety in Muzaffarpur district. Application of NPK fertilizers in Patna, Nalanda and Muzaffarpur was found to be 215:210:115, 170:188:120 and 150:166:96 kg/ha against the recommended doses of 180:80:100 kg/ha. The seed rate of potato was the highest in Nalanda (33.6 q/ha) followed by Patna (28.8 q/ha) and Muzaffarpur (20.6 q/ha). Due to low adoption of recommended practices in Muzaffarpur, average yield of potato in the district was only 20.6 t/ha while it was 33.6 t/ha in Nalanda and 28.8 t/ha in Patna. Moreover, 25 potato technology demonstrations were laid out in Bihar and Uttar Pradesh. Analysis of data revealed that new varieties of CPRI like Kufri Garima and Kufri Khyati performed better than existing varieties Kufri Pukhraj and Kufri Bahar in UP. Also, with recommended dose of pesticides there was lesser incidence of pest and diseases on these varieties as compared to local check.

During this period, Social Sciences Division conducted an ICAR sponsored 21-days Summer School on “Advances in Quality Potato Production and Post-harvest Management”. The impact of this training course revealed that average increase in knowledge of trainees before and after training was estimated at 25.7%. In addition, 9 trainings, 5 *Kisan Mela* 3 awareness camps and 15 live phone in programmes/ agricultural talk were also organized.

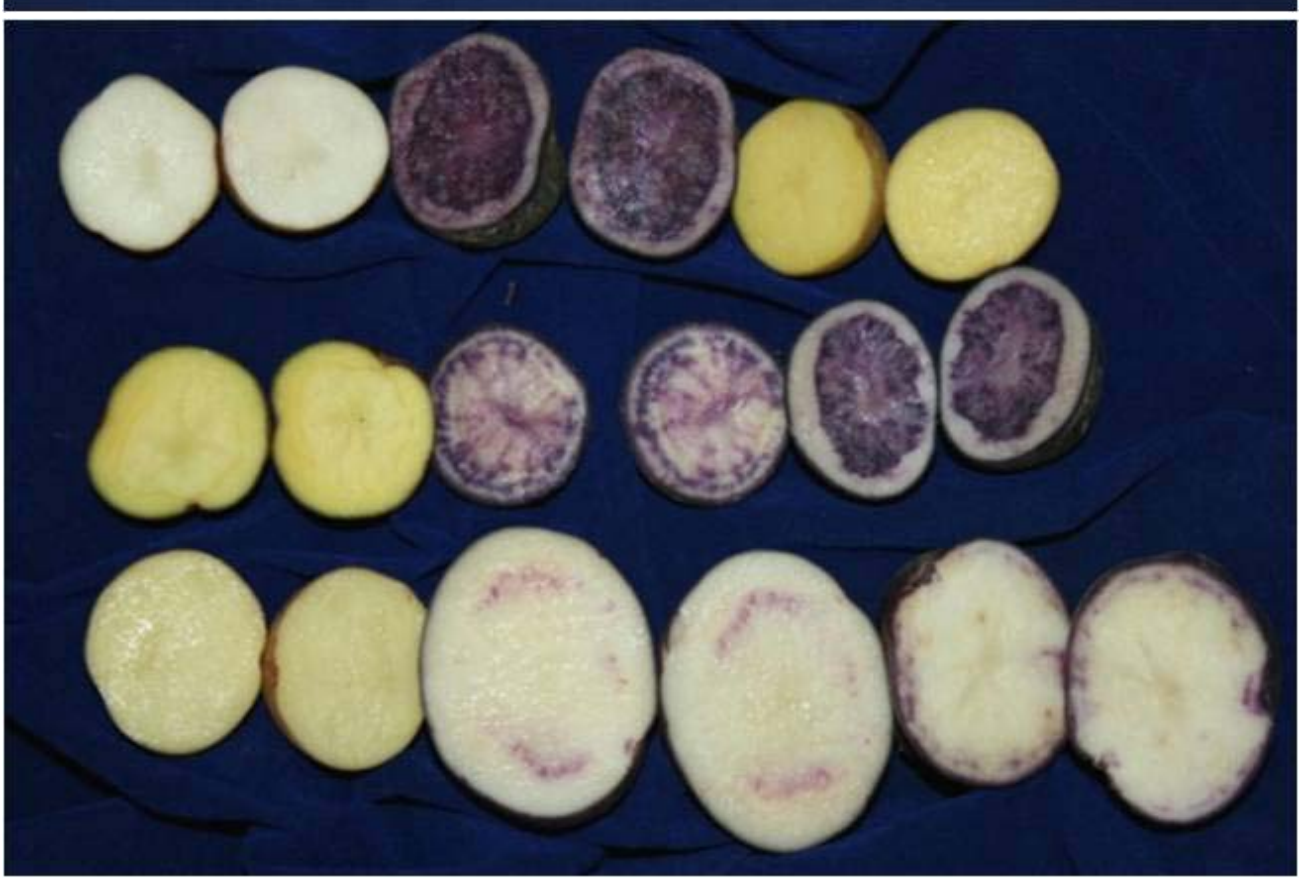
Research Programmes

RESEARCH PROGRAMMES, PROGRAMME LEADERS AND ASSOCIATES FOR THE YEAR 2013-14

Sl. No.	Research Programmes & Institute Code No.	Programme Leader and Associates
1.	Management and enhancement of potato germplasm. P1-2010/1-IPR-F30/0210	Dr. Vinay Bhardwaj. **Associates:** Drs. Vinod Kumar, Dalamu, Raj Kumar, Jagesh Kumar Tiwari, G Vanishree, SK Luthra, Ratna Preeti Kaur, Sanjeev Sharma, A Jeevalatha, Kamlesh Malik, MS Gurjar, R Uma Maheshwari, Ashiv Mehta, Name Singh, Bandana, SP Trehan, MJ Sadawarti, Shambhu Kumar, R Baswaraj, R Sudha, Aarthi Bairwa, KR Naik (Dharwad), Kiran Kumar (Hassan), Anil Gupta (Hissar), Kameshwar Sen and Shruti Gupta.
2.	Development of improved varieties. P1-2010/2-IPR-F30/0210	Dr. SK Luthra. **Associates:** Drs. Raj Kumar, Shambhu Kumar, VK Gupta, Ratna Preeti Kaur, Sanjay Rawal, SP Trehan, SK Singh, Mehi Lal, RK Arora, Rahul R Bakade, Ashiv Mehta, Vinay Bhardwaj, Bandna, AK Srivastava, Jagesh Kumar Tiwari, VK Yadav, Harvir Singh, Ravinder Sharma, Ramesh Chand and Vineet Sharma.
3.	Biotechnology in potato improvement. P1-2010/3-IPR-F30/0210	Dr. Jagesh Kumar Tiwari. **Associates:** Drs. VU Patil, Shashi Rawat, Baswaraj Raigond, Vinay Bhardwaj, Sanjeev Sharma, Brajesh Singh, Raj Kumar, SK Luthra, S Sundaresha and Dalamu.
4.	Resource management strategies and information technology tools for potato based cropping systems. P1-2010/4-IPR-F27/0210	Dr. SS Lal. **Associates:** Drs. PM Govindakrishnan, VK Dua, Shashi Rawat, SP Singh, Sanjay Rawal, RK Arora, SK Singh, MA Khan, SK Yadav, RK Rana, R Uma Maheshwari, Name Singh, EP Venkatasalam, R Sudha, Aarthi Bairwa, Islam Ahmed, Ashwani Kumar, Sushil Kumar and Yogesh.
5.	Nutrients and water management. P1-2010/5-IPR-F25/0210	Dr. SP Trehan. **Associates:** Drs. MC Sood, VK Dua, Manoj Kumar, Name Singh, MK Jatav, MA Khan, Raj Kumar, SK Yadav, AK Sharma, Sushil Kumar and Yogesh.
6.	Nutrient dynamics studies on long term manurial/fertilizer application and organic farming in potato production. P1-2010/6-IPR-F25/0210	Dr. NC Upadhayay/Sanjay Rawal. **Associates:** Drs. MC Sood, MA Khan, Anuj Bhatnagar, Mahesh Kumar and Avinash Chaudhary.
7.	Farm machines for potato cultivation. P1-2010/7-IPR-N20/0210	Er. Manjit Singh. **Associates:**Ers. Sunil Gulati, Sukhwinder Singh, Dr. RK Rana, Tarlochan Singh, Jagdish Chander and Gurdev Singh.
8.	Management of late blight. P1-2010/8-IPR-H20/0210	Dr. SK Kaushik. **Associates:** Drs. BP Singh, Sanjeev Sharma, Mehi Lal, RK Arora, MA Khan, Vinay Bhardwaj, AK Srivastav, Shashi Rawat, Ravinder Kumar, S Sundaresha, R Umamaheshwari, MS Gurjar, Dalamu, G Vanishree, R Sudha, Islam Ahmed, Subhash Chand and SBS Parihar.

Sl. No.	Research Programmes & Institute Code No.	Programme Leader and Associates
9.	Molecular characterization, detection and management of potato pathogens. P1-2010/9-IPR-H20/0210	Dr. (Ms) A Jeevalatha. **Associates:** Drs. Baswaraj Raigond, Vinay Sagar, Sanjeev Sharma, VU Patil, Jagesh Kumar Tiwari, EP Venkatasalam, Ravinder Kumar, S Sundaresha, RP Pant, Sridhar Jandrajupalli, Vallepu Venkataswarlu and Tarvinder Kochar.
10.	Characterization, detection and management of major soil and tuber borne pathogens of potato. P1-2010/10-IPR-H20/0210	Dr. RK Arora. **Associates:** Drs. Vinay Sagar, KK Pandey, A Jeevalatha, Malkhan Singh Gurjar and Rahul R Bakade.
11.	Population dynamics and management of potato pests. P1-2010/11-IPR-H20/0210	Dr. (Mrs.) Kamlesh Malik. **Associates:** Drs. Anuj Bhatnagar, Vallepu Venkateswarlu and Sridhar Jandarjupalli.
12.	Management of potato nematodes. P1-2010/12-IPR-H10/0210	Dr. R Uma Maheshwari. **Associates:** Drs. Vinod Kumar, EP Venkatasalam, R Sudha, Aarthi Bairwa and B Chandran.
13.	Physiological and genetic approaches in managing heat & water stress under sub-tropical environment in potato. P1-2010/13-IPR-F60/0210	Dr. JS Minhas. **Associates:** Drs. Devendra Kumar, VK Gupta, Sanjay Rawal, Kamlesh Malik, Brajesh Singh, Shashi Rawat, Name Singh, Shelly Chopra and Om Pal Singh.
14.	Potato storage: Efficient and eco-friendly methods for improved quality. P1-2010/14-IPR-F60/0210	Dr. (Mrs.) Ashiv Mehta. **Associates:** Drs. Brajesh Singh, Bandana, Pinky Raigond, MA Khan, Yogesh Gupta and Vineet Sharma.
15.	Nutritional value of potato and potato products. P1-2010/15-IPR-Q10/0210	Dr. Brajesh Singh. **Associates:** Drs. Ashiv Mehta, Pinky Raigond, Bandana, Vineet Sharma and Yogesh Gupta.
16.	Production of breeder seed of potato through conventional and hi-tech System. P1-2010/16-IPR-F00/0210	Dr. KK Pandey. **Associates:** Drs. BP Singh, EP Venkatasalam, Vinod Kumar, Ashwani Kumar Sharma, SK Kaushik, Dhruv Kumar, Vinay Singh, JS Minhas, RK Arora, Satyajit Roy, SP Singh, MJ Sadawarti, Manoj Kumar, SK Singh, Rahul R Bakade, Sukhwinder Singh, R Muthuraj, Ratna Preeti Kaur, RK Singh, TK Bag, Parvesh Jassal, Sumita Sharma, RK Verma, Balak Ram Singh, KP Singh, NK Sood, Jasvir Singh, Santosh Kumar, Pushpender Kumar, Satinder Kumar, Kapil Kumar Sharma, Akhilesh Kumar, Arun Kumar Singh, YP Singh, RK Samadhiya, Sanjay Sharma, Harveer Singh and V Rajindran.
17.	Impact of potato technologies developed by the Institute. P1-2010/17-IPR-C00/0210	Dr. NK Pandey. **Associates:** Drs. Rajesh Kumar Rana, Dhiraj Kumar Singh, SK Yadav, Ravinder Kumar, TK Sinha and Ashok Kumar Chauhan.
18.	Climate change impact and adaptation strategies for potato crop. P1-2010/18-IPR-F27/0210	Dr. VK Dua. **Associates:** Drs. BP Singh, Shashi Rawat, Sanjay Rawal, SK Singh, SP Singh, Mehi Lal, Sanjeev Sharma, Vinay Sagar, Kamlesh Malik, Anuj Bhatnagar, Islam Ahmed and Sushil Kumar.

Division of Crop Improvement



Programme 1: Management and Enhancement of Potato Germplasm

Collection

CPRI has been designated as National Repository for potato germplasm. The present germplasm collection at CPRI consists of more than 4,100 accessions of cultivated and wild species collected from 30 countries. Efforts were continued to augment the potato germplasm collection at CPRI. During the period under report, 26 accessions including 9 accessions from Nitherlands, 5 accessions from Estonia, 4 accessions from Australia, 4 accessions from New Zealand, 2 accessions from Canada and 2 accessions from China were imported and added to germplasm collection of the institute. Besides, the TPS of 282 accessions belonging to 43 species were imported from USA. Thirty seven indigenous samples were also collected from plains of Assam (25 samples, Fig. 1), Lahul & Spiti (1 sample), Manipur (2 samples), West Bengal (2 samples) and Leh & Ladhakh (7 samples) regions.

Conservation

One thousand four hundred twenty one (1421) Tuberosum accessions, 768 Andigena accessions and 69 indigenous samples were maintained in fields at Jalandhar. Nearly 1350 Tuberosum accessions and 90 indigenous samples were maintained in fields at Kufri (Fig. 2). Ten dihaploids of indigenous varieties were

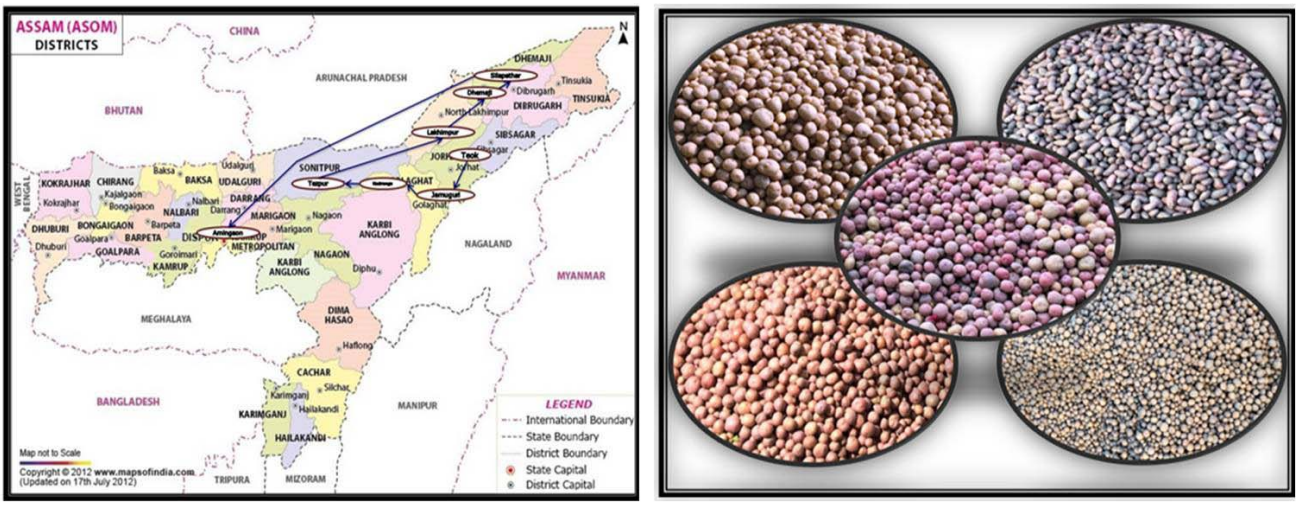


Fig.1.Germplasm exploration in the plains of Assam

Fig.2. Maintenance of Tuberosum accessions in field at Kufri

maintained in glasshouses at Shimla. Six hundred seven (607) accessions of 136 wild species were conserved (both in tuber and TPS forms) at CPRI, Shimla. Nodal cuttings of 30 elite clones of 13 *Solanum* species promising for various biotic and abiotic stresses were used for *in-vitro* conservation.

Nearly 1950 Tuberosum accessions including 167 DUS reference collection were maintained in *in vitro* form. Minitubers of 194 accessions from *in-vitro* repository were produced and added to the germplasm collection maintained under field conditions at Jalandhar and Kufri. Fifty-eight mericlones of 16 varieties were tested for their freedom from all viruses and four varieties viz., K. Bahar, K. Surya, K. Jyoti and K. Lauvkar were found free from all viruses.

Evaluation

A large number of accessions were evaluated for various biotic and abiotic stresses and also for adaptability and physico-chemical qualities. Promising accessions identified are listed in Table 1.

Table 1. Evaluation of potato germplasm

Character	Location	No. of accessions evaluated	Promising accessions identified
Adaptability	Kufri		
	Replicated	20	None
	Row Trial	180	CP nos. CP 2379, 1516, 2183 and 1475.
	Jalandhar Spring	100	None
	Modipuram		
	Autumn (early)	66	K. Sadabahar, CP nos. 3685, 3468, 3687, 3654, 3612, 3478, 3764, K. Pukhraj and K. Surya.
	Autumn (Main)	75	CP nos. 3872, 3910, K. Garima , 3869, 3859, 3786, 3854, K. Khyati, K. Pushkar, and 3845.
Late blight Foliage	Kufri (field)	29 (replicated)	6-Highly resistant (CP No.s 1012, 1085, 1187, 1319, 2003 and 2320.
	Kufri (field)	180	14-Highly resistant (CP Nos. 1475, 1479, 1481, 1869, 2018, 2209, 2159, 2177, 2183, 2191, 2279, 2298, 2330 and 2379); 15-Resistant; 37-Moderately resistant.
	Shillong (field)	77	2- Resistant (CP Nos. 3605 and CP 3841); 12-Moderately resistant.
	Shimla(Lab)	89	7-Highly resistant (CP Nos. 1392, 1523, 3567, 4003, 4010, 4027 and 4196); 42-Resistant; 34-Moderately resistant.
Late blight Tuber	Shimla (Lab)	112	11-Highly resistant (CP Nos. 1205, 1215, 1392, 1680, 1747, 1896, 3203, 3603, 4010, 4112, 4195); 49-Resistant; 21-Moderately resistant.
Viruses PVX & PVY	Shimla	64	14-Resistant (PVX and PVY) viz. CP Nos. 1896, 2192, 2237, 3225, 3348, 3367, 3423, 3501, 3565, 3621, 4052, 4191, 4193 and 4196; 38-Resistant (PVY); 20-Resistant (PVX).
	PSTVd	83	12 accessions viz., CP Nos. 1172, 1431, 1644, 1671, 2007, 2313, 2335, 2338, 2342, 3066, 3359 and 3718 were free.
Leaf hopper and Mites	Modipuram	66	None of the accession had < 5 % mite damage. Eleven accessions viz., CP Nos. 3468, 3473, 3483, 3603, 3620, 3655, 3676, 3683, 3685, 3689 and 3785 had hoper burn & mite damage <20%.
Cyst nematodes	Ooty	151	8 accessions viz., CP Nos. 3136, 3286, 3325, 3326, 3396, 4020, 4178 and JEX/A 232 were resistant to both species of potato cyst nematode.
Keeping quality	Jalandhar	107	7-Best keepers (CP Nos. 3195, 3209, 3424 and 3468; JEX/A Nos 30, 299 and 379); 20-good keepers and 13-average keepers.
Chipping	Jalandhar	75	Six accessions viz. CP Nos. 3281, 3325, 3361, 3424, 3485, 3500 were found to be suitable for chipping.CP Nos. 3424 and 3500 are potential parents for processing based on dry matter, chip colour and keeping quality.

Character	Location	No. of accessions evaluated	Promising accessions identified
Vitamin C	Modipuram	97	13 accessions viz. CP Nos. 1589, 1590, 1608, 1622, 1623, 1665, 1667, 1668, 1697 and JEX/A Nos. 361, 413, 622, 1081 possessed high vitamin C (> 24mg/100 g fresh tuber weight).
Water use efficiency	Modipuram	23	9 accessions viz. CP Nos. 1969, 1987, 2013, 2066, 2071, 2073, 2076, 2090 and 2110 were promising. 4 accessions viz. CP Nos. 1304, 1316, 1330 and 1343 were consistently promising during last 3 years.
Foliage maturity	Patna	100	5 accessions viz., CP Nos. 1549, 1551, 1646, 1695 and 1701 were early maturing i.e. > 80% foliage maturity at 70 days.·
	Jalandhar	1397	• 2 accessions viz., CP Nos. 1409 and 3203 were very early with 100% maturity in 71 days. • 7 accessions viz., CP Nos. 1408, 2033, 2101, 3072, 3366, 3428 and 3559 were early with maturing in 78 days. • 12 accessions viz., CP Nos. 1418, 1513, 1588, 1968, 2197, 2402, 2413, 3124, 3412, 3438, 3495 and 3590- medium with maturity in 85 days. • 33 accessions viz., CP Nos. 1340, 1341, 1377, 1417, 1485, 1515, 1906, 1918, 1919, 2012, 2167, 2294, 2416, 3174, 3258, 3259, 3358, 3422, 3445, 3478, 3542, 3632, 3644, 3646, 3647, 3661, 3702, 3778, 3956, 3959, 3982, 4247 and 4256 were medium late with maturity in 92 days

Development of *Tuberosum* core collection

To conduct various genetic studies, data on 1397 Tuberosum accessions was recorded on 16 (morphological and tuber) traits (Fig. 3) at Jalandhar to establish a core collection of tuberosum germplasm.

Fig. 3. Variability in potato germplasm for tuber and flesh colour

Ploidy estimation of potato genotypes using flow cytometer

Eight test germplasm samples namely KDW-5, KDW-31, KLK-13, KLK-21, KLM-10, KLM-12, KJT-2 and KJT-15, and two controls K. Bahar (4*x*,tetraploid) and C-13 (2*x*, diploid) were analyzed for ploidy levels based on nuclear DNA contents. In vitro-grown leaf tissues were used for ploidy estimation using PartecCystain® UV Ploidy kit in Partec flow cytometer. All samples were analyzed for more than 1000 particles and run in duplicates. The median value range was 50 to 58 for C-13 (2*x*) and 103 to 112 for K. Bahar (4*x*). The results showed that the median of G1 peak of KDW-5, KLM-10, KLT-15, KLM-12, KDW-31 and KLK-21 were matched with K. Bahar (4*x*); whereas KLK-13 and KJT-2 were similar to C-13(2*x*). The DNA ploidy analysis suggests that six samples viz., KDW-5, KLM-10, KLT-15, KLM-12, KDW-31 and KLK-21 are tetraploid whereas two samples namely KLK-13 and KJT-2 are diploid (Fig. 4).

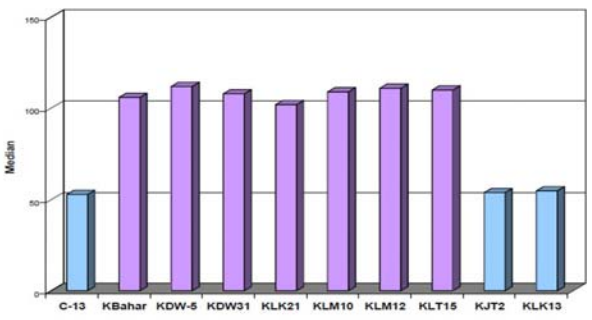


Fig. 4.Ploidy analysis of potato genotypes using flow cytometer

Genetic enhancement of Tuberosum and Andigena

In order to break undesirable linkages between late blight resistance and late foliage maturity in tuberosum germplasm, a total of 9,571 true potato seeds were produced from 28 successful crosses at Kufri. In seedling stage, 979 promising clones of 28 families were selected at 90 days on the basis of desirable tuber characters at Jalandhar. In F_1C_1 generation from 1935 clones evaluated, 505 clones of 32 families were selected. In F_1C_2 generation, 10 clones were selected from the 11 clones evaluated. For andigena improvement, crosses were made among unrelated andigena cross populations in second cycle of andigena population to develop third cycle andigena cross populations. Due to cross incompatibility most of the crosses did not produce any seed, while some crosses produced only few shriveled seeds. At Kufri out of 56 crosses attempted only 602 seeds from 8 crosses were obtained.

Maintenance of cross populations

In clonal generations 29 first cycle and 42 second cycle andigena cross populations from unrelated andigena cross combinations were maintained for further evaluation.

EVALUATION OF WILD SPECIES

Screening for late blight resistance: One hundred fourteen clones of 26 wild species were evaluated at Kufri for late blight under natural epiphytotic condition. Sixty two clones (Table 2) were either highly resistant (AUDPC $\leq$100) or resistant (AUDPC 101-200). Under lab conditions, 158 clones of 32 wild species were screened for late blight resistance by detached leaf method (Fig. 5) using complex races of *Phytophthora infestans*. Four clones were highly resistant (lesion area up to 1.0 cm^2), four clones were resistant (lesion area 1.1 to 2.5 cm^2) and sixty two clones were moderately resistant (lesion area 2.51 to 6.0 cm^2).

Fig.5.Screening wild species for late blight resistance

Screening for bacterial wilt resistance: Seventy six clones of different wild species were screened for bacterial wilt resistance at Hassan, Karnataka known as hot spot for bacterial wilt. Ten clones were highly resistant (0-5% wilting) while 2 clones (Table 2) were resistant (5-20% wilting).

Documentation

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

Table 2. Promising wild potato clones for different traits

Trait	Promising accessions identified
Late blight in natural epiphytotic condition	*Highly Resistant*: SS Nos. 1770-06, 1770-08 (*S. arnezii*), 1773-01 (*S. avilesii*), 2332-04 (*S.bukasovii*), 2169-03, 2178-01 (*S. bulbocastanum*), 1730-0, 1825 *(Kufri)* 08, 1825-09 (*S. cardiophyllum*), 2593-01, 2595-0, 2595-01, 2597-02 (*S. chacoensessp.chacoense*), 1846-06, 2727-03 (*S. demissum*), 1652-09 (*S. jamesii*), 2609-01, 2609-08, 2609-09, 2609-10, 2609-14, 2609-15, 2609-16, 2609-18, 2609-19, 2609-20, 2610-07, 2610-08, 2610-09 (*S. microdontum*), 1999-02 (*S. pascoense*), 2765-17 (*S. phureja ssp. phureja*), 2616-03, 2616-10, 2655-0 (*S. pinnatisectum*), 2289-02 (*S. sparsipilum*), 2706-07 (*S. stenophyllidium*), 2559-01, 2712-0, 2713-09 (*S. stoloniferum*), 2671-01, 2686-0, 2781-12, 2781-14, 2781-15, 2781-16, 2781-17, 2781-18, 2781-33 (*S. tubersoum ssp. andigena*).
Late blight by detached leaf method	*Highly Resistant*: SS Nos. 1848-17 (*S. demissum*), 2615-08, 2616-12 (*S. pinnatisectum*), 2379-0 (*S. tuberosum ssp. andigena*).
	Resistant: SS Nos. 1825-18 (*S. cardiophyllum*), 2609-16, 2610-03 (*S. microdontum*), 2615-04 (*S. pinnatisectum*).
Bacterial wilt (Hassan)	*Highly Resistant*: SS Nos. 2038-02, 2040-10, 2045-08, 2044-05 and 2044-44 (*S. tuberosum ssp. andigena*), 1659-02 (*S. mona*), 1724-06 (*S. sparsipilum*), 1725-44 (*S. spegazzinii*), 1848-20 and 1732-0 (*S. demissum*).
	Resistant: SS Nos. 1725-83 (*S. spegazzinii*), 2064-10 (*S. tuberosum* ssp. *andigena*).

Programme 2: Development of improved varieties

Project 1. Breeding improved varieties for plains

Hybridization

A total of 4, 28, 524 true potato seeds were obtained from the 169 successful crosses at Jalandhar, Modipuram and Patna.

Seedling stage

A total of 39,778 seedlings were raised in field from sowing of 1, 72, 552 true potato seeds of 102 crosses. At harvest, 4670 promising clones were selected.

Initial clonal stages

In initial clonal stages (F_1C_1, F_1C_2, F_1C_3), 8,559 clones were evaluated at 60/75/90 days and 1,976 promising clones were selected.

Replicated yield trials

Eighty nine advanced stage hybrids were evaluated in 10 yield trials at 60/75/90 days at Jalandhar, Modipuram and Patna and 38 promising hybrids were selected. In preliminary yield trials, 24 promising hybrids namely J/8-76, J/8-85, J/8-90, J/8-91, J/8-116, J/8-119, J/8-120 and J/8-128 (Jalandhar), MS/8-88, MS/8-1565, MS/10-885, MS/10-927 MS/10-940, MS/10-966, MS/10-1529, MS/10-2206, MP/6-39 and MCIP/9-12 (Modipuram), PS/9-9, PS/9-16, PS/9-18, PS/9-23, PS/9-28 and PS/9-38 (Patna) were selected from 64 hybrids evaluated. In confirmatory yield trials, 12 promising hybrids namely J/7-5, J/7-15, J/7-21, J/7-24, J/7-37, J/7-61 and J/6-182 (Jalandhar), MS/9-723, MS/9-1083 and MS/9-2196 (Modipuram), PS/8-8 and PS/8-31 (Patna) were selected from 19 hybrids evaluated. In final yield trial two advanced hybrids namely MS/8-1148 (Modipuram) and PS/07-7 (Patna) were selected from the 6 hybrids evaluated.

Proposal for introduction of advanced stage hybrids in AICRP

Based on consistent performance during last three years, four advanced stage hybrids namely J/6-182 (Jalandhar), MS/8-1148, MS/8-1565 (Modipuram), PS/7-7 (Patna) are being proposed for introduction in AICRP for multi-location testing (Table 3, 4, 5 and 6).

J/6-182 (CP 3125 x MS/82-797): The hybrid J/6-182 gave 3.5% and 8.5% higher total yield over control K. Khyati at 60 and 75 days harvests, respectively (Table 3). Tuber dry matter of J/6-182 (17.4%) is significantly better than K. Khyati (15.0%). It possesses white, ovoid tubers with shallow eyes and cream flesh colour (Fig. 6).

MS/8-1148 (K. Surya x CP3125): The hybrid produced 31%, 4% and 7% higher total tuber yield than K. Bahar, K. Pukhraj and K Sadabahar, respectively at 90 days (Table 4). MS/8-1148 produces attractive light yellow, ovoid tubers with shallow eyes and yellow flesh colour (Fig. 6). It possesses moderate tuber dry matter (17%), good keeping quality and moderate resistance (AUDPC 445) to late blight than K. Bahar (AUDPC 794) under Modipuram conditions.

Table 3. Performance of advanced hybrid J/2-14 being proposed in AICRP from Jalandhar

Genotype	Total tuber yield t/ha							
	2011-12		2012-13		2013-2014		Mean	
	60 days	75 days	60 days	75 days	60 days	75 days	60 days	75 days
J/6-182	30.40	41.50	28.60	37.30	30.70	40.20	29.90	39.70
K. Pukhraj	27.90	36.70	27.90	34.90	28.00	37.90	27.90	36.50
K. Khyati	29.10	36.70	28.70	35.2 0	28.80	38.00	28.90	36.60
CD (0.05)	2.430	3.61	2.18	2.02	1.85	3.05		

Table 4. Performance of advanced hybrid MS/8-1148 being proposed in AICRP from Modipuram

Genotype	Total tuber yield t/ha							
	2011-12		2012-13		2013-2014		Mean	
	75 days	90 days	75 days	90 days	75 days	90 days	75 days	90 days
MS/8-1148	33.64	41.72	38.83	54.04	33.56	47.76	35.34	47.84
K. Bahar	22.77	27.93	31.51	44.54	30.61	37.50	28.30	36.66
K. Pukhraj	33.01	37.96	39.80	47.33	39.39	52.32	37.40	45.87
K. Sadabahar	31.46	40.36	34.44	46.46	34.45	47.49	33.45	44.77
CD (0.05)	2.07	3.85	1.75	2.02	1.32	1.51		

Table 5. Performance of advanced hybrid MS/8-1565 being proposed in AICRP from Modipuram

Genotype	Total tuber yield t/ha				Mean	
	2012-13		2013-14			
	75 days	90 days	75 days	90 days	75 days	90 days
MS/8-1565	38.00	43.48	35.60	42.13	36.80	42.81
K. Arun	30.93	46.93	31.91	48.51	31.42	47.72
K. Lalima	28.92	37.31	32.50	41.96	30.71	39.64
K. Sindhuri	23.72	35.58	28.55	37.06	26.14	36.32
K.Bahar	31.30	40.63	32.28	35.56	31.79	38.10
CD (0.05)	1.96	1.78	0.93	1.91		

Table 6. Performance of PS/7-7 being initiated in AICRP from Patna

Genotype	Total tuber yield t/ha						
	2011-12	2012-13		2013-14		Mean	
	75 days	75 days	90 days	75 days	90 days	75 days	90 days
PS/7-7	23.68	28.67	34.82	22.93	35.25	25.09	35.04
K. Arun	23.15	28.58	34.41	24.62	35.99	25.45	35.20
K. Lalima	22.12	27.98	33.58	21.40	32.96	23.83	33.27
CD (0.05)	1.48	2.75	3.48	1.06	1.09	-	
CV (%)	4.06	5.92	6.07	3.02	2.07	-	

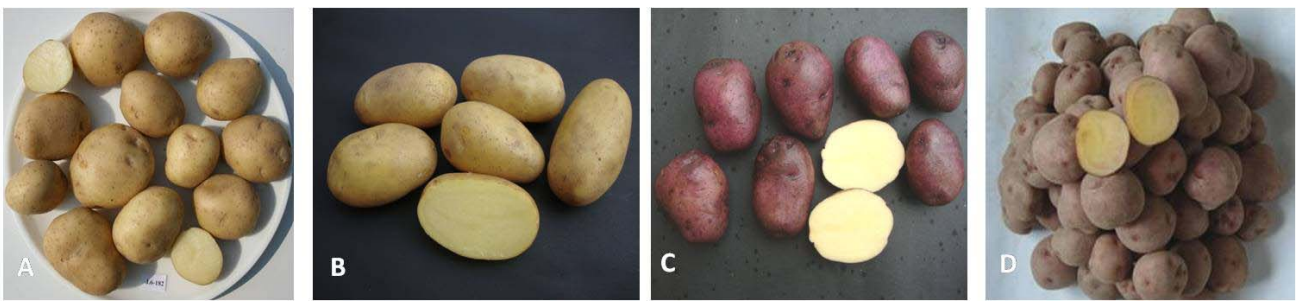


Fig. 6. Tubers of J/6-182 (A), MS/8-1148 (B), MS/8-1565 (C) and PS/7-7 (D) proposed for AICRP

MS/8-1565 (MS/89-1095 x CP3290): The hybrid MS/8-1565 is suitable for specialty sector and produced 17%, 20%, 41% and 16% higher total tuber yield than K Arun, K Lalima, K Sindhuri and K. Bahar, respectively at 75 days. The hybrid showed advantage of 7%, 18% and 12% higher total tuber yield than K Lalima, K Sindhuri and K. Bahar, respectively at 90 days (Table 5). It produces attractive purple, ovoid tubers with shallow eyes and yellow flesh colour (Fig. 6). MS/8-1565 possesses moderate tuber dry matter (18%), good keeping quality and moderate resistance (AUDPC 445) to late blight than K. Bahar (AUDPC 794) under Modipuram conditions.

PS/7-7 (K. Arun x Desiree): The hybrid produced 5% higher total tuber yield than K. Lalima at 75 and 90 days (Table 6). PS/7-7 produces red, round tuber with medium eyes and yellow flesh colour (Fig. 6). It possesses 18.7% dry matter, medium dormancy with good keeping quality and moderate resistance to late blight under Patna conditions.

Advanced hybrid introduced in AICRP

Based on superior performance during 2010-2013, the hybrid MS/7-645 (K. Anand x K. Chipsona-3) was approved by Institute Research Council 2013 and introduced into AICRP. It produced 24%, 11% and 14% higher total tuber yield than K. Bahar, K. Pukhraj and K Sadabahar, respectively at 90 days. It produces light yellow, ovoid tubers with shallow eyes and light yellow flesh colour(Fig. 7). MS/7-645 possesses 16% tuber dry matter, good keeping quality and field resistance to late blight.

Registration of potato varieties with PPV & FRA, New Delhi

Thirteen Indian potato varieties were registered with authority in "extent variety" category, while DUS characterization of 2 new potato varieties K. Gaurav & K. Garima (for morphological traits) was undertaken at Jalandhar and Modipuram locations.

Release of new red skin potato variety

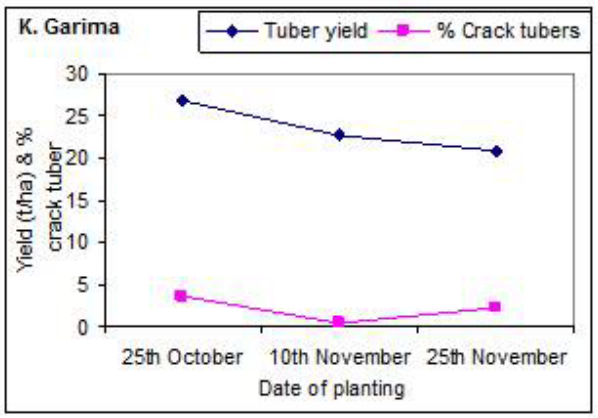
The red skin advanced hybrid 2001P-55 was recommended for release for indo-gangetic plains in 31st group meeting of AICRP (Potato) held during 20-22 September-2013 at Patna. The hybrid has been named as Kufri Lalit. It possess moderate tuber dry matter, good keeping quality and is field resistant to late blight. It produces light red, round tubers with medium deep eyes and light yellow flesh colour (Fig. 8).

Screening of CIP-CPRI clones for drought tolerance

Five CIP-CPRI advanced clones were evaluated at Jodhpur (Rajasthan) for drought tolerance. Genotype CP4175/397006.18 achieved consistently highest Drought Tolerance Index (DTI) during both the crop seasons. This hybrid was found promising based upon its overall yield performance, drought tolerance ability, superior keeping quality and organoleptic traits.

Fig.7. MS/7-645: Leaf (A), Inflorescence (B), tubers (C) and sprout (D)

Fig.8.Tubers of new red skin potato variety KufriLalit



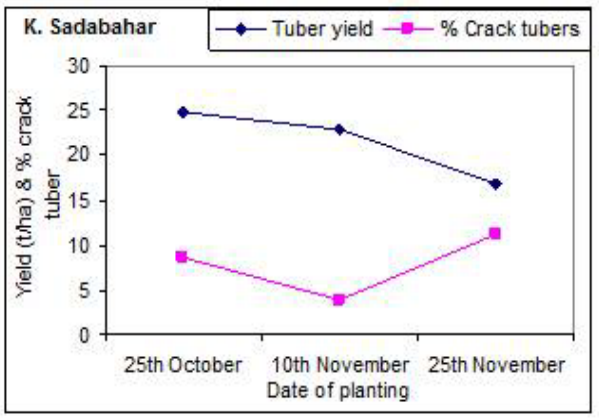


Fig. 9 and 10: Performance of K. Garima and K. Sadabahar at different dates of planting

Optimization of date of planting at Modipuram

The date of planting was optimized in K. Sadabahar and K. Garima. Tuber yield reduction was consistent with delay in planting in K. Garima (8.4-15.3%) and K. Sadabahar (8.1-25.9%) with respective dates (Fig. 9 and 10). Planting of K. Sadabahar may be delayed by 10th November as the variety recorded comparable productivity while planted at 25th October (24.8 t/ha) and 10th November (22.8 t/ha). K. Garima had drastic yield reduction between 25th October (26.8 t/ha) and 10th November (22.7 t/ha), but afterward decrease was insignificant on 25th November (20.8 t/ha). Minimum tuber crack were observed with delay in planting on 10th November in K. Sadabahar (3.8%) and K. Garima (0.4%).

Optimization of crop geometry of K.Sadabahar at Modipuram

The crop geometry of K. Sadabahr was estimated under flood irrigation for maximum tuber yields. Graded tuber number and yield exhibited increasing trend with widening of rows and K. Sadabahar recorded maximum marketable tuber number (2,95,833 tubers/ha) and yield (34.2 t/ha) with row spacing of 72 cm (28.5 inches). Increase in plant population improved graded tuber number and productivity and K. Sadabahar had optimum marketable tuber number (2,88,173 tubers/ha) and yield (28.9 t/ha) with 100% plant population i.e. plant to plant spacing of 16.5 cm (6.5 inches).

Optimization of crop geometry of K. Garima at Modipuram

The crop geometry of K. Garima was optimized under flood irrigation for maximum tuber yields. Graded tuber number and yield was comparable with 60 and 66 cm row spacing and these parameter declined sharply with wider spacing of 72 cm. K. Garima had maximum marketable tuber number (3,40,000 tubers/ha) and yield (32.3 t/ha) with row spacing of 60 cm (24 inches). Increase in plant population from 80 to 100% improved graded tuber number and productivity and K. Garima had optimum marketable tuber number (3,02,037 tubers/ha) and yield (30.1 t/ha) with 100% plant population i.e. plant to plant spacing of 20 cm (8 inches).

Standardization of N, P and K requirement of K. Lalit at Patna

Maximum yield (28.57 t/ha) was recorded in treatment N_{150} $K_{100}P_{60}$, hence, this treatment may be economically viable for cultivation of K. Lalit in Bihar.

Evaluation of advanced stage hybrids for late blight resistance

At Kufri: Twenty-seven advanced hybrids were evaluated for resistance to late blight in field under natural epiyphytotic conditions at Kufri. Only four hybrids viz., MP/4-816, MS/8-1463, MS/8-1565 and MCIP/9-12 had moderate resistance to late blight.

At Modipuram: Among 48 advanced hybrids evaluated for late blight resistance, five hybrid viz., MS/9-723 (AUDPC 39), MS/10-239 (44), MS/10-924 (98), MS/10-966 (67), and MS/10-1214 (104) had moderate resistance compared to K. Bahar (AUDPC 794; Fig. 11).

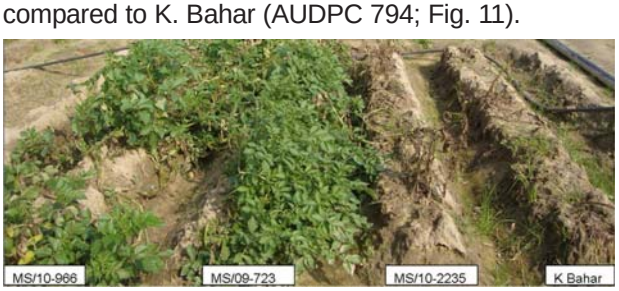


Fig.11. MS/09-723 and MS/10-966 showing resistance to late blight

Project 2. Breeding for processing and export quality

Hybridization and seedling stage

A total of 92,458 TPS of 41 crosses were produced and were subsequently sown in nursery bed for seedling rising. At harvest, 1045 clones were selected from the 20,060 seedlings transplanted.

Initial clonal stages

A total of 582 clones in initial clonal stages (F_1C_1, F_1C_2 and F_1C_3) were evaluatedat 90 days and 394 clones were retained based on tuber and processing attributes. In F_1C_4 stage, 10 hybrids namely MP/9-3, MP/9-21, MP/9-22, MP/9-28, MP/9-36, MP/9-45, MP/9-73, MP/9-85, MP/9-86 and MP/9-91 were selected based on tuber yield, tuber and processing attributes.

Advanced clonal stages

Fifteen hybrids along with six control varieties were evaluated at 75 and 90 days and on the basis of total tuber yield, tuber characters, processing grade yield, dry matter and chip/French fries colour, seven hybrids namely MP/7-214, MP/8-57, MP/8-172, MP/8-1622, MP/8-1900 (for chips) and MP/8-62, MP/8-329 (for French fry) were selected.

Promising hybrids identified

Based on processing grade, total tuber yield, tuber dry matter and desirable chip/French fry colour score, five superior advanced hybrids were identified.

MP/6-39 (MP/97-644 x K. Pukhraj): MP/6-39 produced 30% (42.68 t/ha) higher total tuber yield over best control K. Chipsona-1 (32.89 t/ha) at 90 days. MP/6-39 possessed moderate tuber dry matter content (18.4%) than 20% in K. Chipsona-1 (Table 7 and 8). Therefore it was evaluated in table potato trial during 2013-14 and it produced 33% and 4% higher tuber yield than K. Bahar and K. Garima, respectively at 90 days. It produces attractive light yellow, ovoid tubers with shallow eyes and light yellow flesh colour (Fig. 12). MP/6-39 possesses moderate tuber dry matter (19%) than K. Bahar (18 %) at 90 days and good keeping quality. It showed slight resistance (AUDPC 350) to late blight than K. Bahar (AUDPC 794) at Modipuram.

MP/6-595 (MP/97-644 x MP/92-35): MP/6-595 is an early maturing hybrid with acceptable chip colour and high tuber dry matter (24.16%) than Atlantic (19.65%) (Table 7 and 8). It produced 5.60% higher processing grade (29.05 t/ha) and 9.38% higher total tuber yield (33.58 t/ha) than Atlantic (27.51 t/ha; 30.70 t/ha) at 90 days. The hybrid produces white, round tubers with medium-deep eyes and white flesh colour (Fig. 12).

MP/8-62 (CP1371 x MP/99-406): MP/8-62(Table 7 and 8) produced 17.93% higher processing grade (29.59 t/ha) and 10.70% higher total tuber yield (33.04 t/ha) than K. Frysona (25.09 t/ha; 29.85 t/ha) at 90 days. It possesses high tuber dry matter (24.69%) and desirable fry colour (3.25) than K. Frysona (20.95% dry matter; 3.40 fry colour). The hybrid produces light yellow oblong tuber with shallow eyes and cream flesh colour and it is suitable for French fries (Fig. 12).

Table 7. Yield performance of superior processing hybrids at Modipuram (90 days)

Genotypes	Processing grade yield t/ha			French fries grade yield t/ha			Total tuber yield t/ha		
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean
MP/6-39	32.40	39.26	35.83	0.00	0.00	0.00	41.30	44.05	42.68
MP/6-595	27.30	30.80	29.05	0.00	0.00	0.00	32.20	34.97	33.58
MP/8-62	32.48	26.70	29.59	12.88	11.60	12.24	36.52	29.57	33.04
MP/8-1900	27.49	30.80	29.15	0.00	0.00	0.00	32.38	34.97	33.67
K. Chipsona-1	24.42	28.30	26.36	7.05	11.16	9.10	31.88	33.90	32.89
K. Chipsona-3	26.43	25.73	26.08	0.00	0.00	0.00	30.87	33.00	31.94
K. Chipsona-4	28.30	27.13	27.72	0.00	0.00	0.00	31.97	30.40	31.19
K. Frysona	24.34	25.83	25.09	10.88	12.42	11.65	30.50	29.20	29.85
Atlantic	28.81	26.20	27.51	0.00	0.00	0.00	31.26	30.13	30.70
C.D. 5%	2.12	2.05		1.28	0.87		2.01	2.56	

Table 8. Processing attributes of superior processing hybrids at Modipuram

Genotypes	Chip/French fry colour			Tuber dry matter (%)		
	2012-13	2013-14	Mean	2012-13	2013-14	Mean
MP/6-39	5.90	3.70	4.80	18.01	18.79	18.40
MP/6-595	4.50	2.20	3.35	24.00	24.32	24.16
MP/8-62	4.50	2.00	3.25	26.75	22.62	24.69
MP/8-1900	3.90	1.30	2.60	24.15	22.28	23.22
K. Chipsona-1	4.80	3.00	3.90	20.29	19.95	20.12
K. Chipsona-3	4.30	3.20	3.75	23.39	21.42	22.41
K. Chipsona-4	6.30	3.30	4.80	21.53	24.76	23.15
K. Frysona	5.00	1.80	3.40	21.32	20.57	20.95
Atlantic	5.30	2.80	4.05	20.40	18.90	19.65

Fig. 12. Promising processing advanced hybrids identified: MP/6-39 (A),MP/8-62 (B), MP/6-595 (C), MP/8-1900 (D) and MP/9-91(E)

MP/8-1900 (MP/98-172 x QB/A-92-4): MP/8-1900 (Table 7 and 8) produced 5.12% higher processing grade (29.15 t/ha) and 2.40% higher total tuber yield (33.67 t/ha) than the best control K. Chipsona-1 (26.36 t/ha; 32.89 t/ha) at 90 days. It possesses high tuber dry matter (23.22%) and desirable chip colour (2.6) than K. Chipsona-1 (dry matter 20.12% and chip colour: 3.9). The hybrid produces light yellow, oval tuber with shallow eyes and cream flesh colour and it is suitable for chips (Fig. 12).

MP/9-91 (CP 1717 x MP/99-406): The hybrid with early maturity, excellent chip colour (up to 2), high tuber dry matter (24%), low glucose content (1.2 mg/100g fresh tuber weight) produced 19% (22.91 t/ha) and 22% (30.21 t/ha) higher tuber yield at 75 and 90 days respectively over best control, Atlantic (19.18 t/ha at 75 days and 24.65 t/ha at 90 days). The hybrid produces white, round tuber with medium-deep eyes and white flesh colour (Fig. 12)

Evaluation of advanced hybrids at Burdwan

Among the four processing hybrids tested at 90 days, MP/7-214 (47 t/ha), MP/4-816 (38 t/ha) for chips and MP/4-578 (39 t/ha) for French Fries produced higher processing and total tuber yield, desirable processing attributes than the control varieties K. Chipsona-3, K. Frysona and Atlantic.

Advanced hybrid introduced in AICRP

Based on superior performance, MP/4-816 (MP/97-847 x MP/92-35) was introduced in AICRP for multi-location testing (Fig. 13). It produces light yellow, ovoid tubers with shallow eyes and yellow flesh and is suitable for chips. It produced 9% higher processing grade (39.1 t/ha) and total tuber yield (44.2 t/ha) than the best control K. Chipsona-3 (32.5 and 40.7 t/ha). It out yielded the exotic variety Atlantic by 29% (30.3 t/ha)

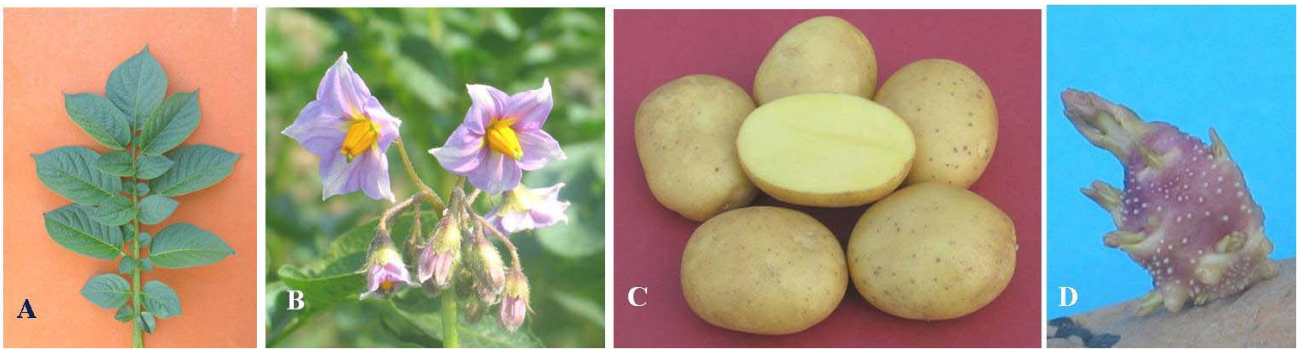


Fig.13. MP/4-816- Leaf (A), Inflorescence (B), tubers (C) and sprout (D)

and 40% (34.2 t/ha) for processing grade and total tuber yield, respectively. It possesses 20% tuber dry matter and chip colour in acceptable range (2.6) than Atlantic (2.4) and K. Chipsona-3 (3.1). It possesses moderate resistance to late blight.

Performance of advanced hybrids at Jalandhar

Among 11 hybrids evaluated at 90 days, MP/6-39 gave the maximum tuber yield (36.7 t/ha) followed by MP/4-816 (36.2 t/ha) and MP/6-86 (34.9 t/ha). Processing grade tuber yield was maximum in MP/6-39 (30.8 t/ha) followed by MP/4-816 (26.3 t/ha) and MP/4-578 (24.6 t/ha). All the genotypes recorded more than 20% dry matter except MP/6-39 and MP/6-86 (19%). Acceptable colour fries were made from all the genotypes, whereas acceptable chips could be made from all the genotypes at harvest except K. Chipsona-4, MP/4-578 and MP/6-86. Reducing sugar contents at harvest were higher in all genotypes (154-546 mg/100 g fresh weight).

Evaluation of advanced CIP clones for processing purpose at Bisuali (Uttar Pradesh)

Advanced CIP clone MCIP/9-11 was evaluated at Bisuali at 90 days for processing purposes. It produced significantly high processing grade tuber yield (28.62 t/ha) than all the control varieties (20.19 t/ha of Atlantic to 22.65 t/ha of K. Chipsona 1). MCIP/9-11 produced significantly high marketable (32.37 t/ha) and total tuber yield (33.35 t/ha) than all the control varieties except K Chipsona-1 (29.90 t/ha and 31.98 t/.ha). It possessed less tuber dry matter (17.77%) than the controls (19.40% of K. Chipsona 1 to 20.40% of Atlantic). A chip made from MCIP/9-11 was graded score of 3.8, which was more than the acceptable limit of 3.

Processing quality of genotypes during storage at 10-12°C at Jalandhar

Processing quality of 13 genotypes were evaluated during storage at 10-12°C with CIPC. Mean dry matter (%) remained higher than 20% during storage up to 180 days and ranged between 20.54 (MP/6-39) to 23.56% (Atlantic). Initial reducing sugar (RS) contents were acceptable (<150 mg/100 g frwt) for chips in all genotypes except MP/4-578 (249.2 mg/100 g frwt) and MP/2-204 (228.2 mg/100 g frwt) which were however acceptable for French fries. Reducing sugar contents increased during storage with mean maximum contents in MP/06-86 (363 mg/100 g frwt). Chip colour at 0 day was unacceptable in MP/4-578 and MP/2-204 which was related well to the higher reducing sugar contents. Chip colour in general deteriorated at 60 days of storage probably due to reduced temperatures (<10°C). Chip colour improved on 90 days of storage, when the potatoes were shifted to BOD incubator maintained at 12°C. Fry colour however, remained acceptable throughout storage up to 150 days in all genotypes.

Evaluation of genotypes under ambient storage at Jalandhar

Advanced hybrids MP/4-578 and MP/4-816 were evaluated for storability and processing quality at room temperature, in heaps with and without CIPC treatment. Total weight losses in CIPC treated potatoes were minimum in MP/4-578 (7.0%) followed by MP/4-816 (7.8%) as compared to control cultivars (9.4-19.4%). In heap untreated (control) these two hybrids also recorded reduced losses at par with best control cultivars. At room temperature (untreated) total weight loss was in MP/4-578 (28%) and MP/4-816 (40%) remained at par with K. Chipsona-1 and K. Chipsona-3.

Dry matter content remained higher than 20%, reducing sugar content was low (<160 mg/100g fresh weight) in all genotypes except MP/4-578 (249 mg/100 g fresh weight) at 0 day of storage. Fry colour was acceptable in all the genotypes at 0 day of storage. Reducing sugar contents decreased during storage in heaps up to 90 days in CIPC treated tubers and chip colour improved and became highly acceptable even in MP/4-578. These genotypes can be used in French fry industry and cottage level chip industry up to 90 days of storage in heap with CIPC treatment. The chip/fry colour improved only up to 60 days of storage at room temperature after which it deteriorated due to high increase in sugar levels (reducing and sucrose).

Identification of early maturing processing parental lines at Shimla

One hundred and fifty-eight accessions reported to be early maturing with desirable processing traits were evaluated in the glass house at Kufri for foliage maturity on 1-5 scale (1 = very early; 5 = very late). These accessions were evaluated for processing traits (chip colour& dry matter content) and 17 genotypes viz., CPNos. 1717, 1917, 1940, 3647, 4075, 4085, 4086, 4087, 4093, 4095, 4117, 4257, 4297, 4302, 4307, 4308 and Lady Rosetta were identified (Fig. 14) having early maturity with acceptable processing attributes (Chip colour <3 and Dry matter content > 20%).

Fig. 14. Chip colour in selected early maturing processing accessions along with controls

Performance of advanced processing hybrids at Shimla

Among the eleven processing hybrids evaluated, MP/8-328 (22.68 t/ha) and MP/8-1467 (18.50 t/ha) out yielded the best control, K.Chipsona-3 (15.46 t/ha).

Optimization of crop geometry of K. Himsona at Modipuram

K. Himsona recorded highest and statistically superior processing grade (34.0 t/ha) and total tuber yield (45.3 t/ha) with row spacing of 66 cm (26 inches) in comparison to 60 cm and 72 cm. Row spacing of 66 cm had 75.0% chip grade yield in comparison to 72 cm (73.8%) and 60 cm (72.1%). Plant spacing did not affect chip grade and total tuber yields and chip grade tuber percentage improved with wider spacing and maximum was observed with 35 cm spacing (75.0%) which was comparable to 30 cm (74.0%). Quality parameters i.e. specific gravity and chip colour were not significantly influenced by various treatments of row and plant spacing.

Optimizing nutrient requirement of MP/4-578 at Modipuram

Nitrogen (270 kg/ha) recorded French fry grade (26.1 t/ha) and total tuber yield (39.8 t/ha) in MP/4-578, which were significantly better over lower doses and comparable to highest N level. Phosphorous (40 kg/ha) had French fry grade (27.8 t/ha) and total tuber yield (39.3 t/ha), which were comparable to all higher P_2O_5 levels. Potassium (75 kg/ha) attained maximum and statistically superior French fry grade (30.2 t/ha) and total tuber yield (41.3 t/ha) over higher K_2O levels. Quality parameters ie specific gravity/fry colour score were not influenced by application of graded N, P_2O_5 and K_2O doses.

Project 3. Development of TPS population

Production of TPS

Produced 272 gm TPS of 20 crosses for population development and 15 gm TPS of 10 crosses involving 10 females and 5 male lines for parental line development at Patna. Produced 0.4 kg of TPS hybrid population 92-PT-27 for distribution and sale purposes.

Evaluation of TPS populations as seedling transplanted crop

At Patna: Among the 5 (red x red) populations evaluated at 90 DAP, population PS8/96-1 (OP) gave significantly higher total tuber yield and 46% red tuber than the control 92-PT-27, while among 14 white x white crosses five populations viz. PT/13-7 (7.73 t/ha), PT/13-8 (7.35 t/ha) (Trial 1), PT/13-16 (11.09 t/ha), PT/

Fig.15.Development of TPS population: Berries (A), TPS (B), Seedling raising (C), Seedling transplant (D), Seedling tubers (E)

13-20 (11.60 t/ha) & PT/13-21 (12.88 t/ha) (Trial 2) gave significantly higher total tuber yield than the control 92-PT-27 (6.32 & 8.04 (t/ha)) in trial 1 and trial 2 respectively (Fig. 15).

At Shillong: Among the 28 TPS populations evaluated during summer season, MST-67 X D-150 (11.32 t/ha), MST-7 X D-150 (12.11 t/ha) and PS5/67-2 X PS8/97-1 (11.44 t/ha) gave significantly higher tuber yield than the control 92PT-27 (9.83 t/ha) as transplanted crop under rainfed conditions.

Evaluation of seedling tubers (F_1C_1)

At Patna: Among the 9 red skinned populations, none of the populations yielded significantly higher than the control K. Kanchan (13.87 t/ha) and 92-PT-27 (10.79 t/ha) at 90 days harvest, however among the 10 white skinned populations evaluated at 90 days, three populations viz., PT/12-2 (7.25 t/ha), PT/12-8 (6.99 t/ha) and PT/12-10 (7.10 t/ha) gave significantly higher total tuber yield than the control 92-PT-27 (5.76 t/ha).

At Shillong: Among the 34 TPS populations evaluated, TPS population PS6/37-1 x D-150 (16.69 t/ha) gave significantly higher tuber yield than control 92PT-27 (13.05 t/ha) under rainfed conditions.

Programme 3: Biotechnology in potato improvement

Whole genome sequence analysis of *Ralstonia solanacearum*, causes bacterial wilt in potato

Whole genome of the four bacterial strains was sequenced using massive-parallel pyrosequencing technology (Roche 454 GS FLX Titanium). Shotgun sequencing runs yielded ~ 2.88 million reads (> 500 bp) of which nearly 99.5% reads were of high quality with genome coverage from 18X (RS48) to 76X (RS75). The filtration of raw reads was performed using Prinseqlite. pl program with optimized parameters. High quality reads were mapped to the publically available reference genomes, GMI1000 (RS25 & RS48), Po82 (RS2) and PSI07 (RS75) using gsMapper with optimized mapping parameters. The total protein coding regions, rRNA and tRNA coding, regulatory and pathogenicity genes including the Type III secretary genes were obtained from the consensus using the .gff (from public database) file with the help of in-house perl scripts. The presence of repetitive elements were analyzed using MISA and was observed that nearly 90% of the elements were of di or tri and 7.3% hexanucleotide repeats. The chromosomes carried higher portion (60-70%) of the repeat elements than megaplsmids in all the four strains.

Whole genome sequence analysis of *Fusarium sambucinum*, causes dry rot in potato

Whole genome sequence of *F. sambucinum* (strain F-4) was done using the Roche-454 pyrosequencing platform. Shotgun sequencing yielded high quality 2,396,357 reads amounting to 919,493,539 bases and 18-fold coverage of its estimated 50 Mb genome. The GS De Novo Assembler (version 2.5.3) yielded 697 contigs (over 500 bp) with an average contig size of 54.1 kb, N50 contig size of 109 Kb and largest contig of 1044.1 kb. The BLASTp analysis of all the predicted genes against the non redundant protein sequences revealed that nearly 80% of the genes had similarity hit with Gibberellazeae (*F. graminearum*), 6% with *F. oxysporum* and remaining with several other organisms. Total rRNA coding genes were predicted to be 64 (34 genes on original strand and 30 genes on reverse complemented strand) using RNAmmer 1.2 Server for eukaryotic genome. Total tRNA coding genes were predicted to be 594 (274 on original strand and 320 on reverse complemented strand) using FindtRNA Version 1.0. There are only few genes characterized so far in *F. sambucinum* like MSF super-family genes which were confirmed in the sequence (Fig. 16).

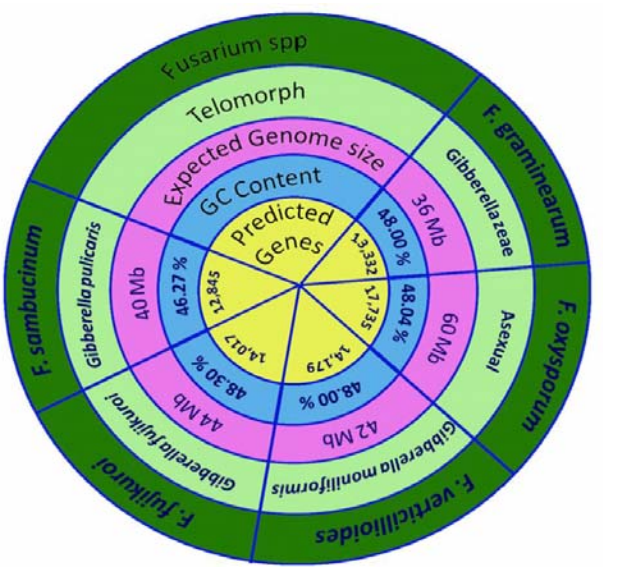


Fig. 16. A comparison of the genome size, predicted genes, and total G-C contents among the Fusarium species

Development of transgenic potato expressing HSP gene for heat stress tolerance

Isolated 476 bp 17.6 Kda HSP gene from the heat stress tolerant variety K. Surya and the gene was put under the control of constitutive cauliflower mosaic virus (CaMV) 35S promoter. The binary vector cassette pBI121 was used for *Agrobacterium*-mediated-transformation of internodal stem explants of K. Bahar. Seventeen microplants out of 100 explants were regenerated on MS medium containing 50µg/ml of kanamycin. Preliminary screening of 16 microplants by using PCR with 35S::17.6Kda HSP primer combination showed 2 Kb fragment size that revealed integration of the 17.6 Kda HSP gene cassette in the K. Bahar. Further NptII gene specific primer revealed

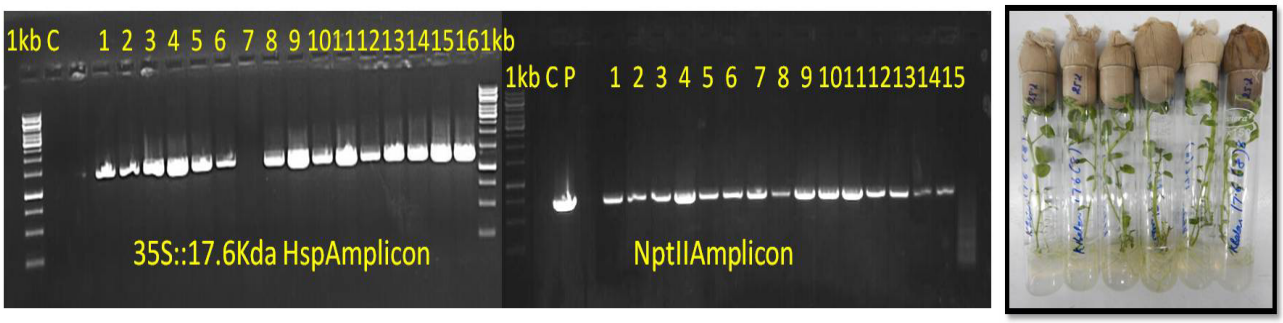


Fig. 17. PCR confirming the integration of 35S promoter: 17.6 KDa HSP gene and NptII gene co-integration in K.Bahar putative transformants.

that 697 bp fragment size and confirmed that co-integration of nptii gene in the K. Bahar transformants (Fig. 17).

Development of F-BOX gene-mediated transgenics potato for late blight resistance

A 1.36 Kb fragment of F-Box gene was isolated from late blight resistant *Solanum spegazinii* for its role in defense against disease. *In silico* analysis of 1.36 kb gene sequence revealed that, 4 predicted ligand binding sites, which codes Lysine, valine, tryptopan, serine. Isolated 1.36 kb F-Box gene was put under the control of 35S constitutive promoter and Arabidopsis translation enhancer gene for hyper expression. The binary vector cassette pRI101AN was used for *Agrobacterium*-mediated-transformation of internodal stem explants of K. Jyoti. Twelve microplants out of 100 explants were regenerated on MS regeneration medium containing 50µg/ml of kanamycin (Fig. 18).

Transcriptional expression analysis for potato tuberisation in response to heat stress

Gene expression analysis from the leaf tissues of K. Surya (heat stress tolerant) vis-a-vis K. Chandramukhi (heat stress sensitive) grown under controlled conditions was done. K. Surya showed stolon swelling on 17th day of heat stress followed by tuber formation on 21st day at 24^{0}C night temperature, whereas KCM did not tuberize(Fig. 19). However, both the cultivars tuberized at 20^{0}C night temperature. Gene expression analysis was executed using cDNA microarrays-based approach. The data was analyzed individually using the Log2 base transformed normalized expression values as input data. On 14th day of stress 4906 genes in K. Surya showed more than two fold change as compared to K. Chandramukhi at 24^{0}C, whereas on 21st day 2500 genes in K. Surya exhibited greater than two fold change than that of K Chandramukhi at 24^{0}C. Further, Venn diagram was used to identify genes expressing exclusively in K.

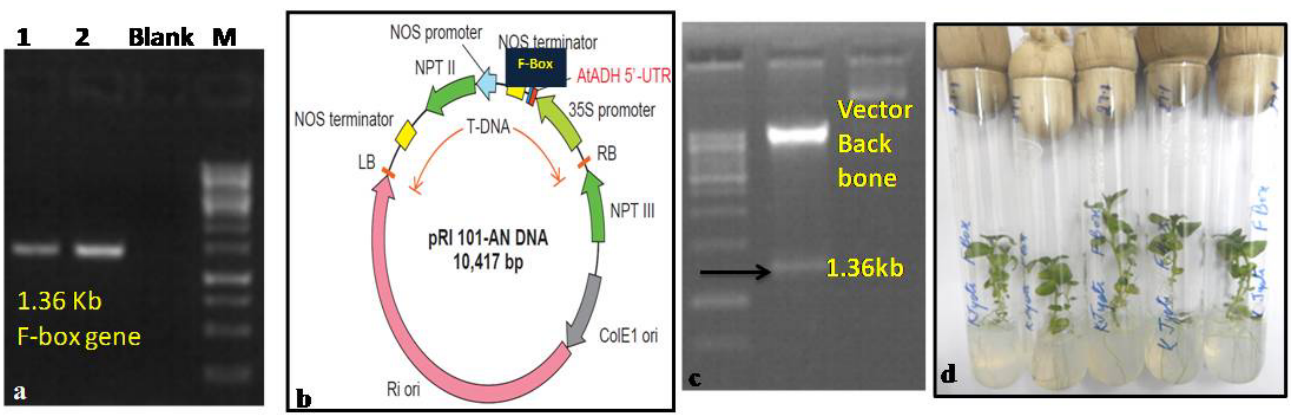


Fig.18. PCR confirming the integration of 1.36 Kb of F-Box gene(a), Binary vector(b), restriction digestion of pRI101 Binary vector with XbaI-SacI(c) and transgenic plants(d)

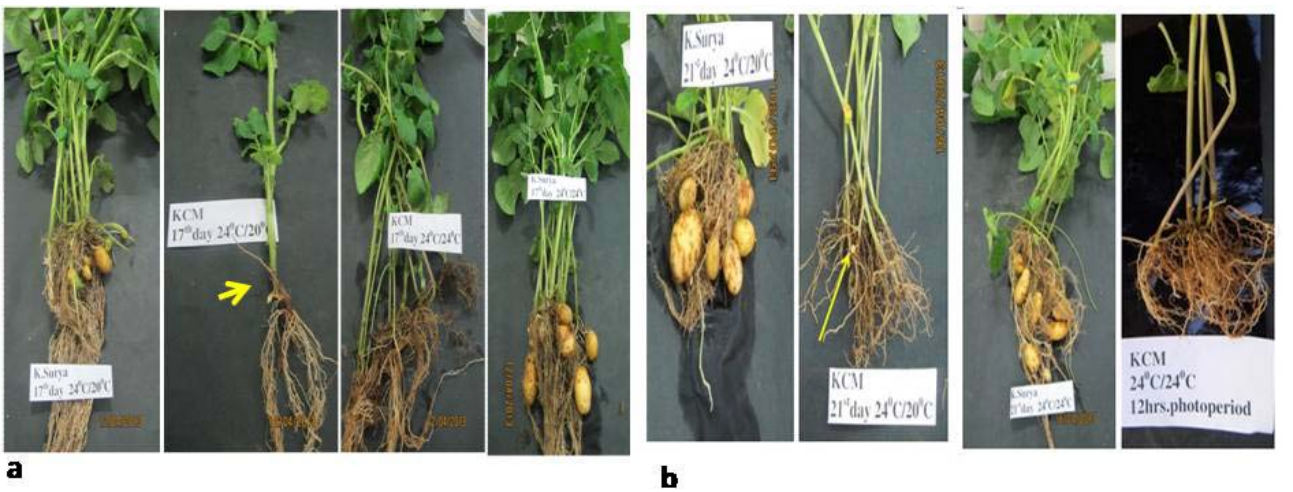


Fig 19: Tuberization of K. Chandramukhiand K. Surya on (a) 17th day of heat stress (20°/24°C and 24°/24° C day/night temp.) and (b) 21st day of heat stress (24°/ 24°C and 24°/24° C day/night temp.)

Surya during stress. Thus, 2432 genes upregulated in K. Surya on 14th day and 448 genes on 21st day (Fig. 20).

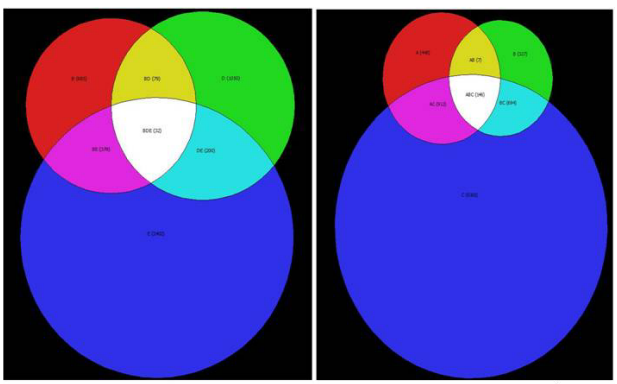


Fig. 20. Venn diagrams showing differentially expressed transcripts expression in K. Surya and K. Chandramukhi on 14th and 21st day of heat stress

Isolation, cloning and characterization of late blight resistance gene analogues (RGAs) from wild *Solanum* species of potato

Disease resistance genes (R-genes) including potato late blight share a high level of similarity at the DNA or protein levels in different plant species. This property of R-genes has been successfully employed to isolate putative resistance gene analogues (RGAs) using a simple PCR-based approach from new plant genomes. Gene-specific primers were successfully employed to amplify nucleotide binding site (NBS) domain of RGAs from late blight resistant wild *Solanum* species. Seventeen non-redundant sequences of RGAs were identified with un-interrupted open reading frames (ORFs) and high amino acid sequence homologies to various nucleotide binding site leucine-rich repeat (NBS-LRR) proteins from GenBank database. The RGAs consisted of three

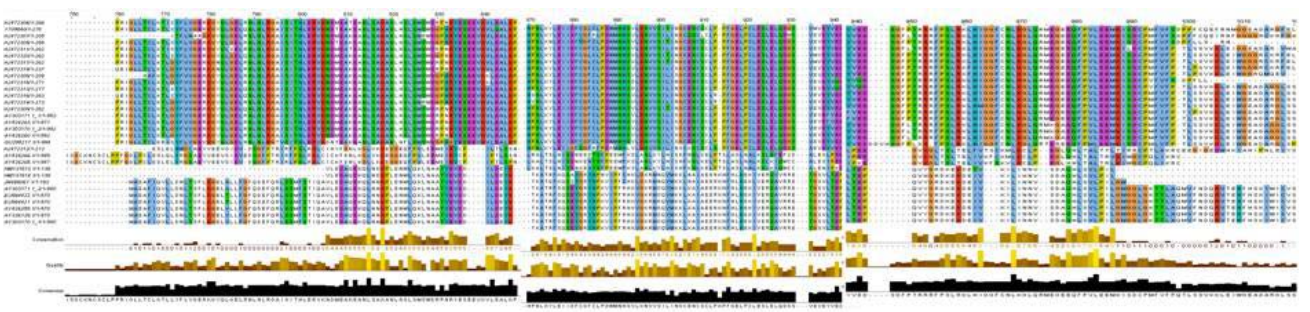


Fig. 21. Multiple sequence alignment of deduced amino acid sequences of the late blight resistance protein genes of the 17 RGAs and 15 reference sequences using ClustalW2.

major conserved domains such as *i*) Leucine-rich repeat containing protein, *ii*) disease resistance protein (TIN-NBS-LRR class), and *iii*) L-domain like structures. Alignment of the DNA (protein) sequence (Fig. 21) and phylogenetic analysis (Fig. 22) of the NBS domain revealed 17 RGAs belong to the disease resistance protein.

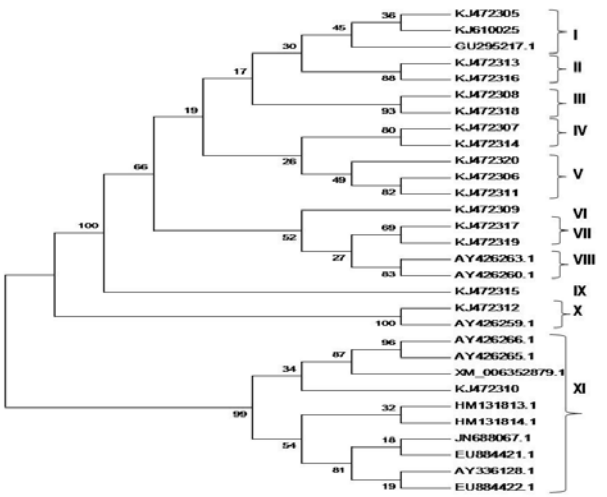


Fig. 22. A cluster analysis based on the Neighbor-Joining coefficient showing relationship between the peptide sequences of the 17 new resistance gene analogues (RGAs) and the reference sequences of late blight resistance protein genes from the NCBI database.

Somatic hybridization in potato improvement

Interspecific symmetric somatic hybridization was carried out between the androgenic dihaploid (C-13) of common potato *S. tuberosum* (2*n*=4*x*=48; 4 EBN) and the wild *Solanum* species. In total, 960 protoplast isolation and electrofusions of C-13 (+) *S. cardiophyllum*, C-13 (+) *S. microdontum*, C-13 (+) *S. iopetalum*, C-13 (+) *S. verrucosum*, C-13 (+) *S. lesteri*, and C-13 (+) *S. stoloniferum* were done. Fused protoplasts were cultured in VKM liquid medium supplemented with glucose at 20ºC in the dark. Following the cell wall development, regenerating cells were cultured on $MS_{13}K$ solid medium at 20ºC under a 16-h photoperiod for the calli development.

Development of new potato somatic hybrids of *S. tuberosum* (+) *S. cardiophyllum*

Fifty microshoots of putative somatic hybrids between *Solanum tuberosum* dihaploid C-13 (+) *S. cardiophyllum* (PI341233) were regenerated from calli and multiplied on MS medium for molecular characterization. From these, only 26 regenerants were able to regenerate into plantlets. Of the 26 regenerants of putative somatic hybrids (Crd-1 to Crd-26), four regenerants namely Crd-6, Crd-10, Crd-16 and Crd-23 were confirmed as true somatic hybrids possessing parent specific bands of C-13 and *S. cardiophyllum*(Fig. 23).

Analysis of plastome and chondriome genome types in potato somatic hybrids

Cytoplasm types of the potato somatic hybrids of *S. tuberosum* (+) *S. etuberosum* were analysed using chloroplast (cp) and mitochondrial (mt) organelle genomes-specific markers. Out of 29 markers (15

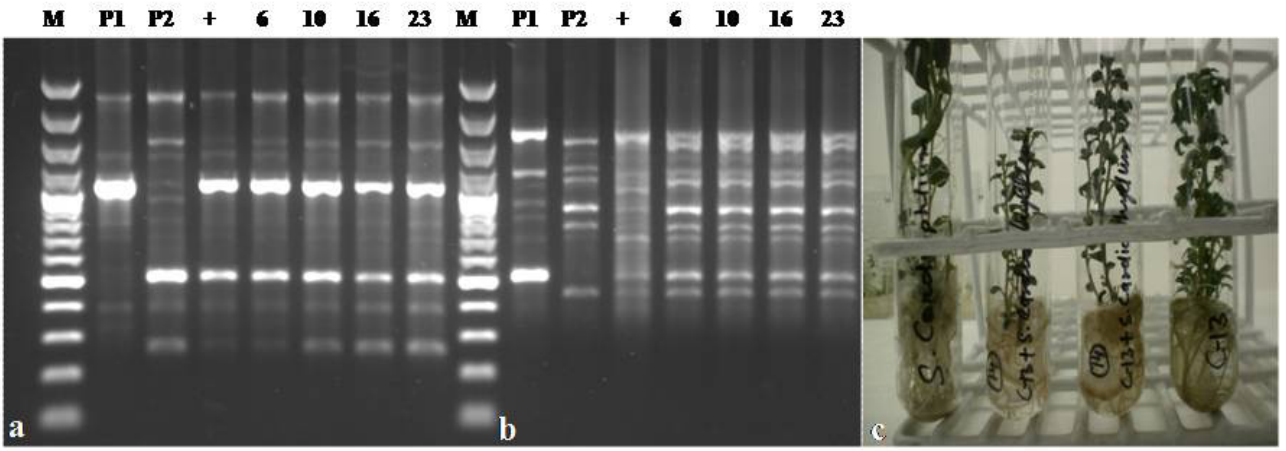


Fig. 23. RAPD profiles of somatic hybrids of C-13 (+) S. cardiophyllum using primers (a) OPAC-06, (b) OPAC-09, (c) in vitro regenerants. P1=C-13, P2= S. cardiophyllum, (+) = DNA mix of parents, and # 6, #10, #16 and #23 denotes interspecific potato somatic hybrids.

cpDNA and 14 mtDNA) amplified in the 26 genotypes, 5 cpDNA (H3, NTCP4, NTCP8, NTCP9 and ALC1/ ALC3) and 13 mtDNA markers showed polymorphism. The study revealed that the somatic hybrids had diverse cytoplasm types consisted predominantly of T-, W-, and C-, with a few A-and S-types chloroplast; and α, β and γ types mitochondrial genomes. Somatic hybridization has unique potential to widen the cytoplasm types of the cultivated gene pools from wild species through introgression by breeding methods (Fig. 24).

13 (+) *S. pinnatisectum* for late blight resistance genes has been performed by using microarrays platform. Study revealed the sets of differentially expressed transcripts with significant differences in the gene expression levels at pre- and post-inoculation stages of *P. infestans* infections. A t-test analysis (at Pd"0.01), identified a total of 2100 genes that were statistically significant. Out of 2100 genes only 320 genes were up-regulated e" 2-fold at 72 h of post-inoculation stage (Fig. 25).

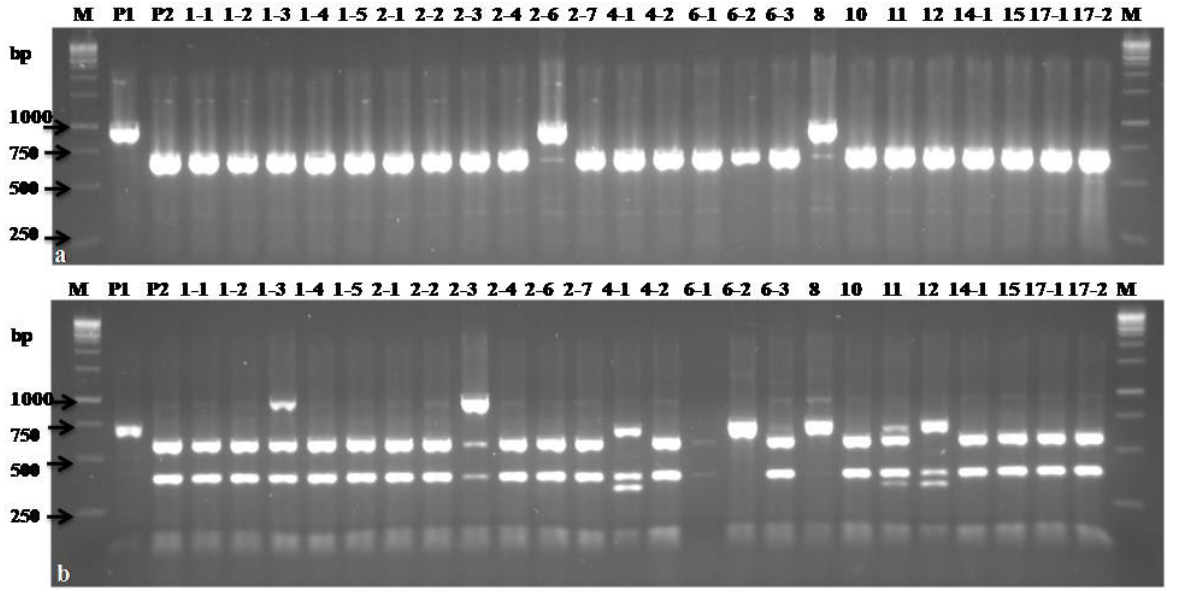


Fig. 24. Cytoplasmic genome profiles of the potato somatic hybrids using polymorphic cpDNA marker a) H3, and mtDNA marker b) rpS14/cob.

Gene expression analysis of potato somatic hybrids using microarrays

Gene expression profiles of interspecific potato somatic hybrids of dihaploid *Solanum tuberosum* C-

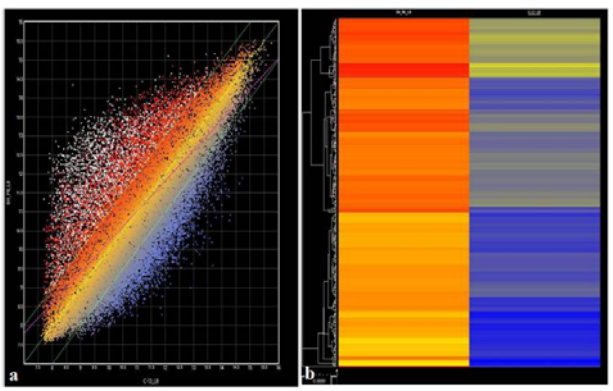


Fig. 25: Scatter plot (a) and Heat map (b) of differentially expressed gene in potato somatic hybrids

Evaluation in seedling stage of crosses involving indigenous varieties and new potato somatic hybrids

In total 4071 true potato seeds of 32 crosses developed using somatic hybrids (SH) as parent in combination with indigenous potato varieties were used for seedling raising and from these, 887 seedlings of 20 crosses were transplanted in the field. At harvest 181 clones of eight crosses namely K. Garima × SH mix pollen, K. Jyoti × SH mix pollen, K. Sadabahar × SH mix pollen, P-8 × K. Jyoti, K. Gaurav × P-2, K. Gaurav × P-3, K. Gaurav × P-7 and K. Gaurav × P-8 were retained (Fig. 26).

Fig. 26. Somatic hybrid seedlings stage

Evaluation of somatic hybrids under field conditions

Ten somatic hybrids of C-13 + *S. pinnatisectum* along with one parent C-13 and six control varieties were evaluated at 90 days and 105 days. None of the somatic hybrid and parent C13 produced tuber yield higher or at par with control varieties. All the somatic hybrids produced significantly higher total tuber yield at 90 and 105 days than the parent C-13 (4.71 and 9.58 t/ha at 90 and 105 days respectively).

Gene expression analysis for nitrogen use efficiency in potato cultivars

Gene expression analysis by real-time PCR (RT-PCR) was executed for nitrogen use efficiency (NUE) among the indigenous cultivars for ammonium transporter (AMT), asparagine synthetase (AS), nitrate reductase (NR) and nitrite reductase (NIR) genes in leaf tissue of K. Gaurav, K. Pukhraj & K. Jyoti cultivars under N and without-N conditions. Results showed that gene expression of AMT and NIR in leaf tissues particularly under without N successfully explained the variation of N efficiency in three cultivars K. Gaurav (highest N efficient), K. Pukhraj and K. Jyoti (least N efficient) which differ widely in N efficiency (Fig. 27).

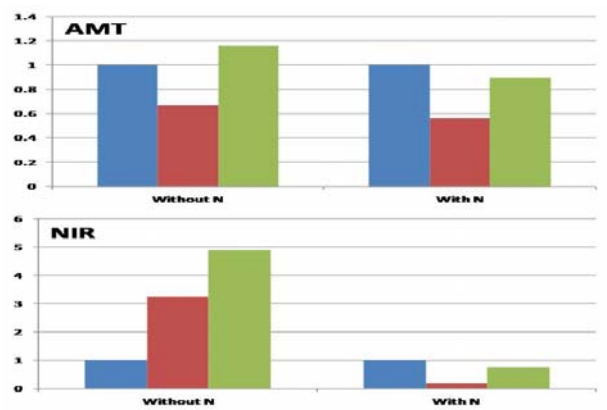


Fig. 27.RT-PCR analysis for AMT and NIR gene in potato

PCR amplification of genes controlling NUE in potato

A total of 19 primer pairs were designed for the genes controlling nitrogen metabolism such as N-uptake and transporter genes (ammonium transporter), N-assimilation genes (nitrate reductase, nitrite reductase and glutamine synthetase), and amino acid metabolism (asparaginessynthetase), of other crop species from the NCBI and the potato genome sequence database. These primers were amplified in the potato cultivars *viz.,* K. Gaurav (highest N efficient), K. Pukhraj and K. Jyoti (least N efficient) for cloning and sequence analysis of the genes (Fig. 28).

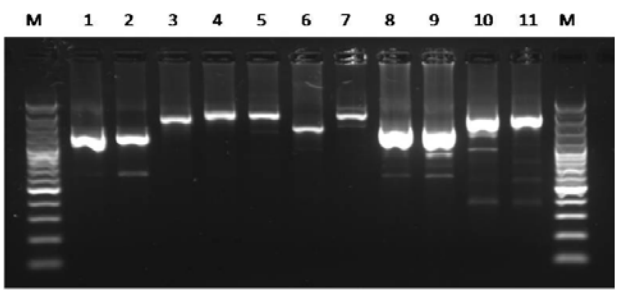


Fig. 28. PCR amplification of different full genes sequences controlling nitrogen metabolism pathways in potato cultivars

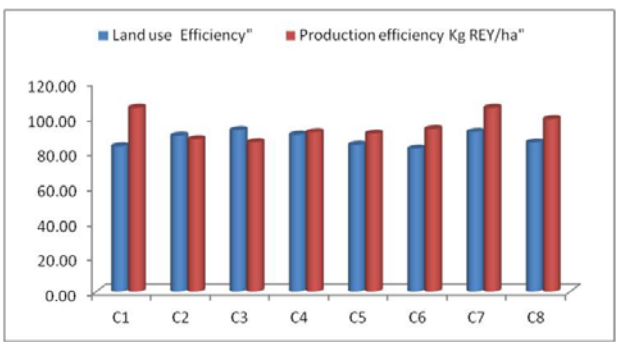
Division of Crop Production

Programme 1: Resource Management and Information Technology in Potato based Cropping Systems

Resource management strategies for potato based cropping systems

Evaluation of potato based cropping systems for resource use efficiency, production potential, soil sustainability and profitability in south Bihar condition

Temporal and spatial crop intensification is enevitable to agument the growing requirement of food in the country like India with burgeoning population. With flexible timing and duration potato becomes very compatible with several crops to fit into multiple sequential and intercropping systems. Therefore, the present investigation was started with potato crop at Patna during 2012-13 to evaluate and select productive, resource use efficient and remunerative potato based crop sequences. The experiment included eight cropping systems with early and main potato crops, rice (puddle and SRI), maize, oat, gram, cowpea, *moong,* sponge guard, bottle gourd and green manuring (*Sesbania*) (Fig. 1)



*C1-early potato (Kufri Surya)-potato (Kufri Khyati)-sponge gaurd-green manuring (*Sesbania*), C2-early potato (Kufri Surya)-gram-maize-cowpea, C3- early potato (Kufri Ashoka)-oat-cowpea- maize, C4- early potato (Kufri Ashoka)-wheat-*moong*-maize, C5- potato-*moong*-rice (SRI), C6- potato-cowpea-rice (puddled), C7- potato-bottle gourd-rice (puddled) and C8- potato-onion –rice (SRI)*

Fig. 1. Land use efficiency (%) and production use efficiency (REY, kg/ha) under different crop sequences at CPRS, Patna

In the first year the average yield of early planted crop of Kufri Surya was in the range of 19.01 t/ha to 20.29 t/ha, while that of Kufri Ashoka was 25.74 t/ha to 27.62 t/ha. In the main season potato crop, the average yield of Kufri Khyati and Kufri Pukhraj was in the range of 36.0-36.2 t/ha. Among the eight cropping systems, potato-bottle gourd–rice was the most productive system in terms of rice equivalent yield (REY) followed by early potato-potato-sponge gourd-green manuring, potato-onion-rice and early potato – wheat-green gram-maize. It was interesting to note that in the above mentioned four cropping systems, the systems having three crops/year out yielded cropping systems having four crops/cycle. The B:C ratio was similar in trend.

The yield of potato crop during second year was significantly influenced by cropping systems and preceding crop. In the early planted potato crop, the tuber yield was significantly higher in the system where green manuring was practiced followed by the system where leguminous crop was taken. In the main season potato crop the tuber yield was significantly higher where rice was transplanted using SRI (system for rice intensification) method without puddling. The tuber yield was reduced in the potato crop taken after puddled rice. This may be due to increase in the bulk density of the plots where puddling was done.

Early potato- oats- cowpea-maize cropping system used the land for more periods in a year having land use efficiency of 92.6% and was followed by potato-bottle gourd- rice and potato-green gram- maize-cowpea cropping system (Fig. 2). Potato-bottle gourd rice and potato-potato-sponge gourd-green manuring cropping systems registered the highest production efficiency (PE) of 105 Kg in terms of rice equivalent yield (REY) per ha/day. This system was closely followed by potato-onion- rice and potato-green gram-rice-system with corresponding values of 98.86 and 93.18 Kg REY/ha/day. Potato-potato-sponge gourd-green manuring cropping system registered the highest production efficiency (Rs.785.82/ha/day) in monetary

Fig. 2. View of a field experiment

term. This system was closely followed by potato-bottle gourd-rice and potato-onion-rice system with corresponding values of Rs.778.94 /ha /day and Rs. 597.640/ha/day, respectively.

Yield gap study of potato production under farmers' practice vis-à-vis recommended practices: In a field experiment at Shimla, to study the yield gap between the potato yields obtained with farmers' practices and with recommended practices it was observed that adoption of improved production technologies led to 60% higher total tuber yield and 67.3% higher market grade (medium + large) tuber yield over control. The results also indicated that application of recommended fertilizers alone over control contributed maximum to yield increase (48% and 54.6% higher total and marketable tuber yields, respectively). Results confirmed the last year's findings and further indicated that adoption of production technology developed by CPRI for hill farmers can increase the productivity by over 40%, *i.e.* the current gap between farmers' and research farm yields.

Evaluation of potato based cropping systems in Meghalaya hills: In a field experiment to evaluate potato based cropping systems during summer and autumn season at Shillong in Meghalaya hills, the highest potato equivalent yield (57.8 t/ha) was recorded under potato-cabbage crop sequence followed by potato- radish crop sequence (45.9 t/ha). In another field experiment to evaluate intercroppings the highest economic yield was recorded under radish sole followed by potato + radish (1:1). Among the different treatments potato + radish intercropping (1:1) recorded the highest land equivalent ratio (1.20) and potato equivalent yield (33.0 t/ha). The planting of radish as an intercrop with potato in the ratio of 1:1 was more remunerative for intercropping system for the hilly region of Meghalaya.

Nutrient economy in cropping systems through use of residual fertility of potato: In order to utilise the residual fertility of potato crop and economise nutrient application in succeeding crop an experiment was conducted at Shillong during summer and autumn season of 2013. Among the different cropping systems potato-cabbage recorded the highest potato equivalent yield (53.34 t/ha) and application of 50% recommended dose of fertilizers (RDF) along with 50% N through FYM to potato and 100% RDF to subsequent crop recorded highest productivity over the treatments either 100% RDF to potato and subsequent crop or 100% RDF to potato and 50% RDF to subsequent crop but were at par with rest of the treatments.

Integrated resource management studies in *kharif* potato

Field experiments were conducted during 2013 at Agricultural Research Station, Madenur, Hassan, Karnataka to develop production technology for *Kharif* potato in plateau areas.

Identification of suitable potato hybrid (combined resistance to late blight and viruses) for *kharif* crop in plateau region: Three late blight resistant hybrids (LBY-15, LBY-17 and SM/92-338) were evaluated against three controls (Kufri Shailja, Kufri Himalini and Kufri Jyoti). Only one hybrid LBY-15 was able to have impressive resistance to late blight as it had only 14% disease spread at 75 days. Kufri Himalini (19.0 t/ha) performed best among all the hybrids/varieties and recorded 15.1% more tuber productivity over second best popular variety of the region Kufri Jyoti (16.4 t/ha).

Identification of suitable processing hybrid for *kharif* crop in plateau region: All the four hybrids (MP/04-578, MP/04-816, MP/05-180 & MP/06-39) evaluated had significantly lower process grade (24.0-79.5%) and total tuber productivity (22.2-74.9%) in comparison to potential controls (Kufri Chipsona-4, Kufri Jyoti and Atlantic).

Optimization of fertilizer requirement for *kharif* potato in Karnataka: Increasing manure application from 10 to 20 t/ha marginally improved the tuber yields and highest mean tuber yield was observed in cv. Kufri Himalini (31.1 t/ha) followed by Kufri Surya (29.9 t/ha) and Kufri Jyoti (28.7 t/ha). Kufri Himalini (38.4 t/ha) recorded the highest yield at 20 t FYM + 75% NPK level, while Kufri Surya had maximum productivity (32.5 t/ha) at 10 t FYM + 75% NPK and Kufri Jyoti attained highest tuber yield (31.8 t/ha) at 10 t FYM + 100% NPK level.

Intercropping studies in *kharif* potato: Inter-cropping with red gram and French bean was not remunerative. In case of maize, only cv. Kufri Himalini exhibited advantage of intercropping (11.7-12.7%) in terms of potato equivalent yields (32.5-32.8 t/ha) over sole potato crop (29.1 t/ha).

Front line demonstrations: In Hassan district, variety Kufri Surya performed better over popular variety Kufri Jyoti and recorded distinctly higher mean tuber numbers (11.6%) and yield (17.4%). It gave higher total tuber yield (16.7- 44.9 t/ha) and tuber numbers (256-551 000/ha) at eight locations in comparison to Kufri Jyoti. Whereas, at two locations *viz.* Halasinahalli, Salgame, Hassan and Ramagowda,

Hirehalli, Halebeedu, Belur Taluk, variety Kufri Jyoti produced higher yield than Kufri Surya.

Management of late blight: First appearance of late blight on potato crop planted on 20.05.13 was recorded on 12.07.2013. The results revealed that all the treatments were effective and recorded significantly low intensity of late blight compared to untreated control. Among the treatments, prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% followed by fenamidon + mancozeb @ 0.3% and one more spray with mancozeb recorded significantly lower disease intensity (28.75%) and higher tuber yield (43.04 t/ha). It was followed by treatments with cymoxanil, mancozeb alone, dimethomorph and azoxystrobin.

Varietal screening for late blight: Among the six varieties planted on 27.05.2013 for testing for their reaction towards late blight, Kufri Girdhari recorded the minimum incidence of late blight (23.75%) followed by Kufri Shailaja (33.75%), Kufri Himalini (36.25%), Kufri Surya (37.5%), Kufri Pukhraj (42.5%) and Kufri Jyoti (62.5%). However, Kufri Surya was the top yielder (39.17 t/ha) followed by Kufri Himalini (32.72 t/ha).

Survey for potato diseases and pests in *kharif* potato areas of Karnataka: In a survey conducted in *Kharif* potato areas of Karnataka in Hassan and Chickmagalur districts from 22.7.2013 to 27.7.2013 the intensity of late blight varied from 0 to 100% and it was nil in Arkalgud and Chikmagalore taluks. Maximum incidence of bacterial wilt (30%) was recorded in Avvarahalli of Hassan taluk. Virus incidence ranged from 2 to 75%. The pests recorded were aphids (5 to 600 per 100 compound leaves), mites (2 to 25%), green leaf hoppers, leaf eating caterpillars (*Spodoptera*, *Helicoverpa*, Hairy caterpillar), stem borers and *Epilachna* beetle.

The survey revealed that there was no incidence of late blight and aphids in Shantiveri and Lingadahalli areas and aphids were recorded only in Tarikere road which is located in the plains. Hence, further studies are necessary for evaluating seed degeneration and the incidence and build up of aphids during the cropping season for exploring the possibilities of seed production in Chikmagalore district.

Monitoring of major diseases and pests of *kharif* potato: Incidence of late blight was first observed on 12.07.2013 and the peak incidence was at 85 days after planting in the crop planted at Madenur, Hassan. Intensity of late blight was found high in Kufri Jyoti in untreated control plots (88.3%) followed by Kufri Himalini (60%) and Kufri Surya (53.3). Incidence of viruses (4.3 to 21.7%), aphids (13.7 to 63.7 per 100 compound leaves), white flies (9 to 32.7 per 100 compound leaves) and leaf hoppers (8.3 to 25.3) were also recorded in standing crop. Whereas, at harvest, common scab and late blight and insect pests *viz.,* potato tuber moth and white grubs were recorded.

Integrated weed management in potato

Weeds have a wide range of ecological amplitude and are in continuous state of change. Frequent interaction between crop production factors with soil and climatic parameters in the cultivated lands results in varying appearance and abundance of weeds. Thus there is a need to understand the phenomenon of weed dynamics and to develop integrated approaches for the management of weeds in potato crop.

In a field experiment at Modipuram during second year (2013-14) in potato cv. Kufri Sadabahar, bentazone (1.5 Kg/ha) as post emergence, reduced total weed dry weight by 92.1 % over weedy check and was comparable to weed free conditions This resulted into at par yields (29.5 t/ha) with weed free conditions (30.3 t/ha). Another molecule sulfosulfuron as post emergence proved very effective against weeds specifically monocots and no phytotoxicity was observed in cv. Kufri Garima. Sulfosulfuron (25 g/ha) decreased total weed dry weight by 75 % over weedy check and this was similar to weed free treatments in total tuber productivity (28.3 t/ha).

Field experiment at Gwalior with bentazone (1.5 Kg/ ha) as post emergence herbicide reduced total weed dry weight by 91.3 % over weedy check and was at par with weed free plots in total tuber productivity (32.0 t/ ha). In another field experiment, sulfosulfuron as post emergence herbicide, was quite effective in controlling weeds particularly monocots, but *cv*. Kufri Jyoti exhibited phytotoxic symptoms, which resulted into yield reduction. Therefore, its time of application is needed to be adjusted. Sulfosulfuron (25 g/ha) though, declined total weed dry weight by 93.1 % over weedy check and this was comparable to weed free plots the total tuber productivity (20.8 t/ha) also reduced significantly in comparison to weed free treatments (27.5 t ha^{-1}).

Development and use of decision support systems/tools

In the era of information technology Expert Systems are needed to provide information readily on crop management practices. The developed decision support system (DSS) on potato weed management "Potato Weed Manager" hosted on institute's website. (http://cpri.ernet.in)

Programme 2: Nutrients and water management in potato

Nutrients and water are the two crop production inputs which are becoming scarce and precious every day. Besides, serious environmental concerns have made it essential to manage these two key inputs most efficiently. To mitigate the declining factor productivity besides maintaining the land and environmental quality both these resources need their judicious use. Utilization of varietal and genetic variability with respect to their efficiency to nutrients and water use along with development of strong management strategies very specific to location and pocket are the main aims of this programme. Important objectives of this programme include exploitation of genetic variability of germplasm for better efficiency of resources, developing nutrient and water management strategy for major potato growing locale based on site specific nutrient management and geo-reference mapping of resources and use of micro-irrigation techniques through drip and fertigation for improving efficiency.

Optimizing N requirement using chlorophyll content index: Time and quantity of N fertilizer to be top dressed is the most important issue in nutrient management of potato crop. Owing to its bearing not only on productivity, efficiency and cost of cultivation but also due to large scale environmental concerns. Efforts are being made worldwide to fine tune the timing and quantity of N fertilizer application so that there is minimum loss to the environment without compromising on productivity level. In this line attempts were made to manage nitrogen on real time basis based on chlorophyll content of potato crop leaves. The experiments were conducted at Shimla, Patna and Gwalior.

At Shimla, in continuation of last year this year also experiment was planned to establish relationship between relative chlorophyll index (RCI) and amount of N to be top dressed. RCI was worked out at every 2-3 days interval by comparing CCI (Chlorophyll content index) value of treatment plot with over fertilized plot using hand held chlorophyll meter (Model CCM 200 of Optiscience make). Results indicated that CCI increased after application of second dose of N and declined thereafter continuously till last observation in the over fertilize plot. All the treatments produced statistically similar tuber yields (14.4-14.8 t/ha). Results from both the year indicated that after basal application of N in potato, crop should be applied at 90% RCI @ 25kg/ha (Fig.3).

At Patna three varieties namely, Kufri Khyati, Kufri Jyoti and Kufri Pukhraj were evaluated for fine tuning of N top dressing with the help of chlorophyll contents index using SPAD reading. Treatments included one over fertilized reference plot (150% of recommended N), one recommended fertilized plot and other plots having top dressing at variable rate based on SPAD reading in comparison to over fertilized reference plot. In treatment plots after basal application of 50% of recommended N and 20% N application at earthing up, 10 or 20% of recommended N was top dressed at 80 or 90% of SPAD value as compared to over fertilized plot. (Fig. 4).

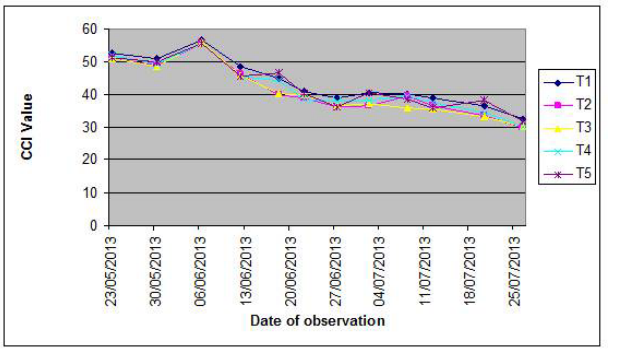
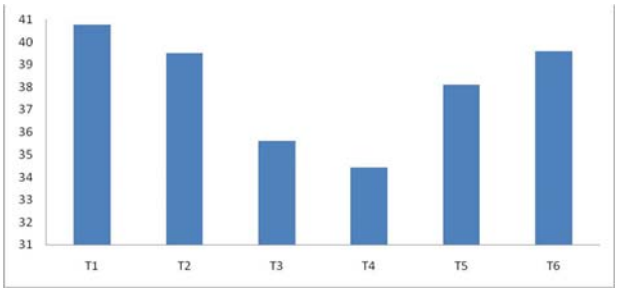


Fig. 3. Change in CCI values with time under different treatmentsT1-control (150 kg N at planting and 100 kg at earthing up), T2- 25 kg N at 90% RCI, T3- 50 kg N at 90% RCI, T4- 25 kg N at 95% RCI and T5- 50 kg N at 95% RCIRCI= relative Chlorophyll Index=CCI in a plot/CCI in control X 100

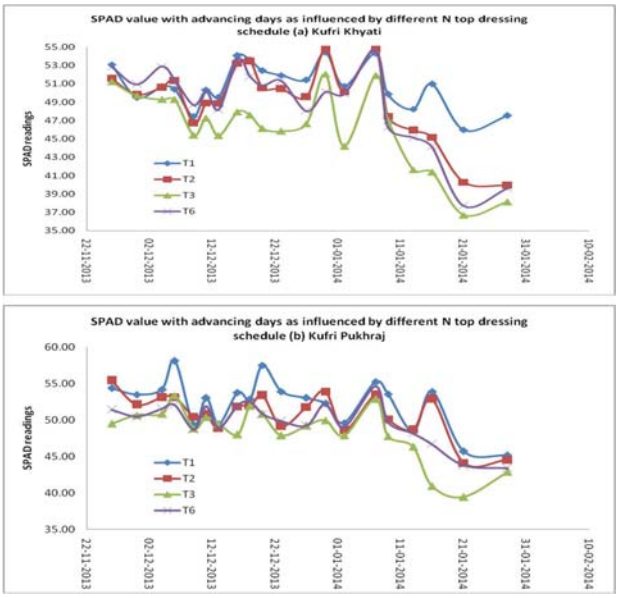
The SPAD value of over fertilized plots in all the three varieties remained the highest almost throughout the season. However, there were fluctuations of the value as and when either N was top dressed or irrigation was given. In general, it tends to decrease with advancing of the season. The treatment where 20% recommended N was applied at 90% of the reference SPAD value gave similar yield as compared to the recommended N level and was significantly better than the treatments where N was top dressed at 80% of the reference SPAD value. The former's yield level was also at par with over fertilized plots. Among varieties Kufri Khyati and Kufri Pukhraj gave better response and yielded significantly better than Kufri Jyoti (Fig. 5). Results indicated that there is possibility to decrease the amount of N to be top dressed by increasing the number of splits and applying N based

on SPAD value in comparison to over fertilized reference plot without compromising on yield.



T_1 : 150% of recommended N half at planting and rest at earthing up; T_2 : Recommended N half at planting and rest at earthing up; T_3: 50% of recommended N at planting, 20% N at earthing up and 10% N at 80% SPAD value of T1; T_4 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 80% SPAD value of T1; T_5 : 50% of recommended N at planting, 20% N at earthing up and 10% N at 90% SPAD value of T1 & T_6 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 90% SPAD value of T1.

Fig. 4. Potato tuber yield (t/ha) as influenced by differential top dressing of N based on SPAD value



T_1 : 150 % of recommended N half at planting and rest at earthing up; T_2 : Recommended N half at planting and rest at earthing up; T_3: 50% of recommended N at planting, 20% N at earthing up and 10% N at 80% SPAD value of T1 & T_6 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 90% SPAD value of T1

Fig. 5. SPAD value with advancing days as influenced by different N top dressing schedule (a) Kufri Khyati and (b) Kufri Pukhraj

Similar experiment was also conducted at Gwalior with two cultivars Kufri Jyoti and Kufri Chandramukhi. Application of 20% of recommended N at 95% of the reference SPAD value proved to be the best as the yield level was similar with that of the recommended N.

Development of site specific nutrient management: With an objective to develop nutrient management strategy very specific to a particular site taking account of both, the intricate soil system and agro climatic condition, a "site specific nutrient management" experiment with over fertilized reference (OFR) and omission plots using variety Kufri Khyati was conducted at Modipuram, Meerut. The maximum yield reduction was observed in N omission plots (19.84 t/ha) as compared to OFR plots. The K omission plots was second to N omission plots with yield reduction of 8.26 t/ha, which was followed by Mg (7.31 t/ha), B (6.01 t/ha) and P (5.01 t/ha). The difference of yield in N omission plots and control plot was only 2.93 t/ha which indicated that the N was the most limiting nutrient element in potato productivity in the region, whereas, S and P appeared to be least limiting as the yield difference in these two element omitted plots showed least yield reduction as compared to OFR.

Geo-referenced mapping of available nutrients and other relevant soil properties: For Geo-referenced mapping of available nutrients soil samples from Agra district of UP and East Khashi Hills district of Meghalaya were collected with simultaneous recording of geographic location using GPS receiver. These samples were analysed for relevant soil properties.

Coating of urea to increase nitrogen use efficiency: Nitrogenous fertilizer happens to be one of the most costly nutrient input and at the same time most mobile nutrient element in soil leading to its loss from the root zone in very short duration. There have been many attempts to increase the efficiency of N fertilizer by increasing the longevity in soil with the help of some amendments. With these objectives experiments were planned at Gwalior and Patna. At Gwalior, highest total tuber yield was recorded with neem coated urea at recommended fertilizer level which was significantly higher over control. Total tuber yield among all other treatments was statistically at par. At Patna, potato tuber yields, neither at recommended N level nor at 75% of recommended N level could be improved significantly by different amendments. However, the yield level at recommended N was found higher as compared to 75% recommended N with all amendments. On

contrary, agronomic efficiency was found higher at 75% of recommended N with different coating materials.

Integrated nutrient management in potato in NEH region: Like last year, the application of 75% recommended dose through fertilizers and remaining recommended dose of N substituted through FYM along with inoculation of Azotobacter and phosphate solubilizing bacteria brought about the significant improvement in plant population, tuber weight and total yield of potato thereby saving 25% fertilizers. In another field experiment, highest tuber yield of potato cultivar Kufri Girdhari (23.7 t/ha) was obtained organically under application of 30 t FYM/ha along with inoculation of biofertilizers (Azotobacter + PSB) which was at par with yield obtain with recommended dose of fertilizers (22.2 t/ha).

Develop/identify nutrient and water efficient potato cultivars/hybrids and characterize nutrient use efficient cultivars

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 genetic stocks and 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. At Jalandhar, trials were conducted for screening nutrient efficient germplasm whereas, for water efficiency screening was done at Modipuram. Field trials for P efficiency with different cultivars was conducted at Shillong and root studies in sand and solution culture was undertaken at Patna.

Confirmatory trial with efficient germplasm J-93-58 and other entries: In the line of previous year's results, germplasm J-93-58 (30.8 t/ha) and J-92-159 (31.4 t/ha) produced significantly higher tuber yield than Kufri Gaurav (27.3 t/ha) at lower dose of N (160 kg/ha). Tuber yield produced by germplasm J-93-58 (30.8 t/ha) and J-92-159 (314 q/ha) at 160 kg N/ha was statistically equal to that produced by Kufri Gaurav (30.2 t/ha) at higher dose of N of 240 kg/ha. In addition to that, germplasm J-93-58, J-92-159 and MS/82-398 having mean tuber yield statistically higher than Kufri Gaurav were also selected for final confirmatory trial to be conducted next year. The germplasm, J-93-98 and J-92-159 appear to be more N efficient than previously identified most N efficient cultivar, Kufri Gaurav based on nitrogen requirement for getting equivalent yield. These two germplasm needed 113 and 100 kg N/ha, respectively to obtain tuber yield of 27.5 t/ha in comparison to 197 kg N/ha required by Kufri Gaurav to produce the same yield.

Another field experiment also confirmed that germplasm J-93-58 has an edge over Kufri Gaurav as this entry produced significantly higher tuber yield than Kufri Gaurav both at 100% and 150% of recommended NPK dose.

Third year replicated trial: Out of five germplasm selected last year were tested at four nitrogen rates under replicated trial with three control varieties, Kufri Gaurav, Kufri Pukhraj and Kufri Jyoti. The mean tuber yields varied between 11.39 and 19.82 t/ha. The three germplasm CP1538, CP1644 and CP1909 having mean tuber yield statistically equal to Kufri Gaurav were selected for confirmatory trial to be conducted next year.

Second year trial: Seven germplasm selected last year were tested under nitrogen deficient and sufficient conditions under plot wise trial with three control varieties, Kufri Gaurav, Kufri Pukhraj and Kufri Jyoti. The mean tuber yields of different hybrids varied between 6.88 and 19.48 t/ha. The two germplasm (CP1987, CP2013) having mean tuber yield more than 16 t/ha have been selected for further testing under replicated trial next year.

First year trial: Fourteen germplasm were tested under nitrogen deficient and sufficient conditions in a single row, 2.4 m long without replication in first year. The tuber yields of different germplasm varied between 2.08 and 9.03 t/ha under N stress (No nitrogen), whereas, mean tuber yields over different rates of N varied between 4.34 and 14.24 t/ha. Nine germplasm (CP2134, CP2123, CP2124, CP2066, CP2110, CP2063, CP2064, CP2065 and CP2132) having mean tuber yield more than 11.7 t/ha were selected for plot wise trial next year.

Screening of hybrid/cultivars for P and water use efficiency

At Shillong, six potato varieties *viz.* Kufri Jyoti, Kufri Giriraj, Kufri Kanchan, Kufri Himalini, Kufri Girdhari and Kufri Megha were evaluated at four phosphate levels (0, 50, 100 and 150 kg P_2O_5/ha) for their P use efficiency. Kufri Girdhari recorded the highest tuber yield at all P levels and appeared the most phosphate efficient among potato cultivars followed by Kufri Giriraj

and Kufri Megha in the acidic soils of NEH region.

At Modipuram, out of 100 genotypes/hybrids evaluated during 5 consecutive years six promising genotypes/ hybrids *viz.* J 93-58, J 92-164, 83-P-142, JN-2207, MS/ 82-279, J 92-167 gave higher potato tuber yield than popular varieties Kufri Bahar and Kufri Pukhraj at all three soil moisture levels (Wet regimes,0.20-0.25 bars; moist regimes, 0.40-0.45 bars and semi-dry regimes, 0.60-0.65 bars), The selected hybrids/genotypes also found promising for higher water use efficiency (WUE).

Root parameters of different cultivars at varying NO_3^- level in solution culture and in sand culture: At Patna different root parameters such as fresh root weight, root length, root surface area and root volume in general increased with increasing NO_3^- level in hydroponics (solution culture studies). Kufri Gaurav and Kufri Pukhraj had highest root length, root volume and surface area at 10 m mol NO_3^- concentration followed by 1 m mol and 0.1 mmol NO_3^- concentration. Whereas, Kufri Jyoti had highest root length and surface area at 1mmol NO_3^- concentration (Fig. 6). In sand culture efficient cultivars like Kufri Khyati, Kufri Gaurav, Kufri Pukhraj and Kufri Lalima had higher root fresh weight, root length and surface area as compared to cultivars like Kufri Kanchan and Kufri Jyoti.

Improving water use efficiency through micro-irrigation

Use of micro-irrigation in high input crop potato is inevitable not only for improving water use efficiency

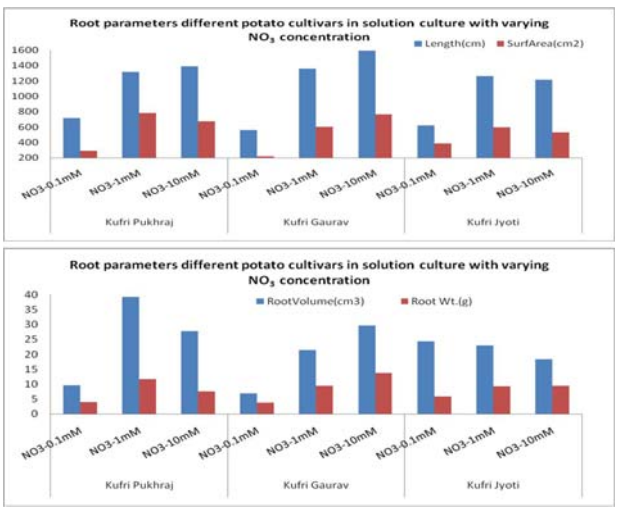


Fig. 6. Root parameters of potato cultivars in solution culture with varying NO_3 concentratiom

but also for improving nutrient efficiency through fertigation. Micro irrigation and mulch based water management experiments were conducted at Shimla and Modipuram with the objectives to conserve soil moisture and improve nutrient and water use efficiency. At Modipuram, fertigation through drip and mulching improved yield as well as nutrient and water use efficiency. The best results were obtained when 75% of recommended NPK was applied as fertigation through drip using liquid fertilizer in eight equal splits after 25% of basal application. This treatment gave the highest yield of 39.0 t/ha which was statistically superior than other fertigation treatment and conventional method of fertilizer application. Among different mulches paddy straw mulch conserved moisture the best and yielded (34.8 t/ha) significantly better over other mulching treatments (black polythene and silver polythene mulch).

In order to establish relation of irrigation quantity with soil texture an experiment was laid out at Modipuram. Irrigation at 2.5 IW:CPE ratio proved to be the best with highest potato tuber yield in all the three type of soil texture (light, slightly medium and medium soil type)

Role of different mulching material and surface conditions on soil moisture conserving, moderating soil temperature and enhancing potato yield: At Shimla, soil moisture contents remained 8-12% higher in poly-mulch condition during drought in comparison to no mulch condition. Black polythene mulch increased surface soil temperature by 1.4-2.7 ºC at 5 cm depth and 1.1 to 1.4 ºC at 10 cm depth compared to bare soil condition. On the other hand silver poly mulch and pine needle mulch reduced soil temperature by 0.5 to 1.0 ºC at 5 cm depth and 0.2 to 0.4 ºC at 10 cm depth and 1.2-2.2 ºC at 5 cm depth and 0.9-1.1 ºC at 10 cm depth, respectively, as compared to no mulch condition. Black poly-mulch showed favorable effect on plant growth parameters in comparison to the silver and no much condition. From the productivity point of view, silver poly mulch proved to be the best, yielding significantly higher over control. On an average the extent of increase in tuber yield was in the order of 31.5, 29.2 and 17.4% under silver poly mulch, pine needle mulch and black poly-mulch, respectively, in comparison to no mulch condition. The soil moisture conservation was better observed in poly mulch plots with 10-12% higher moisture in 0-90 cm soil depth followed by pine needle mulch as compared to control (no mulch).

Programme 3: Nutrient dynamics studies on long term manurial/ fertilizer application and organic farming in potato production

The long-term manurial experiments are required to know the production potential of cropping systems on long term basis and effects of nutrient application scheduling on soil physical, chemical and biological properties as well as on pest complex and quality of produce. A correct appraisal of influence of the cropping system on the dynamics of soil fertility/productivity cannot be made within a short period because of native soil fertility, carry over effect of previous crops, manuring and seasonal variations. Thus a long term experiment with three cropping systems was initiated during 2006-07 with the objective of estimating the effect of organic and inorganic source of nutrient on sustainability of system productivity.

Results from the current year revealed that the mean system productivity was maximum in rice-potato-wheat cropping system (60.0 t/ha) followed by Maize-Potato-Onion (54.2 t/ha) and Groundnut- Potato- *Moong* bean system (48.9 t/ha) (Fig. 7). The treatment receiving inorganic, secondary and micro nutrients application recorded highest and markedly better system productivity in all three cropping systems. Among other treatments, 100% inorganic nutritient application alongwith crop residues incorporation showed comparable productivity in rice-potato-wheat cropping system (69.3 t/ha). Organic nutrition was able to sustain system productivity in Rice-Potato-Wheat as yield decline was marginal (3.1%), whereas, other systems showed drastic yield reduction.

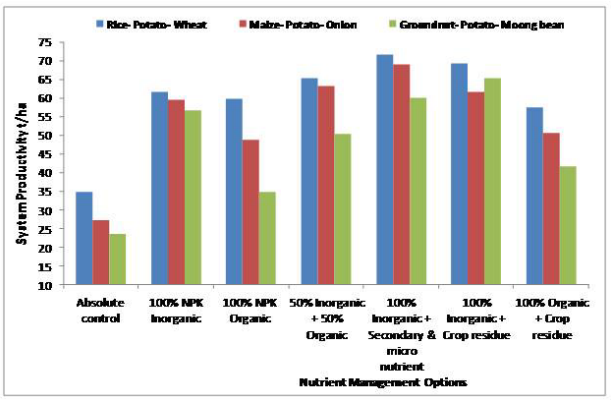


Fig. 7. System productivity of different crop sequences as influenced by various nutrient management options

Potato crop recorded maximum tuber productivity (26.0- 37.0 t/ha) with inorganic and secondary & micro nutrients in all the crop sequences and significant reduction in tuber yields was observed with organic nutrition (15.6- 49.3%) in all three systems. Productivity of Rice, Onion and *Moong* bean was at par in both 100% organic and 100% inorganic source of nutrition; whereas, wheat (46.1%), maize (18.0%) and groundnut (29.4%) had drastic reduction in their respective economic productivity.

Organic farming for potato production

Field study was continuing on fixed plots since 2005-06 with the objective of examining influence of organic source of nutrition on crop productivity consisting five nutrient supply options (Fig. 8). Substitution of inorganic nutrients with vermi-compost significantly declined mean tuber yield and further 100% substitution by vermicompost decreased the yield of the varieties Kufri Anand and Kufri Chipsona-1 by 30.5 and 26.9%, respectively. Yields were comparable in both the varieties in treatments receiving 100% inorganics and 50% inorganic with 50% vermi-compost.

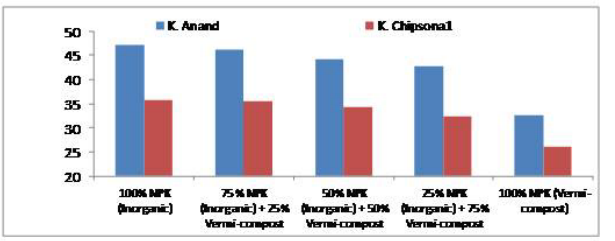


Fig. 8. Effect of organic (vermi-compost) and inorganic nutrient supply on potato productivity (t/ha)

Impact of long term use of organic and inorganic sources of nutrient on physical, chemical and biological properties of soil, pest complex and quality of produce: Soil analysis at regular interval in long term manurial experiment revealed that incorporation of crop residue as well as use of organic manure, with or without fertilizers improved the organic carbon content of soil as well as microbial biomass carbon and dehydrogenase activity. Carbon

sequestration rate was higher in residue incorporation plots as compared to treatments receiving inorganics alone. Distinct variations were observed in soil bio-chemical properties after seven crop cycles. Organic carbon content increased in all treatment over control. The greatest increase in organic carbon content was found in 100% organically treated plot, which was comparable to treatment receiving 50-50 % nutrients from organic and inorganic sources (Fig. 9). Microbial biomass carbon followed the same trend as organic carbon. Similar trends were observed in case of alkaline phosphatase activity and dehydogenase activity also, as these parameters were comparable in 100% NPK through inorganic + crop residues and 100% NPK through inorganic + secondary and micro nutrients (Figs. 10, 11 and 12). This may be ascribed to balance supply of nutrients that proliferated root biomass, and increased carbon content, available nitrogen and carbon sequestration rate.

Disease and Pest Complex: Incidence of severe mosaic, apical leaf curl and hopper burn varied with different nutrient management alternatives in potato crop. Crops grown on organic source exhibited less damage as compared to that on inorganic nutrition or part of both. Thrips and leaf folder population were recorded high on groundnut and rice, respectively. Population trend of thrips and leaf folder did not show any significant differences due to various source of nutrition in long term manurial trial, however, organic manured plots recorded less damage as compared to other combinations. Groundnut crop suffered severe attack by fungus *Aspergillus* Spp. in all the plots during rainy season. There was also severe attack of insects and virus on groundnut crop.

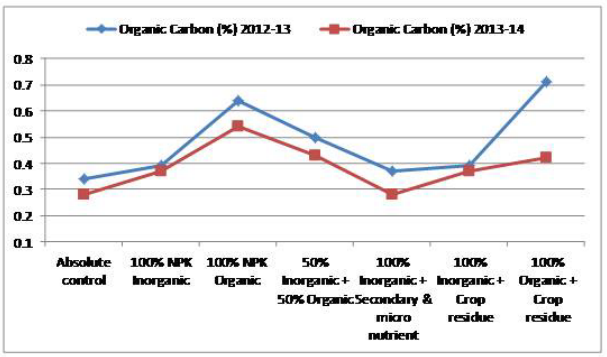


Fig. 9. Effect of nutrient management options on organic carbon content (%) in Groundnut- Potato- Moong *bean system*

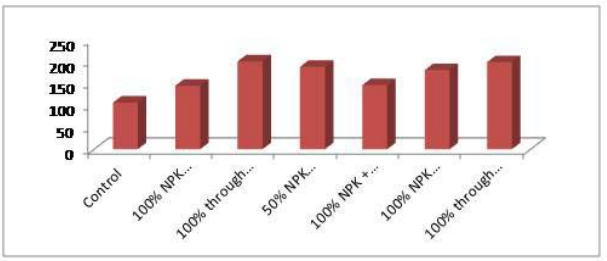


Fig. 10. Microbial biomass carbon (mg/kg) in Groundnut-Potato- Moong *bean system*

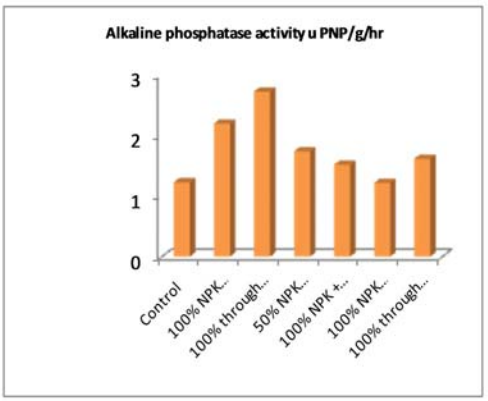


Fig. 11. Alkaline phosphatase activity (µ/PNP/g/hr)in Groundnut- Potato- Moong *bean system*

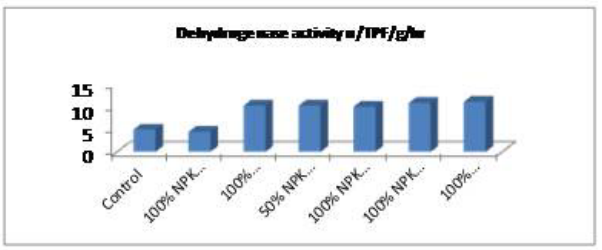


Fig. 12. Dehydrogenase activity (µ/TPF/g/hr) in Groundnut-Potato- Moong *bean system*

Programme 4: Climate Change Impact and Adaptation Strategies for Potato Crop

Climate change impact on potato productivity in Uttar Pradesh and adaptation strategies

Global climate is changing as a result of increased greenhouse gases emission and it is now an acknowledged fact that global green house gas emissions will continue for next few decades. These increases in GHGs have resulted in warming of the climate system by 0.74°C between 1906 and 2005, which has been much higher in recent decades. The global atmospheric concentration of carbon dioxide has increased markedly as a result of human activities since 1750. Although increase in atmospheric carbon dioxide has a fertilization effect on crops, it can reduce crop duration too. As per the IPCC 4th Assessment Report, an increase in temperature ranging from 0.78ºC during September, October, November to 1.17ºC during December, January, February is expected under A1FI scenario by 2020 in South Asia. This is likely to seriously impact the availability of suitable growing period for potato in India.

Uttar Pradesh, the largest potato producing state of India, accounts for about 34% of national potato production. Thus, a study was undertaken to assess the impact of climate change on potato productivity in Uttar Pradesh under A1FI scenario and to identify suitable cultivar and date of planting for adaptation through simulation studies using WOFOST crop growth model. Three potato cultivars belonging to three different maturity group were used (Kufri Badshah – late maturing, Kufri Bahar – medium maturing and Kufri Pukhraj – early maturing) and the analysis was done for baseline scenario (2000) and for future climate scenarios of the years 2020 and 2055 using A1FI scenario of temperature and atmospheric CO_2. Potential production of potato cultivars was estimated for 61 different locations across Uttar Pradesh. Under baseline scenario, the mean productivity of Kufri Badshah, Kufri Bahar and Kufri Pukhraj was 46.0, 46.8

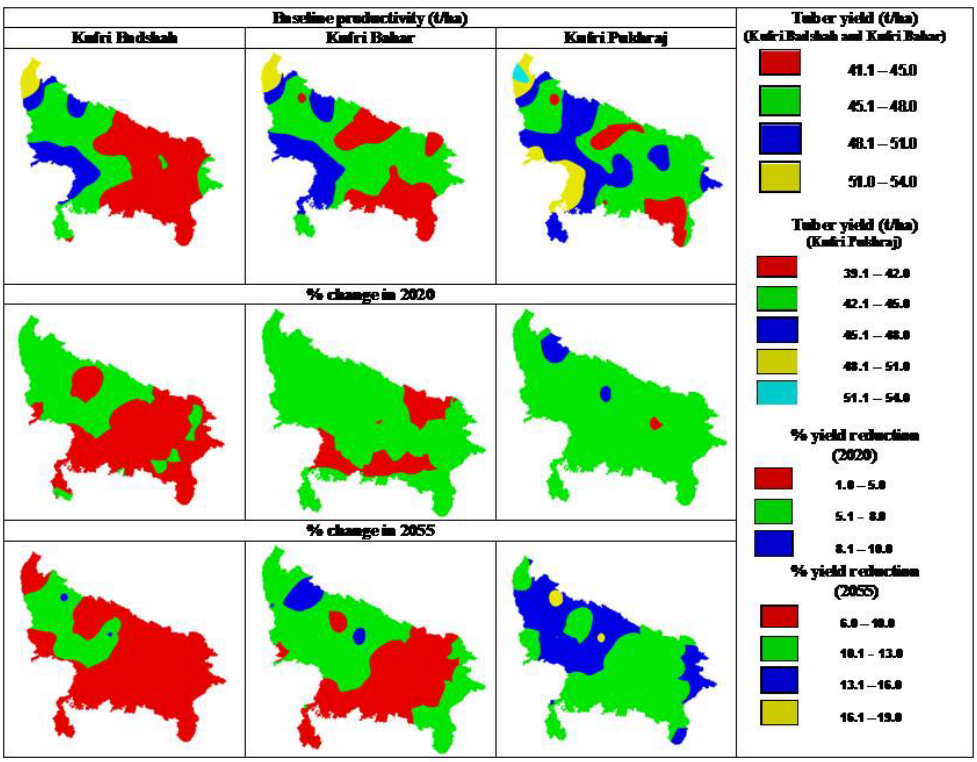


Fig. 13. Potential productivity of different potato cultivars under baseline and changes in future climatic scenario

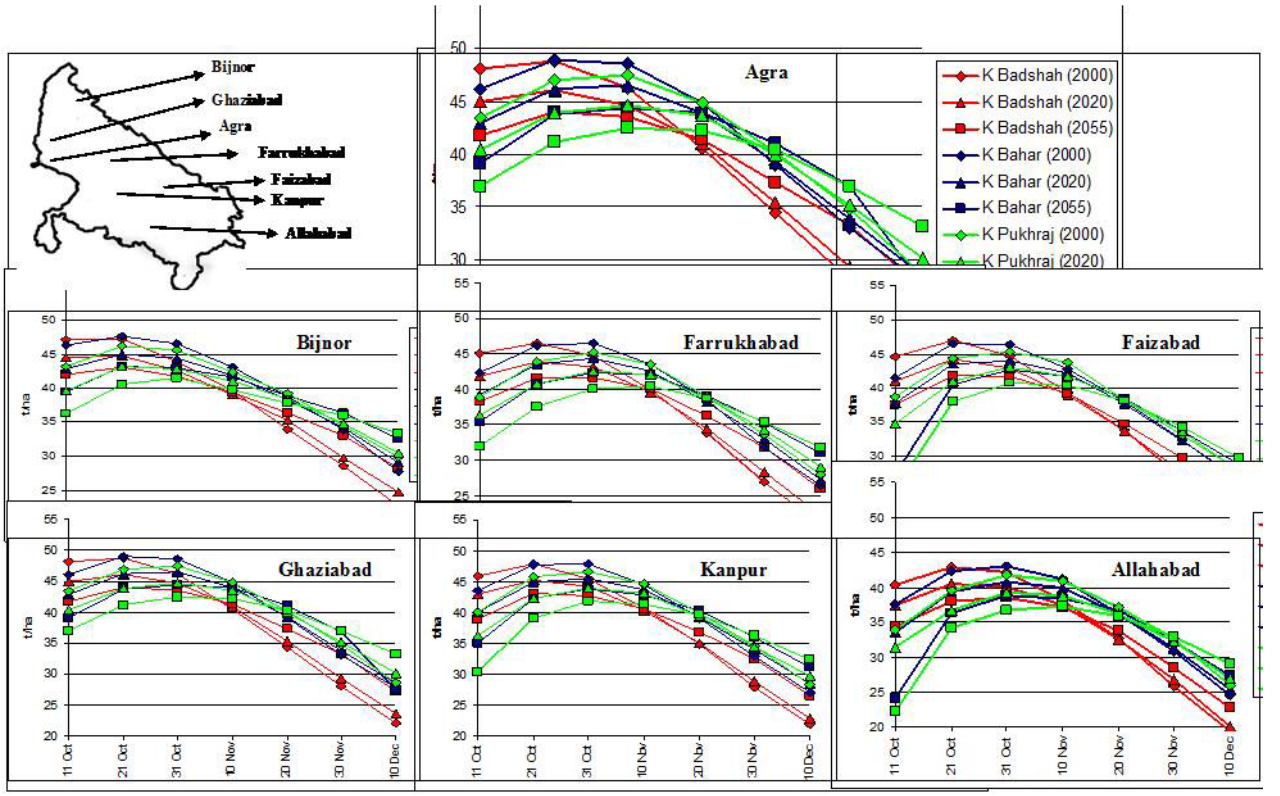


Fig. 14. WOFOST simulated potential productivity of potato cultivars at different dates of planting under current (2000) and future climate scenarios

and 45.3 t/ha, respectively (Fig. 13). Although the increase in CO_2 concentration alone is expected to bring an increase of 4.0 to 4.5% in productivity in 2020 and 17.0 to 19.5% in 2055, the corresponding increase in temperature is likely to decrease the mean productivity by 8.5 to 10.4% and 17.7 to 27.5% in 2020 and 2055, respectively. Overall, under the combined impact of increased CO_2 and temperature, the model has projected a decline in productivity of Kufri Badshah, Kufri Bahar and Kufri Pukhraj to the tune of 5.5, 6.1 and 7.0%, respectively in 2020 and 9.4, 10.9 and 13.4%, respectively in 2055 without adaptation. Rescheduling can be an immediate option against climate change for short duration cultivar in Uttar Pradesh. With the existing cultivars, changing planting date with selection of suitable variety can cut down the yield reduction by about half in 2020 and by one third in 2055 (Fig. 14).

Potential impact of climate change on potato late blight outbreak in western Uttar Pradesh and Punjab using JHULSACAST model

Late blight caused by *Phytophthora infestans* is often regarded as the most important disease of potato globally. Under climate change scenario, the temperature change is likely to affect the late blight out break in Punjab and western Uttar Pradesh, thus affecting the potato seed production. Keeping this in view, a study was initiated to investigate the impact of climate change on late blight in Punjab and western Uttar Pradesh using JHULSACAST. The model was run using districts level data on minimum and maximum temperature for baseline (year 2000) and future climate scenarios (years 2020 and 2055) for 13 districts of Punjab and 21 districts of western Uttar Pradesh. Under the favourable relative humidity in Punjab, the model predicted earliest late blight appearance during 13th to 25th October in baseline scenario (2000) which is expected to be delayed by 0 to 6 days in 2020 and 12 to 14 days in 2055 scenarios (Fig. 15). In western Uttar Pradesh, earliest late blight appearance in potato crop season was predicted during 13th October to 1st November in baseline year 2000 and is expected to be delayed by 0 to 8 days in 2020 and 10-21 days in 2055 (Fig. 16). The change in date of late blight appearance and its delay in years 2020 and 2055 is due to expected increase in temperature by 1.08 and 2.98ºC, respectively over the baseline year 2000. In Punjab,

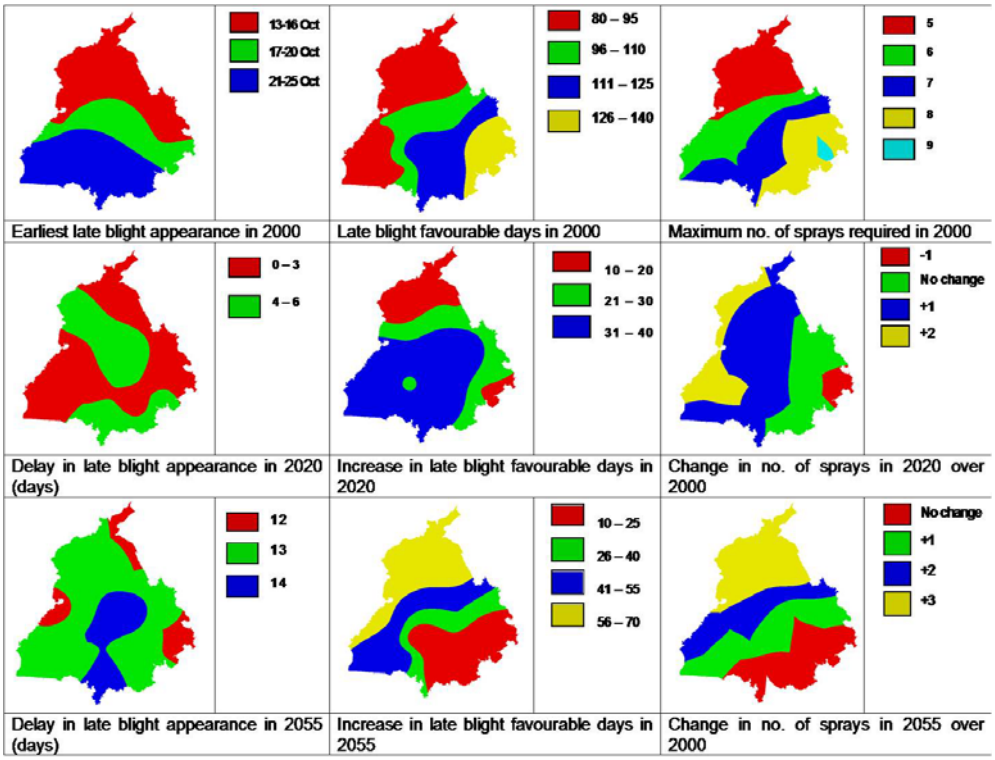


Fig. 15. Distribution of LB appearance, LB favourable days and delay in LB appearance in Punjab in years 2000, 2020 and 2055.

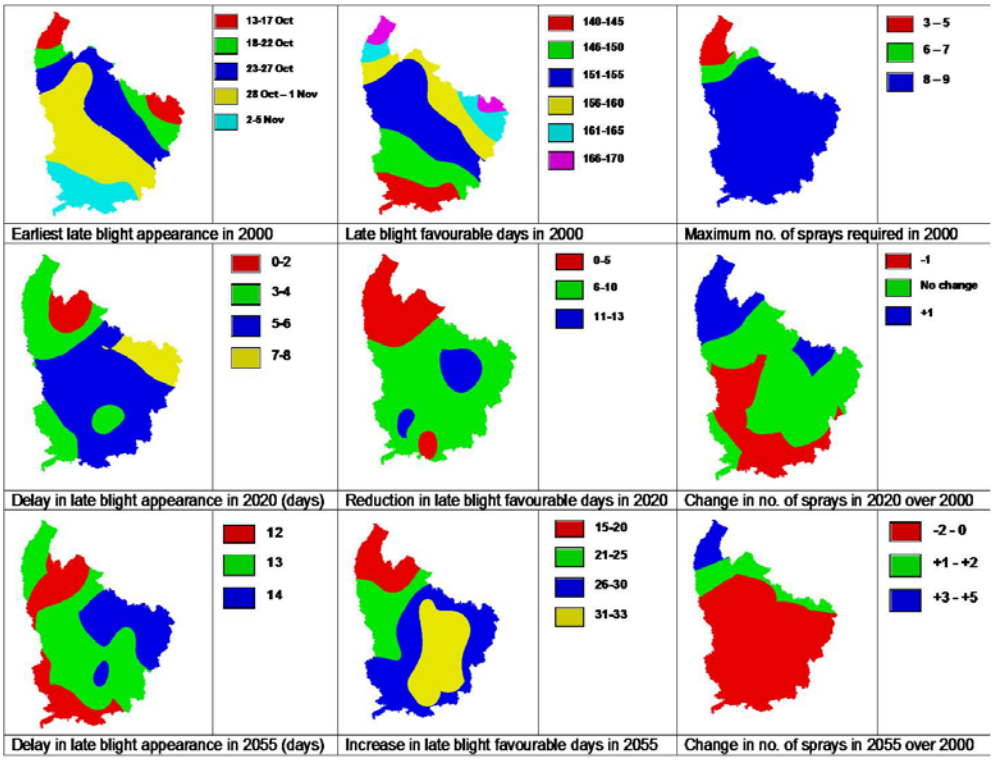


Fig. 16. Distribution of LB appearance, LB favourable days and delay in LB appearance in western Uttar Pradesh in years 2000, 2020 and 2055.

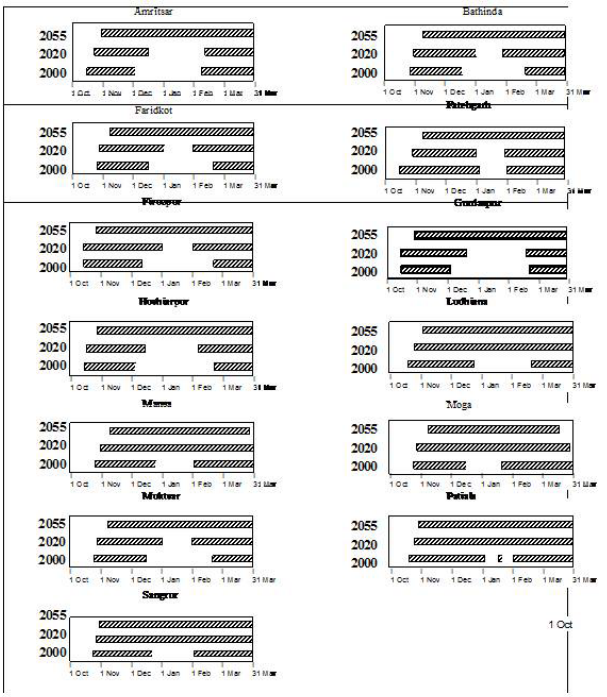


Fig. 17. Late blight favourable period in Punjab

there were average 105 late blight favourable days out of 182 suitable potato growth days in year 2000; the number is likely to be increased to 135 and 140 days in 2020 and 2055 respectively in Punjab (Fig. 17). In western Uttar Pradesh, potato growing season was warmer which would decrease late blight favorable days by 7 and 27 in 2020 and 2055, respectively. The number of sprays required to control late blight in potato seed crop would be 7.3 and 8 in future scenario (2020 and 2055) in comparison to 6.5 in baseline (2000) in Punjab. In contrast, there would be no change in number of sprays in year 2020 (over baseline year 2000) in western Uttar Pradesh, however, due to further increase in temperature in year 2055, it could be reduced by 2.

Effect of higher temperature on *Phytophthora infestans*

Phytophthora infestans is known as a cool climate pathogen. However, this pathogen has a capability to adapt to changing weather condition for its survival and growth. In an experiment conducted to study effect of higher temperature on radial growth on *P. infestans.* a subset of isolates was found to grow well at 30ºC, which was grown well earlier upto 28ºC only. It can be concluded that *P. infestans* could adopt to grow at higher temperature.

Climate analogues and late blight appearance

Different climate analogues (place where climate today is similar to the given future climate of a place of interest) were surveyed during current season for observing late blight appearance. It was observed that at similar analogues (30 year future climate) late blight appeared at different dates. At Jalandhar (31.326 ºN, 75.579 ºE) late blight appeared on 24 th December, 2013 while at its analogue Baghpat, late blight appeared on 1 Feb, 2014. Similarly, at Patna (25.617 ºN, 85.167 ºE), which is an analogue of Agra (26.753 ºN, 78.773 ºE) late blight appeared at different dates.

Yield loss assessment due to late blight

To develop a model on yield loss due to late blight, an experiment was conducted under different weather conditions with two varieties and three dates of planting. During the season, disease severity ranged from 1-100%, rains was also co-factor for spreading the blight. Overall 8-20% economic yield was observed at 2nd Nov, 2013 date of planting, whereas, up to 15% economic yield was in 17 Nov, 2013 date of planting.

Survivability of *Ralstonia solanacearum* at different temperature

Bacterial wilt of potato is a serious threat for potato production especially in hills. Its spores survive at wide range of temperatures depending upon strains. For their effective management, it is essential to know the temperature regimes in which bacterial wilt strains survive. At Shimla, all the four different *R. solanacearum* strains *viz*., RS-2 (phylotype II bv 2), RS-25 (phylotype I bv 4), RS-50 (phylotype I bv 3) and RS-75 (phylotype IV bv 2T) survived up to seventeen months of storage in distilled water at 20ºC. The strains, RS-2 (potato race, bv 2) remained viable up to 17 months at 24 and 28 ºC and up to 8 months at 32ºC.The strains RS-25 (general race, bv4) and RS-50 (general race,bv 3) remained viable up to 11 months at 24 and 28ºC and up to 3 and 2 months, respectively, at 32 ºC. The strain RS-75 (tropical race, bv 2T) remained viable up to 11 months at 24, up to 10 months at 28ºC and up to 8 months at 32ºC. However, none of the strain survived after one month of incubation at 37 and 40ºC.

Effect of abiotic factors on sucking pest

The early crop of potato which is planted under high temperature regime in the month of September in Indo-

Gangetic plains, suffers great losses due to many sucking pests like whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*) leafhopper (*Amrasca b. biguttula*) and mite (*Polyphagotarsonemus latus*). To prepare ourself for future climates and for developing effective management strategies against potato pests under changing scenario of abiotic factors with respect to biotic stresses *i.e.* insect pests, the information on pest dynamics is required which is being generated through study on early planted crops at Modipuram and Gwalior. As far as mite and hopper burn is concerned, the past three years study has indicated that under a given set of abiotic factors one pest can dominate and replace the other at Modipuram. The combination of temperatures and relative humidity resulted in very high percentage of hopperburn (80%) which resulted in 70% loss in the yield in 2011, whereas during 2012 mite burning was higher while burning due to leafhopper was only 9-16%. The losses and pests scenario in 2013 was similar to 2012. The average per cent emergence of pest remained poor on all dates of planting due to high temperature. The effect of mite feeding was more (upto 60% burn) and hopper burn percentage was low. Whitefly was highest in first week of November in 5th October planted crop and in second week of November in 10th October planted crop (Fig.18 a). The average leafhopper population was low on all dates of planting (Fig. 18 b) possibly because the development of mite fast and plants infested by mite are less preferred by leafhopper. Higher rainfall (more than 50 mm) in both the years in combination with high temperature resulted in higher mite population. The presence of aphid, *A. gossypii* continued throughout the crop duration and was highest in first week of November in 15th September planted crop (Fig. 18 c). Since last 3-4 years it has been observed that leafhopper, *A. biguttula* and mite, *P.latus* are occurring in October planted main crop too due to change in abiotic conditions. A change of pest scenario could be expected in near future due to migration of these sucking pests from early potato/other vegetable crops to main crop of potato.

At Gwalior, the highest thrips population (44.75/ 5plants) was recorded in September planted crop with high incidence of stem necrosis disease. Similarly high incidence of white fly population (32.25/5 plants) was also recorded in early planted crop (*i.e.* September planted crop). The leafhopper and aphids remained low in early planted crop. In general yields were low and the highest total tuber yields (13.87 t / ha) was recorded in potato crop which was planted on 5th of October with low incidence of thrips, leafhopper and white fly population. High temperature (30-35ºC) and low humidity (55-60%) prevelent were not favorable for insect growth and also inhibited the tuber formation. The three years data revealed that higher temperature at early planted crop triggered the incidence of insect vector especially thrips on potato crop, resulting high incidence of stem necrosis disease.

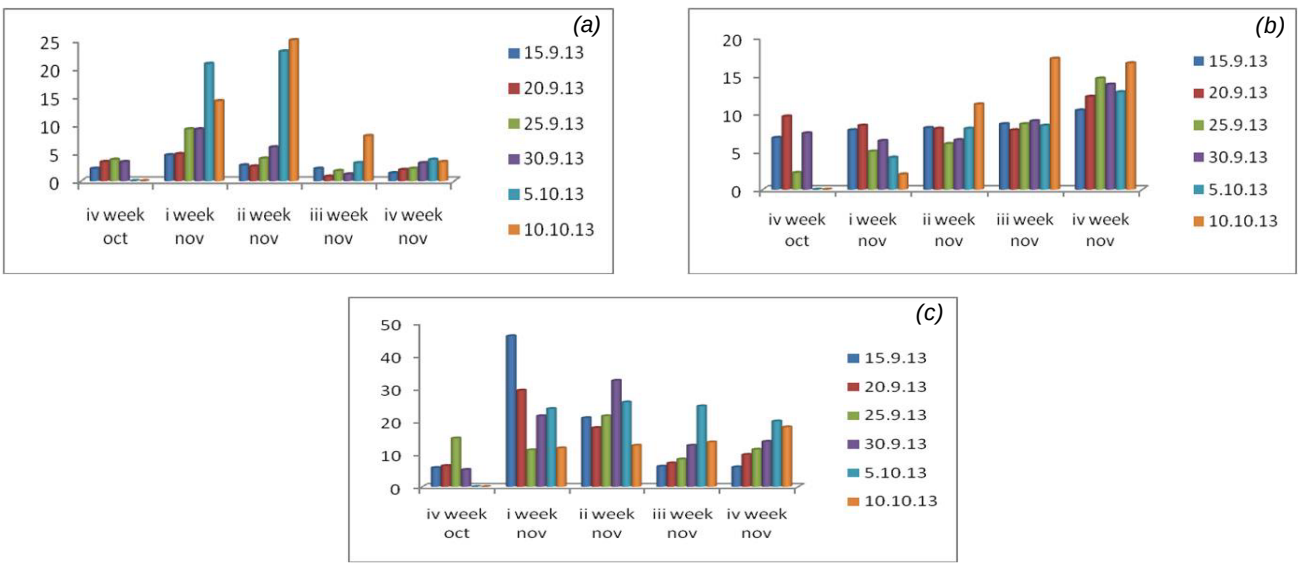


Fig. 17. Effect of different dates of planting on (a) whitefly (b) Leafhopper and (c) Aphis gossypii population during 2013

Programme 5: Farm Machines for Potato Cultivation

Farm machines and equipment have a special role in potato cultivation since it is a short duration and input intensive crop. There is a need to reduce the labour requirement and human drudgery through development of appropriate equipment and machines for all types of farmers, from small and marginal farmers to those having big farms. Therefore, present programme has been undertaken and its immediate objectives is to develop potato graders for small to medium farmers and for experimental plots, development of combine harvester and to develop and improve aeroponic systems for seed potato production.

Development of potato combine harvester

The collection of dug tubers is carried out manually, even under the mechanized harvesting of potato, in India, which consumes lot of labour and time. The operation is also full of drudgery. In addition, the farmers are facing acute labour shortage now a days especially at the time of harvesting. The work was undertaken to develop tractor operated small, compact and low cost potato combine harvester to do away with manual collection of tubers thereby save upon labour, time and thus reduce the cost of operation and drudgery involved in collection of tubers. A prototype of tractor operated, a 2-row potato combine harvester was developed in the past to dig out and collect the dug tubers simultaneously in a trolley.

During this year, the fabrication of a new prototype of a 2-row tractor operated potato combine harvester (Prototype-II) with added provision for tuber inspection and simultaneous collection of tubers in bags or crates was carried out. The prototype comprised of five major systems *viz*. main frame, digging cum horizontal conveying system, cage wheel type vertical conveying system, trash separator and tuber inspection cum bag/ crate filling system and the power transmission system.

The digging blades of prototype harvester dig out two adjacent rows of potato crop during actual operation. The dug material is conveyed to the elevator rod chain conveyor. The chain carries the material behind while agitating and sieving the loose soil. The remaining soil-potato mass is carried and dropped over the lower side of the cage wheel. The cage wheel carries the material up through the perforated compartments in the rotating cage wheel and drops it over the inclined trash removal system .The interceptors fixed over the rubber sheet catch hold of vines/ weeds etc. but allow the tubers to roll down to the inspection table. The moving conveyor of the inspection table facilitates the inspection of the tubers for removal of unwanted material viz. rotten tubers, mother tubers, clods etc by the persons standing on both side of the table. The tubers thus separated from the trash move on to delivery chute and are collected in the bags/crates. The filled bags/crates are collected on the platform and are removed at the appropriate place and interval. Unlike the previous prototype (RP-I), this prototype (RP-II) requires only one tractor to complete the harvesting operation.

Field evaluation and testing

The prototype was run at no load condition. The speeds of different sub systems were optimized under simulated conditions. Preliminary trials were also conducted in the actual field conditions, on the potato crop variety Kufri Surya raised for testing of the prototype machine. The performance of cage wheel type vertical conveyor and other systems was found to be satisfactory. The design of the trash separator was found to be effective to separate out the weeds from the dug tubers. The tuber inspection table also worked satisfactorily. Observations were made during testing for further improvement of the prototype, which shall be taken into consideration for design and material improvements of the prototype. Spillage of tubers and bruising was observed in some of the systems. The reasons for the same were found out for their rectification. The prototype was found to require safety covers on moving parts and some other provisions for the safety of workers. The prototype required a 45HP tractor and 4 to 5 persons for its operation.

Development of improved square wire mesh type of potato grader for pre-cold storage of potatoes

Grading or classification of potato tubers according to their size makes them more acceptable in market and is a requirement for production of certified seed. Manual grading is slow, labour intensive and non uniform and is further affected due to the low availability of labourers during peak season. Thus mechanizing the grading operation is desirable both

for reducing the cost and time required for the operation and ensuring uniformity in the grades. The commercially available graders are suitable only for grading of post cold storage tubers, when their skin becomes hard enough to resist bruising. Therefore, an attempt was undertaken to develop grader for pre-cold store tubers within acceptable limit of bruising. An improved square mesh type of potato grader of 2.5 tonne/hr capacity and to provide three grades was developed for small farmers and experimental plots. The prototype grader could be operated both manually as well as with the help of an engine.

During the year under report, the fabrication of a power operated potato grader for medium farmers with three numbers of the grading sieves and targeted capacity of 5-6 tons/hr. was undertaken. The grader was designed keeping in view farmer's requirement, local available material and ease of operation. Major systems of the grader are the main frame, grading mechanism and power transmission system. This grader has been designed to grade the material in four size grades (< 20, 20-32, 32-52 & >52mm).

Design, development & evaluation of small grader

Design work and selection of material required for fabrication of various systems/mechanisms of the small grader (Rubber rollers type) for experimental plots and for small farmers, was carried out. The major systems of the grader shall be the mainframe, grading rollers, and power transmission. Fabrication of the main frame and of grading mechanism of the grader, was also carried out. The main frame of the grader resembles the shape of a rectangular box and is mainly fabricated out of 38 mmx5 mm angle iron. Hollow rubber rollers having square hole in the center shall be mounted on steel shafts and will constitute the grading mechanism of this prototype. These shafts with rubber rollers resembling the shape of a tambourine/ reel will revolve about their own axis in the same direction thereby conveying forward the tuber material received on them. This grader has been designed to grade the potatoes in the three different size grades.

The design of a new small plot machine for grading of experimental produce was prepared considering the points and parameters such as easy operation (by one person), easy transport (wheels, weight < 25 kg, capacity 25-30 kg/batch).

First model of the machine was fabricated using a three ply rubber sheet. Preliminary trials indicated that there are fair chances that this machine will be of good use to the scientific community involved in potato research.

Evaluation of different growth chambers under aeroponic system

Aeroponic system, a soilless mini seed production system was developed and improved in the past in respect of design of grow chambers and planting trays for better space use efficiency, and efficient tuber picking system. New growth chamber made of bricks and mortar was developed and compared with thermocol and polythene chambers for thermal conductance and temperature variation. New ceramic nozzles were tested and compared with the PVC nozzles for misting in aeroponic growth chambers. The aeroponic systems were installed at CPRI, Shimla and its stations at Patna and Shillong. A mini soilless production system was developed for conducting experiments on nutrient supply and for raising vegetable crops other than potato.

During the year, another experimental aeroponic system was installed at CPRS, Jalandhar and an experiment was conducted. This unit consisted of three independent aeroponic units having different designs of grow chambers. In this experiment four cultivars were tested for their performance. All the nutrient solution parameters (EC, pH, TDS) and spray time were kept same in all the systems. Only difference was of root zone temperature variation (Fig. 19). Response of different varieties when planted on 8th of Dec, 2013 is shown in figures 20, 21 and 22. Similar experiment was conducted at CPRIC, Modipuram with two verities (Kufri Bahar and Kufri Khyati; Fig. 23). Average number of tubers/plant was found 32.3, 44.7 and 58.5 in brick box, Styrofoam box and polysheet box, respectively.

Designing of a machine for grading aeroponically produced minitubers

Aeroponically produced mini tubers usually ranged from 1.0 to 6.0 g in weight depending upon variety, picking time and picking frequency. Therefore, for grading purposes, machines designed for general potato crop cannot be used for aeroponically produced tubers. For grading of these tiny tubers, a conceptual design was prepared at Jalandhar keeping in view considerations such as electric operated, making three grades on size basis (<1.5, 1.5- 3.0 and > 3.0 g), damage to the mini tubers should be nil, capacity

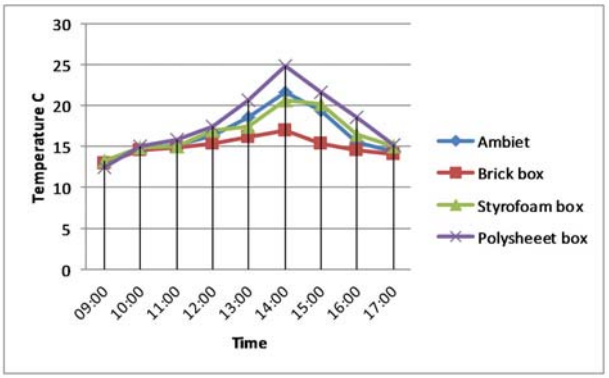


Fig. 19. Variation of temperature in root zone in different grow boxes

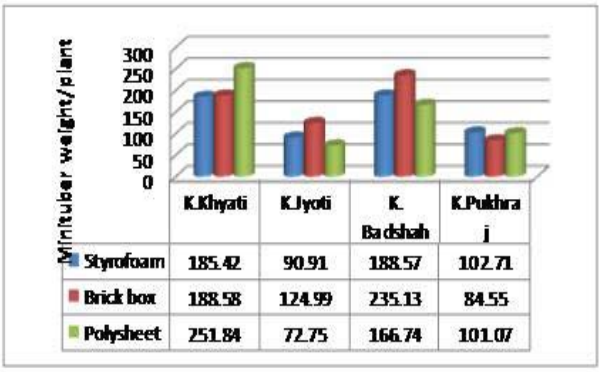


Fig. 20. Minituber production/plant in different grow chambers

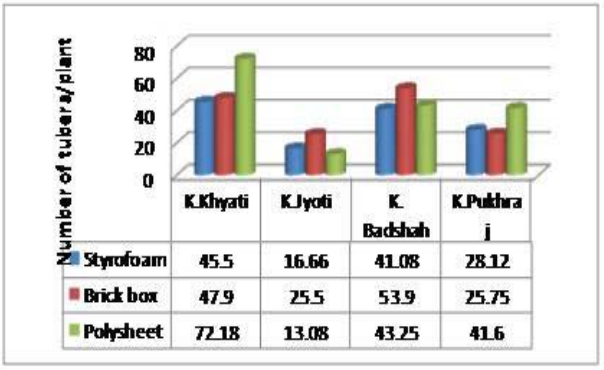


Fig. 21. Average number of minitubers per plant in different grow chambers

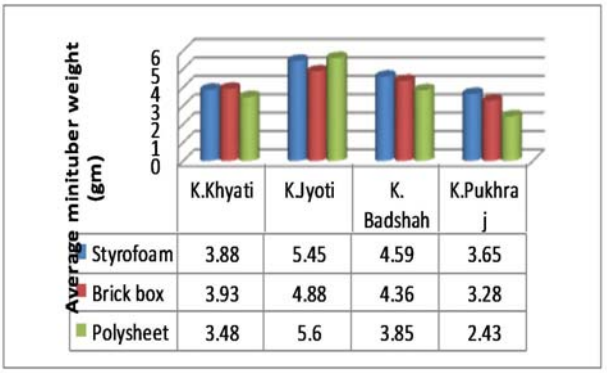


Fig. 22. Average minituber weight in different grow chambers

Fig. 23. A view of mini tuber production of Kufri Khyati in aeroponic system

Fig. 24. New Aeroponic System installed at CPRS, Jalandhar

should be 14000-15000 tubers/hour and easy to transport (provided with wheels weight < 60 kg).

Development of a portable aeroponics system for experiments

Design of an earlier portable aeroponic unit was improved. This unit consists of basic subsystems *viz.* grow box cum nutrient solution chamber, misting unit having two nozzles, pumping unit, filters, electrical controls, gauges and electronic timer. Grow box is a moulded unit. This portable system can be used for conducting experiments on potato and other crops (Fig. 24).

Division of Plant Protection

Programme 1: Management of late blight

Weather parameters i.e. temperature and humidity play vital role in the appearance and spread of late blight disease. However, these conditions in the subtropical plain have remained erratic during the last couple of years. Consequently the late blight appearance and further spread has also been erratic in entire potato growing regions. Therefore, during the current crop season varying degree of crop losses were observed in different states. Besides, new pathogen populations are also emerging which are more virulent and tolerant to the new molecules of fungicides. These new populations are also being monitored through molecular tools and for their management, new approaches like gene silencing and new molecules are being tested. In the present scenario, management of the disease has become more challenging and farmers need to take advantage of all strategies developed and deployed by the institute including web based tools i.e. INDO-BLIGHTCAST, JHULSACAST and Decision Support System to minimize the losses caused by potato late blight.

Pathogen population structure

Late blight appeared on 11 July, 2013 on cv. Kufri Jyoti in Shimla hills but its build up was slow due to higher minimum temperature (>15^{o}C). The spread of the disease was fast in August but no significant losses were observed as the crop matured by that time. Overall, the severity ranged from 30-60%. Late blight appeared in Punjab on November 7, 2013 in village Machhiwara, district Ludhiana but remained restricted to a few fields and did not spread further till end of December 2013. The disease built up rapidly from the second week of January and late planted crop suffered heavily with severity ranging from 5 to 75% in different fields. Overall, about 10-15% loss in potato production in Punjab is expected due to late blight during the current year. A roving survey was also undertaken in Hooghly, Burdwan and Bankura districts of West Bengal which cultivate around 60% of the total potato crop grown in West Bengal. Overall, around 30% of the area in these three districts was affected by late blight which could result in about 10-15% loss in potato production. Late blight disease was observed in Western Uttar Pradesh at Kaval in Muzaffarnagar district on 7th December on cv Kufri Bahar and disease severity varied from 0-100% in Western UP and 5-100% in central UP depending upon the variety grown and fungicides sprayed. It is expected that overall 10-20% yield will be reduced due to severe attack of late blight. In Hassan and Chickmagalur districts of Karnataka, severity ranged from 5-100% in *Kharif* potato and about 10-15% yield losses are expected. Similarly in Uttarakhand blight severity ranged from 5-100%.

Monitoring of *P. infestans* population for mating types, prevalence of physiological races and sensitivity to metalaxyl was done for the states of Himachal Pradesh, Punjab (Jalandhar), Meghalaya (Shillong), Karnataka, Uttar Pradesh and Uttarakhand. Results revealed that the frequency of occurrence of A_1 mating type was 100% in Punjab while frequency of A_2 mating type was 23% in Uttar Pradesh, 94% in Meghalaya, 84% in Uttarakhand and cent-percent in Himachal Pradesh. The results of prevalence of physiological races revealed that the pathogen population in these states consisted of complex races (11 genes) and frequency of occurrence of 11 genes was 100% in all the locations except in two isolates from Uttar Pradesh which had 9-10 genes. Comparison of *P. infestans* population for metalaxyl sensitivity in different parts of the country revealed that a total of 11% population in Himachal Pradesh, 38% in Meghalaya and 16% in Punjab exhibited tolerance at 300 ppm whereas 60% isolates from Uttar Pradesh, 42% from Uttarkhand and 25% from Karanataka were tolerant at 200pmm.

The population structure of *P. infestans,* the causal agent of late blights of potato and tomato has undergone major changes in the world during the past two decades. Molecular markers such as mtDNA haplotyping and SSR provided a good tool to study the genotypic structure of *P. infestans.* A sub set of population comprising 166 isolates collected from Himachal Pradesh, Meghalaya, Punjab, Bihar, Karnataka, Uttar Pradesh and Uttarakhand was analysed with primer F2-R2 (digested with *Msp*I) and F4-R4 (cut with *Eco*R1) for mitochondrial haplotyping revealed that all the isolates belonged to the Ia haplotype (**Fig. 1**). These results revealed that the new population has displaced the old population (Ib) in most of the regions.

Twenty published SSR markers were screened for polymorphism in two diverse sub sets of *P. infestans* population and only 5 markers *viz*, Pinf SSR1, Pi04, Pinf SSR2, Pi 89, and Pi4B showing polymorphism in the Indian population of *P. infestans* were selected. Amongst these, two primers i.e. Pinf SSR1 and Pi04

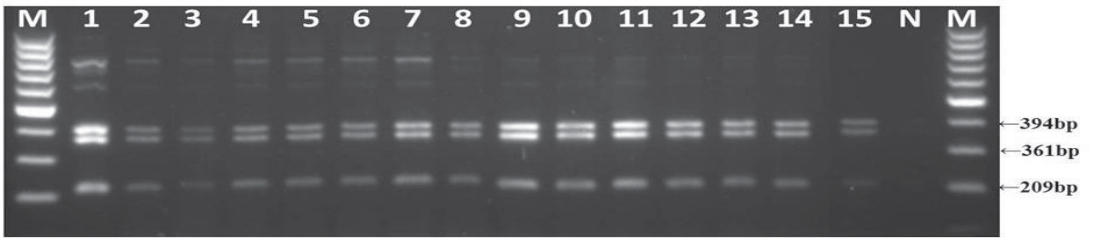


Fig. 1: *Mt haplotyping with primer F2R2 & F4R4 digested with EcoR1; lanes M= 100bp ladder, 1-15= P. infestans isolates, N= negative control*

were selected for genotyping and two alleles (229 and 245bp) were observed with primer Pinf SSR1 in 96 isolates of *P. infestans* (**Fig. 2a & 2b**) while three alleles were observed with Primer Pi04 (**Fig. 3a & 3b)** in 248 isolates of *P. infestans*. Among three alleles, 171 bp size loci were observed in most of the isolates. These primers will be used for further genotyping of the complete set of *P. infestans* population conserved at the Institute.

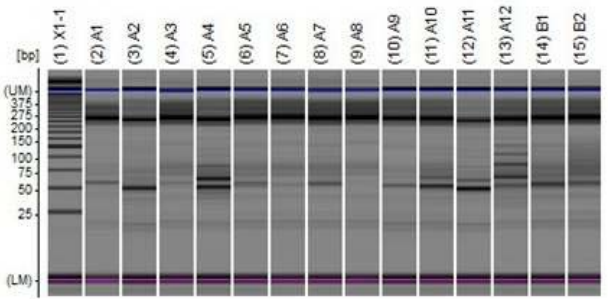


Fig. 2a *SSR Genotyping of P. infestans isolates with Pinf SSR1 primer*

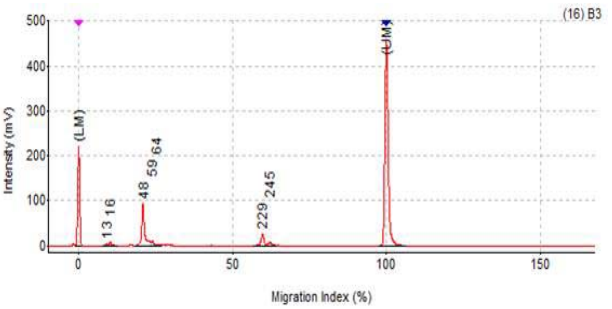


Fig. 2b: *Electropherogram of P. infestans isolate with Pinf SSR1 primer*

Development of lateral flow device (LFD)/ dipstick for detection of *Phytophthora infestans*

Phytophthora infestans cell wall based protein gene (392bp, **Fig. 4**) has been isolated and cloned into pETSUMO expression vector. Positive clones were

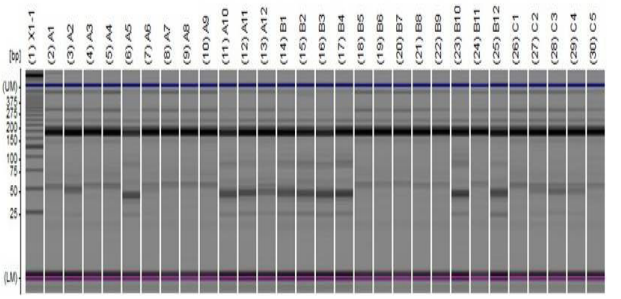


Fig. 3a *SSR Genotyping of P. infestans isolates with Pi04 primer*

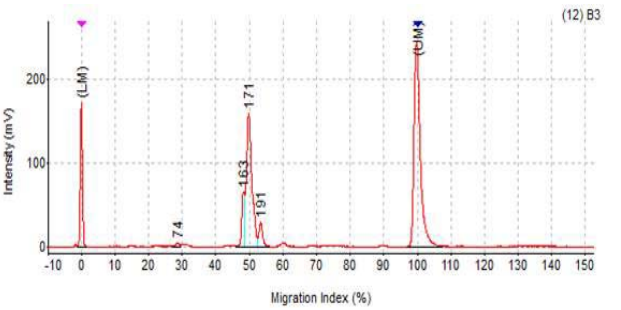


Fig. 3b: *Electropherogram of P. infestans isolate with Pi04 primer*

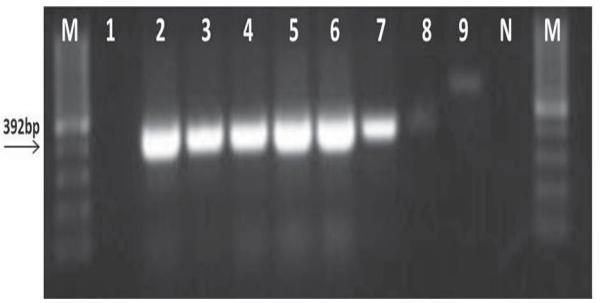


Fig. 4: *Colony PCR amplification of Phytophthora infestans cell wall based protein gene in T/A vector; lanes M=100bp ladder, 1-9= colonies, N= negative control*

confirmed through colony PCR by using vector specific T7 promoter primer and revealed the 650bp fragment size (**Fig. 5**) and confirmed the integration of the gene.

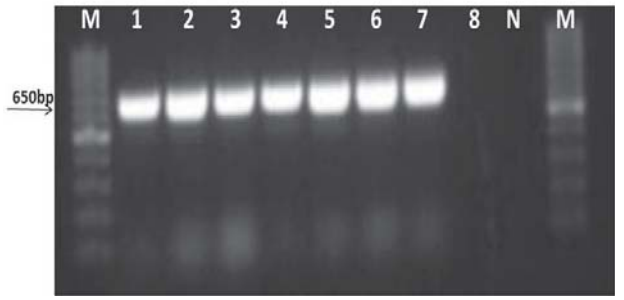


Fig. 5: *Colony PCR confirming the integration of cell wall based protein gene in pETSUMO vector; lanes M= 100bp ladder, 2-8= colonies, N= negative control*

Protein was extracted and purified using G-Bioscience protein extraction kit. The purified protein was detected through SDS PAGE, which revealed the ~12KDa protein size (**Fig. 6**) and has been customized for developing polyclonal antibody and finally it will be used for development of dipstick for easy detection of *P. infestans* .

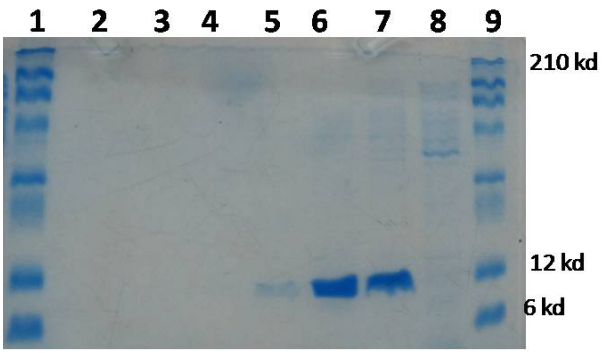


Fig. 6: *SDS-PAGE results of purified recombinant protein; lanes 1&9= PAGE marker, 2= Elution-8, 3= Elution-7, 4= Elution-6, 5= Elution-3, 6-Elution-2, 7- Elution-1, 8= un-induced*

Development of *Avr3a*-siRNA transgenic lines for late blight resistance

Transgenic lines (avr3a-siRNA) developed and found positive for late blight resistance last year were further screened for copy number using southern blot analysis. All the four moderately silenced lines were found positive for presence of *NPTII* gene. Three out of the four lines had single copy of transgene (Kufri Khyati 1037, Kufri Pukharaj 2173, Kufri Pukhraj 2155) and one line (Kufri Pukharaj 2086) had three copies of transgene (**Fig. 7**). In the present study, vector backbone pBI121 have selectable marker gene *NPTII* at left border, so the copy number of *NPTII* gene corresponds to the copy number of *Avr3a* gene. These lines will be further screened for siRNA expression through northern hybridisation.

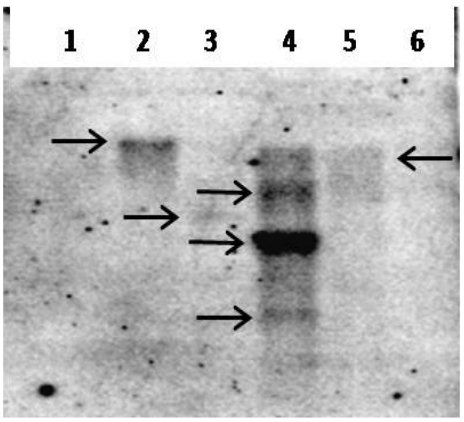


Fig. 7: *DNA gel blot of control and four iIR-Avr3a RNAi lines; lanes 1= Kufri Khyati (control) and 6= Kufri Pukhraj (control), lanes 2= Kufri Khyati 1037, 3= Kufri Pukhraj 2173 and 5= Kufri Pukhraj 2155 showing one copy number each while lane 4= Kufri Pukhraj 2086 has three copy numbers*

Silencing of transposable elements in *P. infestans* to reduce pathogen dynamism

Transposable elements are often called selfish or junk DNA, but they have had a profound influence on the evolution of the genomes and likely the biology of plant pathogens. Bioinformatics analyses have revealed that the *P. infestans* genome is organized into gene-rich islands separated by extensive stretches of gene-poor and highly repetitive DNA. The repetitive DNA is rich in transposable elements. Effector genes are preferentially located in the gene poor and repeat (transposon)-rich genomic regions. *P. infestans* has the largest known oomycetes genome at 240Mb and has been estimated that 74% of the genome comprises of highly repeated sequences. *In-silico* analysis of retro transposon element encoding 1kb size fragment GYPSY -1a has been retrieved from Broad Institute of Technology, *Phytophthora infestans* genome data base. Identified the effective region (372bp), which generates at least 3-4 siRNA by using siRNA prediction tool software and designed the sense and antisense primer for 372bp region to develop the RNAi construct for development of transgenics to reduce the pathogen dynamism.

Differential gene expression during asexual development of *Phytopthora infestans*

To understand different developmental stages during asexual spore production in *P. infestans*, a microarray analysis using cDNA of mycelia, sporangia and zoospores was performed in a single 12X135K Nimblegen array slide. Data revealed that out of 18,034

potato protein coding genes, 1933 genes were upregulated (>2 fold expression) in sporangia where upregulation of 43 genes was >10 fold while in zoospores, 1668 genes were upregulated at 2 fold expression and 61 genes at 15 fold expressions. This indicates that temperature conditions play a role in regulating the genes responsible for sporogenesis. Venn diagram and clustergram analysis revealed that 116 genes (>9 fold expression) (**Fig. 8 & Fig. 9**) were unique to mycelium, sporangium, zoospores and 24hr challenge inoculated Kufri Bahar leaf sample. In future, the highly regulated genes will be validated through real time PCR as well as through dsRNA transfection studies to prove sporogenesis.

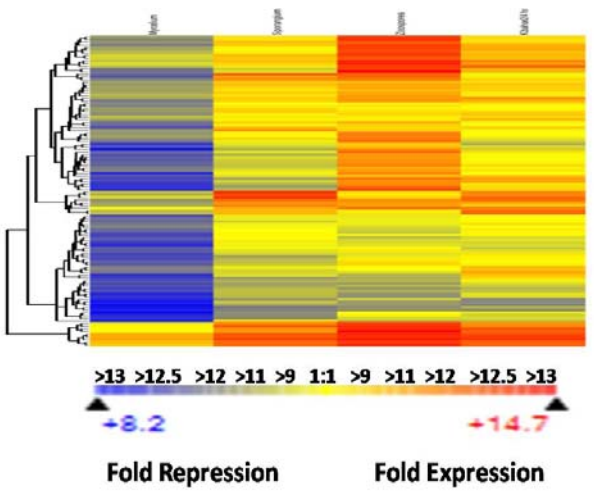


Fig. 8: *Clustergram shows the different classes of gene expression profiles. Out of 18,078 P. infestans genes, 116 genes were classified as unique genes and belongs to mycelium, sporangium, zoospores and Kufri Bahar infected samples (samples drawn after 24hrs of challenge inoculation)*

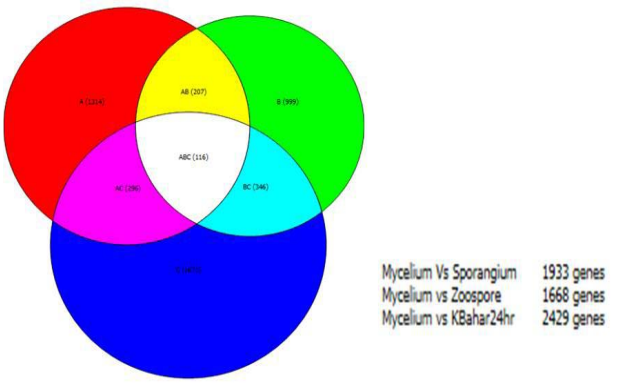


Fig. 9: *Venn diagramme shows the expression of unique genes in sporangium (a), zoospores (b) and Kufri Bahar samples drawn after 24hrs of challenge inoculation (c)*

Expression of *Npt II* protein in SP 951 and RB Kufri Jyoti transgenic hybrids

Semi-quantitative reverse transcriptase PCR was performed to confirm the co-integration of *NptII* gene in the genome of SP951 and its hybrids (KJ-16, KJ-65, KJ-66 & KJ-77). Expression of *NptII* transcript was detected by using *Npt-II* gene specific primer (Npt-II-F 'GAGGCTATTCGGCTATGACTG NptII-R 'GCGATACC GTAAACACGAGG) in all the selected Kufri Jyoti hybrids as well as in SP951 transgenic line. The studies revealed an expected 690 bp fragment size (**Fig. 10**) in parental line SP951 and Kufri Jyoti hybrids; whereas absence of fragment was observed in Kufri Jyoti cultivar indicating non specificity of the gene. Expression of marker gene in the genome of Kufri Jyoti hybrids indicates the co-integration of *Npt-II* gene and confirmed the bioefficacy of the RB transgenic hybrids.

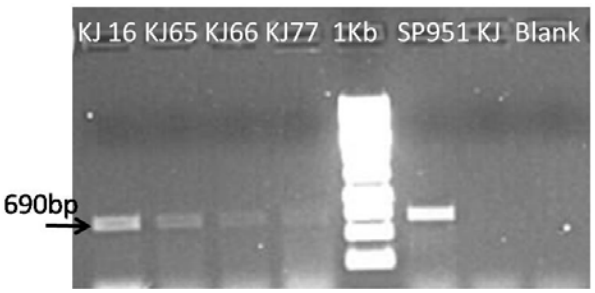


Fig. 10: *Reverse transcriptase PCR amplification of NptII gene expression from the Kufri Jyoti hybrid lines*

Disease epidemiology

The JHULSACAST forecasting model developed for Punjab predicted late blight accurately this year also. The weather conditions were satisfied on October 31, 2013 and the disease appeared (village Macchiwara in district Ludhiana) on November 7, 2013. Similarly, the model predicted late blight accurately in western Uttar Pradesh. Accordingly, the farmers were advised through press and All India Radio to protect the crop through prophylactic sprays. Three software modules have been developed for management of late blight i.e. i) decision rules for forecasting first appearance of late blight in plains during rainy and non-rainy years based on temperature, RH, and rainfall data, ii) decision rules for need based application of fungicides, and iii) regression models for yield loss assessment. All these modules have been combined and a web based decision support system for western Uttar Pradesh has been developed and hosted on CPRI server for the direct benefit of the farmers.

INDO-BLIGHTCAST- a web based forecasting model, which is applicable pan India, has been developed to predict the first appearance of late blight disease using daily weather data of meteorological stations. This is an improvement over the JHULSACAST model, which requires hourly data of temperature, relative humidity and daily rainfall. INDO-BLIGHTCAST requires only daily weather and does not need local calibration for different regions. Hence, it is more robust and its predictions are broader based. This model has two modules one for data entry and the other for the general users to see the status of late blight forecast (**Fig. 11**). Green colour indicates that late blight is not likely to appear soon; yellow colour indicates that late blight would appear very soon; and red colour indicates that the weather conditions have become suitable for late blight and it can appear any time within fifteen days. Thus, depending upon the time required for taking control measures, the user may start preventive measures at yellow or red colour indication. The model has been developed and tested using the data on late blight appearance monitored at CPRI regional stations and AICRP centres over the past several years.

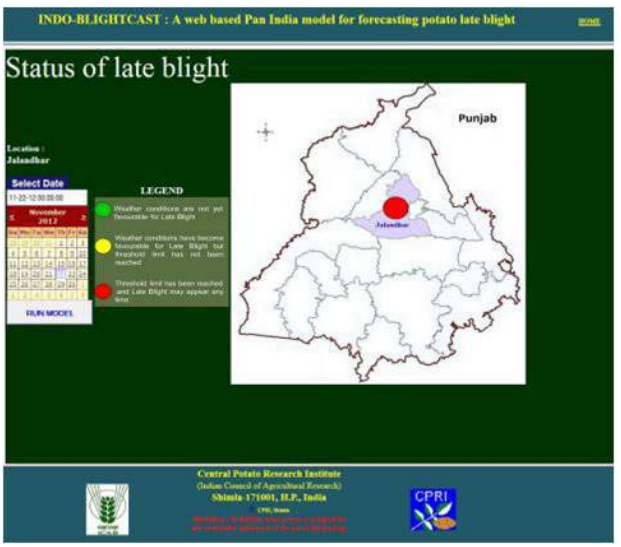


Fig. 11: *Indo-Blight Cast- A disease forecasting web based system*

Disease Management

Evaluation of rhamnolipid based formulation against *P. infestans*

Rhamnolipid based formulation was tested for its phytotoxicity and bioefficacy on potato plant against late blight. The result from detached leaves showed a significant reduction in lesion area when the leaves were treated at a concentration of 0.2% (lesion area 0.06 cm^2 as compare to control 9.8 cm^2 on 5th day of inoculation). However, at concentration 0.15% and below a lesion area of 1.5 cm^2 and more was observed on 5th day of inoculation (**Fig. 12**). The formulation was also tested for its phytotoxicity and no phytotoxicity was observed up to 0.25% concentration on whole plant (**Fig. 13**).

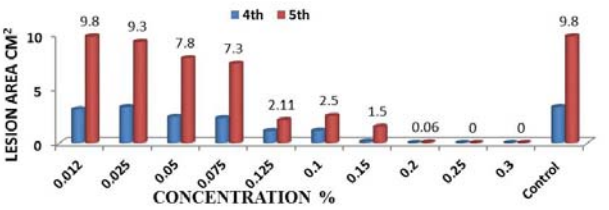


Fig. 12: *Effect of rhamnolipid-based formulation on late blight lesion development on potato leaves*

Phytotoxicity at 0.3%

No phytotoxicity at 0.25%

Fig. 13*: Evaluation of rhamnolipid for phytotoxicity on potato plant*

Performance of rhamnolipid based formulation for late blight management

A field trial was carried out to evaluate a rhamnolipid based formulation for management of late blight at Jalandhar in Punjab. Four sprays of the rhamnolipid based formulations were applied @ 0.25% at 7 day interval starting from first appearance of late blight in the adjoining plots. Spray of rhamnolipid based formulation resulted statistically significant decrease in disease severity over the control. The final disease severity in plots sprayed with rhamnolipid was 72.5% as compared to 94.5% in unsprayed control. The final disease severity was 9.25% in plots sprayed with mancozeb, 18.7% in case of propineb and 56.2% in Azoxystobin. No statistically significant increase in yield or decrease in tuber infection over the unsprayed control plots was observed by sprays of rhamnolipid. Rhamnolipid based formulation was also tested under field trials at two locations at 0.25% concentration along with three contact fungicides in Uttar Pradesh. At Modipuram terminal disease severity was 45% as compared to control (100%) while at Lavad (farmer field) it was 47.50% (**Fig. 14)** as compared to control (92.50 %).

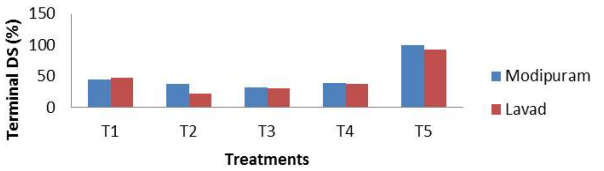


Fig. 14: *Evaluation of rhamnolipid based formulation against late blight of potato at two locations (Meerut & Lavad); T1: rhamnolipid (0.25%), T2: Mancozeb (0.2%), T3: Chlorothalonil (0.2%), T4: Propineb (0.2%), T5- control*

Integrated disease management using bio-agents can reduce the number of fungicides sprays for managing late blight. In this effort an experiment was conducted for three years for integrated management of late blight. Among 10 treatments, treatments combination- *Bacillus subtilis* (B5) + *Trichoderma viride* (before disease appearance) - Cymoxanil based fungicide (at disease appearance) and subsequently *B. subtilis* (B5) + *T. viride* spray was found highly effective with lowest disease severity (31.67%) compared to control (90.0%). Similarly, developed botanical formulation was tested in field against late blight of potato at two concentrations (1.0 & 2.0%) and 2.0% formulation showed better results.

It is known that *P. infestans* changes its behaviour very quickly with prolonged exposure to fungicides. Therefore, new fungicides need to be tested regularly to decide spray schedules for managing the disease. In this context last year experiment was repeated during current season. Amongst eight treatments, treatment combination of mancozeb (0.2%) - mancozeb (0.2%) + dimethomorph (0.2%) – mancozeb (0.2%) + dimethomorph (0.2%) recorded lowest disease severity (21%) as against control (93.3%) Micronutrient boron used with different combinations of fungicides showed less disease severity than fungicides alone.

Induction of resistance to *Phytophthora infestans* by phosphorus acid and BABA

Plants defend themselves from pathogen infection through a wide variety of mechanism that can be local or systemic, constitutive or inducible. Kufri Chandramukhi plants were sprayed with â- amino butyric acid (BABA) and phosphorus acid (1g/L and 2g/L) and then challenge inoculated with *P. infestans*. The results showed that foliar application of BABA and phosphorous acid @ 2.0g/L resulted in 60 and 80% reduction in disease after 55-60 days of planting compared to control. The expression of the defence related genes *â-1,3 glucanase*, *phytophthora inhibitor* and *cyclophilin* was analysed by real time polymerase chain reaction. All three defence related genes were up regulated in response to *P. infestans* infection. In addition, a higher level of *â-1, 3 glucanase* gene induction was detected in 2.0g/L foliar application treatment after 72 hrs of pathogen inoculation compared to control (**Fig. 15**). While, the phytophthora inhibitor induction was found higher after 120 hrs of pathogen inoculation compare to control treatment (**Fig. 16**).

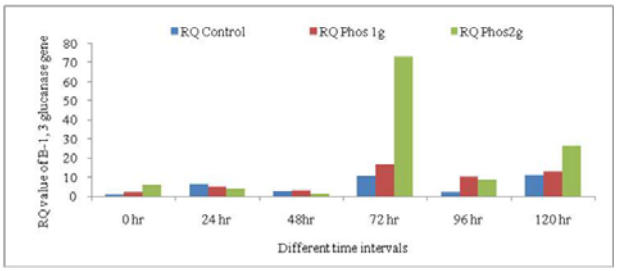


Fig. 15: *Effect of phosphorous acid treatment on the expression of â -1,3 glucanase gene during P. infestans infection of potato*

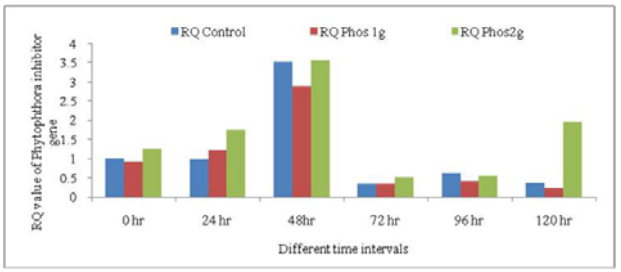


Fig. 16: *Effect of phosphorous acid treatment on the expression of phytophthora inhibitor gene during P. infestans infection of potato*

Breeding cultivars for multiple disease resistance for Indian hills and plateau region

Late blight and viruses, particularly PVY are the major impediments for potato cultivation in entire potato growing areas in India. Breeding cultivars having tolerance to these biotic stresses, using marker assisted selection (MAS) has been initiated in the institute. Recently the specific markers have been validated in parental lines which were inter-crossed to pyramid multiple disease resistance in single host back ground. MAS will be practiced in the segregating progenies that will reduce the time to develop new varieties having multiple disease resistance.

A total of 1, 04,651 hybrid TPS were produced from 69 successful crosses among selected late blight resistant parents attempted at Kufri, Shimla and Shillong. About 12,800 seedlings of 18 crosses were screened against late blight under controlled conditions at Shimla and 1489 resistant seedlings were selected. The highest number of resistant seedlings were obtained in the cross CP-2379 x Kufri Himalini (19.2%) followed by CP-2370 x Kufri Himalini (11.6%), Kufri Arun x CP-2407 (11%), CP-3198 x Kufri Girdhari (10.9%) and CP-2379 x Kufri Girdhari (10.8%). At harvest 146 clones were obtained. At Shillong, 348 clones have been selected from 12 crosses based on tuber characters and resistance to late blight. In the initial stages (F_1C_1 to F_1C_5), 1259 genotypes were evaluated under natural field conditions at Kufri and Shillong for their disease resistance and adaptability and 568 clones were selected.

In advanced stage trials at Kufri, 16 hybrids were evaluated in replicated trials and 6 were selected. Hybrid SM/00-42 has been identified for introduction into AICRP (P) for multi-location trials. At Shillong, 5 hybrids were tested in three replications for late blight resistance and hybrid LBY-15 showed better level of resistance against late blight and none of the hybrids showed higher yield than Kufri Girdhari. At Ootacamund, seven hybrids were evaluated in replicated trials and one hybrid viz. SM/02-07 (24.5 t/ha) out yielded the best control Kufri Girdhari (23.9 t/ha).

Identification and pyramiding of R-Genes linked to late blight resistance using marker assisted selection

R genes identification linked to late blight resistance:

Seventy-eight (78) potato (*Solanum tuberosum*) accessions were screened for presence of late blight resistance genes *R1* and *R3a* utilising PCR based markers R1AS (1400 bp), COSA (210 bp) and R3 (1380 bp) (**Fig. 17).** Ten potato accessions viz., CP1604, CP1608, CP1651, CP1685, CP2001, CP2378, CP2379, CP2399, CP3216 and CP3788 showed presence of *R1* gene, while 7 accessions viz., CP3171, CP4220, CP4223, CP4238, CP4240, CP4329 and CP4330 possessed both *R1* and *R3a* genes.

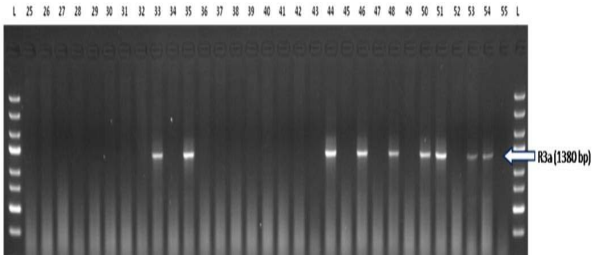


Fig. 17: *Screening potato germplasm lines for presence of R3a gene*

R genes pyramiding:

Eighteen clones possessing stacked R1and R3a genes (identified during the last year) were evaluated for late

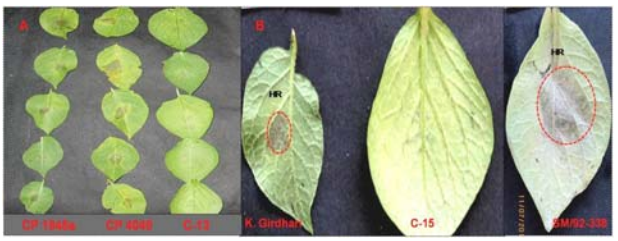


Fig. 18*: A: Phenotype of the clone#13 having stacked genes R1 and R3a compared with parents of the cross (CP 4045 × CP1945a)*
B: Clone#15 compared with parents, SM92338 & Kufri Girdhari. Both of these clones were scored as highly resistant; while CP 1945, CP 4045 and SM /92-338 scored MR and Kufri Girdhari scored resistant

blight resistance through detached leaf bioassay (**Fig. 18**). The resistance level in these clones ranged from resistant to highly resistant. All clones were advanced to F_1C_2 generation. These selected clones will be field screened for late blight resistance under natural epiphytotic conditions and desirable agronomic traits.

Pyramiding multiple disease resistance in potato using marker assisted selection

R genes identification linked to PCN resistance:

Sixty-three accessions, including 58 advanced potato hybrids (late blight & PCN resistant) and 5 varieties i.e. Kufri Jyoti, Kufri Giriraj, Kufri Girdhari, Kufri Swarna and Kufri Neelima, were screened for presence of genes conferring resistance to *Globodera* spp. using gene specific markers (**Fig. 19**). H1 gene imparting resistance against *Ro1* pathotype of *Globodera rostochiensis* was present in 37 accessions. *Grp1* gene conferring resistance to *G. pallida* (TG432 marker) was present in 24 accessions. SNP marker HC_QRL was present in 44 accessions and marker SPUD 1636 associated with the Gpa5 & Gpa6 QTL was present in 4 breeding lines and variety, Kufri Swarna.

Identification of parents with multiple disease resistance:

Following this strategy, fourteen elite genotypes possessing multiple disease resistance genes with late blight (R1, R2 or R3), PVY resistance (*Ryadg* gene) and PCN resistance (*HC* or *H1*) namely, CP 2067, CP 3771, CP 4039, CP 4046, CP 4047, CP 4052, CP 4054, CP 4055, CP 4056, CP 3400, CP 2137, CP 3904, CP 3907, MP /04-578 were identified through MAS.

Pyramiding multiple disease resistance:

Parental lines possessing multiple disease resistant genes were inter- crossed to stack multiple genes in single host back ground. Twenty five crosses were attempted among parents possessing multiple resistant genes and about 13,968 hybrid TPS were obtained in 15 successful crosses. These hybrid seeds will be used next year to raise the segregating population of different crosses for the identification of recombinants with multiple disease resistance genes and yield through MAS. Finally few selected hybrids will be challenge inoculated for confirming the resistances. This programme is expected to produce superior cultivars parental lines with multiple disease resistances.

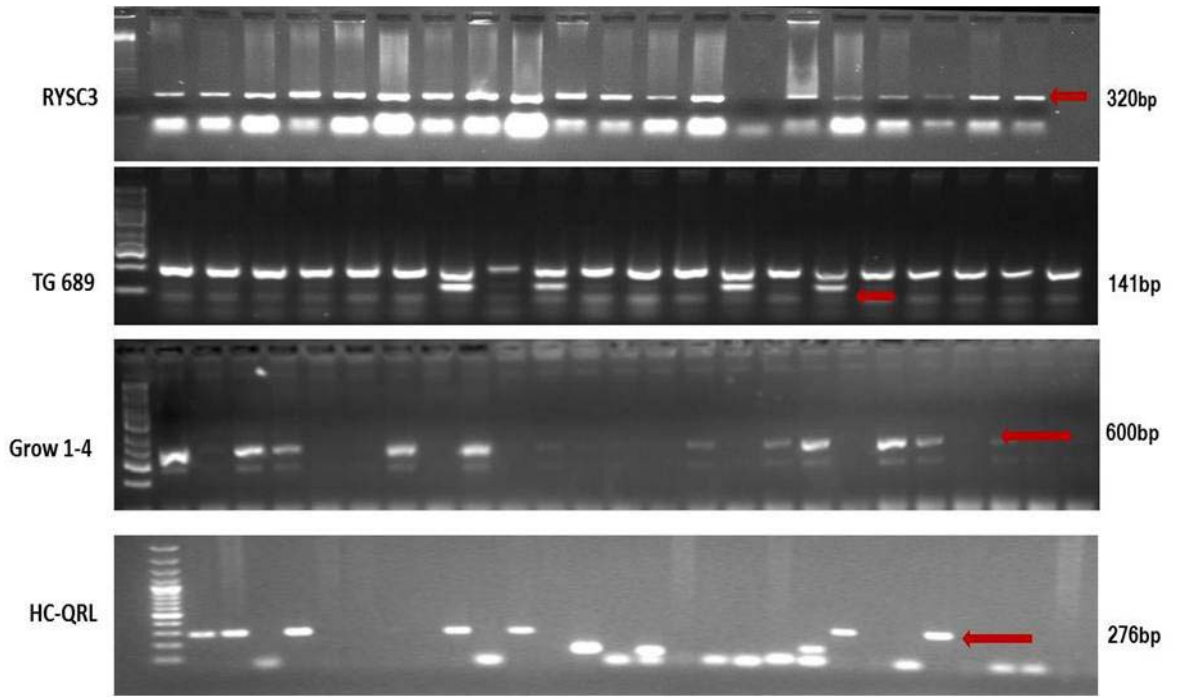


Fig. 19: *Resistance genes detected by PCR based marker linked to PVY (slide 1) and potato cyst nematode (slides 2, 3 and 4)*

Programme 2: Molecular characterization, detection and management of potato pathogens

Maintenance and mass multiplication of potato viruses for antisera production

Pure cultures of Potato virus X, S, Y, A, M and PLRV were maintained on standard hosts while ToLCNDV-potato was maintained in infected potato tubers, PSTVd on tomato and potato germplasm *viz*., CP nos.1291, 1641, 1874, 2419, and 3166. Two viruses, *Potato virus Y* and *Potato virus S* were propagated in the propagative hosts and the purified virus particles were used to inject rabbit to raise antisera. Twenty five microlitre of each antisera was obtained with 1:4096 titre. ELISA kits were prepared for five viruses and supplied to Seed Technology Division for testing 10,000 samples under seed production. Leaves from white fly inoculated *Nicotiana benthamiana* plants were collected and processed for purification of ToLCNDV-potato but the virus yield was very low.

Screening of germplasm accessions for virus resistance

Sixty four germplasm accessions were tested for PVY and PVX resistance through mechanical inoculation and virus titre was tested by DAS-ELISA. Fourteen CP nos. were found having combined resistance to PVX and PVY, 24 CP nos. to PVY and 6 CP nos. to PVX, respectively. Twenty CP nos. were found susceptible to both PVY and PVX.

Testing of potato viruses under Standard Operating Procedure for Accredited Test Laboratory (NCS-TCP) through DAS-ELISA

Two hundred and twenty samples of M/s Technico Agric Science Pvt Ltd. Baddi, Distt. Solan (HP), M/s McCains India Pvt Ltd., and M/s PepsiCo India Holdings, Channo, Distt. Hoshiarpur (Punjab) were tested for the presence of PVX, PVS, PVY, PVA, PVM, and PLRV by DAS- ELISA and ToLCNDV-potato by PCR under Accredited Test Laboratory (NCS-TCP). Besides, 85 samples from regional stations of CPRI, AICRP on Potato centres and M/s Technico Agric Science Pvt Ltd. Baddi, Distt. Solan (HP) were also tested for the above seven viruses through DAS-ELISA/ PCR under non-ATL.

Post entry quarantine testing

Fifteen samples of different potato varieties of M/s Pepsico India Holdings Pvt Ltd, Channo, Distt. Hoshiarpur (Punjab) and Crop Improvement Division were planted in the quarantine glass house and tested for quarantined pathogens through DAS-ELISA and RT-PCR.

Testing of mericlones/ germplasm for PSTVd and virus infection

A total of 83 *in vitro* samples/mericlones of Crop Improvement Division and five samples from M/s Technico Agric Science Pvt Ltd, Baddi, Distt. Solan (HP) were tested for PSTVd infection through RT-PCR and quarantine viruses through DAS-ELISA. Eighty eight samples from Seed Technology Division were tested for PSTVd, PLRV, PVX, PAMV and ToLCNDV-potato through PCR/RT-PCR assay. Forty seven samples from Gwalior, 20 samples from Modipuram, 21 samples from Crop Improvement Division were tested for ToLCNDV-potato, and/PLRV/PVX through PCR/RT-PCR assay. Twenty eight mericlones from Crop Improvement Division and twenty six tissue cultured plants from Division of Seed Technology were tested for PVY, PVM, PVS and PVA, while 23 samples from CPRS, Gwalior were tested for PVA by RT-PCR.

Collection of virus infected samples and EM examination

Field visits were conducted in different potato growing areas of Western UP *viz*., Mawana, Kharkoda, Muzaffarnagar, Siwaya and Machhari. Plants showing mosaic, chlorotic spots (**Fig. 20**) and upward/ downward curling (**Fig. 21**) were collected and processed for electron microscopy, ELISA and PCR.

PCR assay using specific primers revealed that all the samples collected from different places were positive for ToLCNDV-potato indicating the very high incidence of the virus in these areas (Fig. 22).

Fig. 20: *Potato leaves showing chlorotic spots and mosaic symptoms*

Fig. 21: *Apical leaf curl symptoms in potato field and single plant showing the apical leaf curl symptoms*

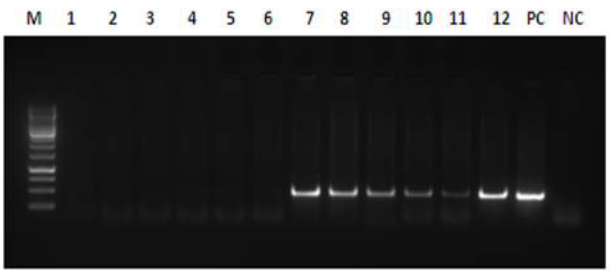


Fig. 22: *PCR analysis of tissue cultured plants and field samples for ToLCNDV-potato; lanes M= ladder, 1-6= tissue cultured plants, 7-12= samples from different locations*

Transmission studies on ToLCNDV-potato

Attempts were made to transmit ToLCNDV-potato from infected potato plants to *N. benthamiana* by *B. tabaci*. After 10 to 15 days of inoculation, the inoculated plants developed mild mosaic symptoms. The inoculated plants were checked under electron microscope and negatively stained leaf dip preparations showed geminate particles (**Fig. 23**). The inoculated plants were also tested by PCR and results were found positive thus confirming the transmission of the virus.

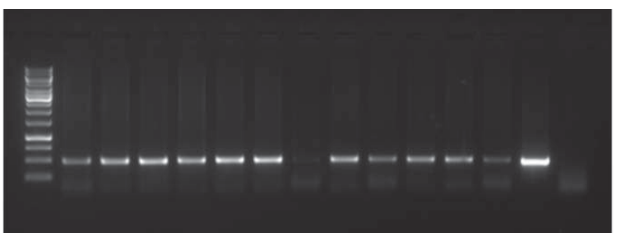


Fig. 23: *PCR analysis of N. benthamiana plants for ToLCNDV-potato*

Electron microscopy and immuno gold electron microscopy of virus detection

Electron microscopy of negatively stained preparations showed geminate particles from the samples showing apical leaf curl symptoms (Fig. 24) and very high concentration of flexuous filamentous particles from mild and severe mosaic affected plants. Decoration of flexuous filamentous particles from mild and severe mosaic plants showed very high concentration of PVX followed by PVY and PVS.

Immuno-gold electron microscopic detection of PVA showed clear elongated particles (**Fig. 25**). The IgG conjugated gold nano particles were allowed to incubate with partially purified PVA infected sap and examined under TEM which showed a good concentration of filamentous flexuous long particle coupled with several colloidal gold (CG) nano particles revealing the presence of PVA (**Fig. 26**). Since only the homologous virus was decorated with IgG-CG complex, it can be used for specific detection and diagnosing a targeted virus even in mixed infection of viruses with similar morphology.

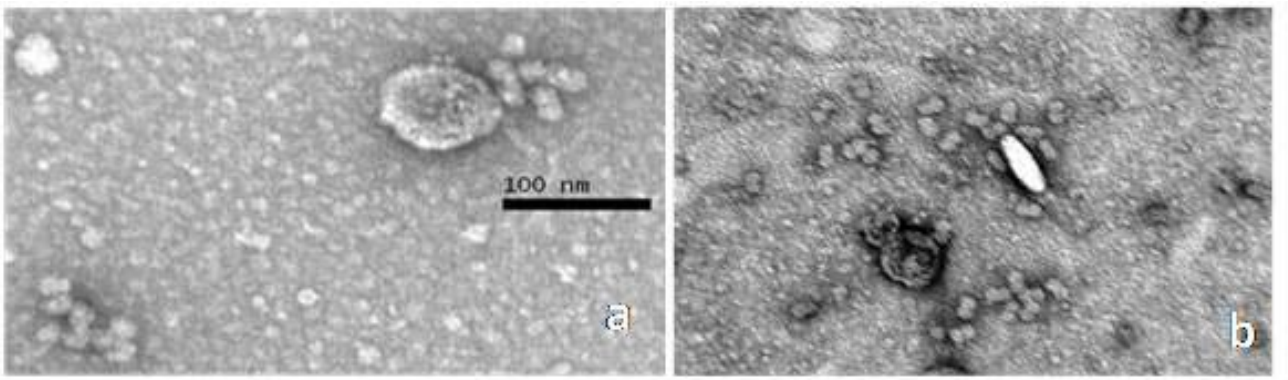


Fig. 24: *Electron micrograph showing geminate particles from N .benthamiana transmitted with ToLCNDV-potato (a); geminate particles from leaf curl affected potato plants (b)*

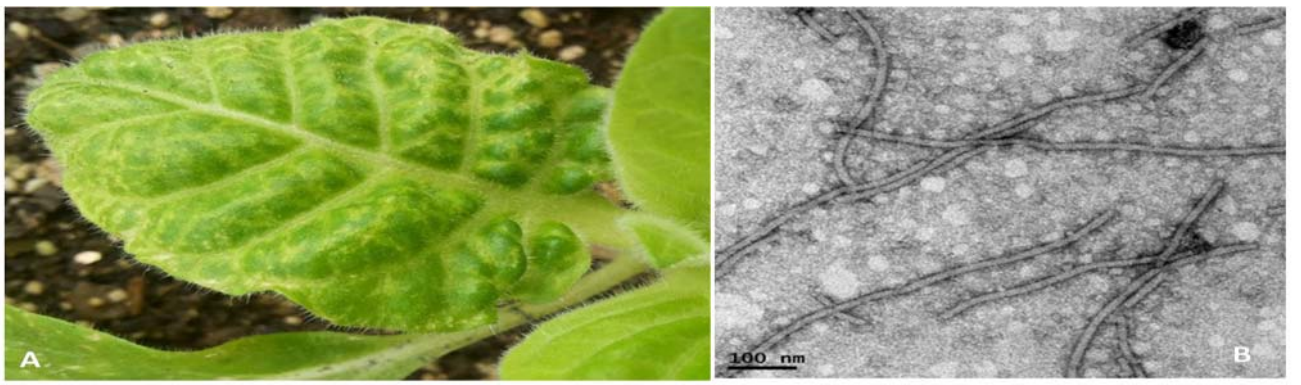


Fig. 25: *Pure culture of (A) and Electron microscopic image of Potato virus A (B)*

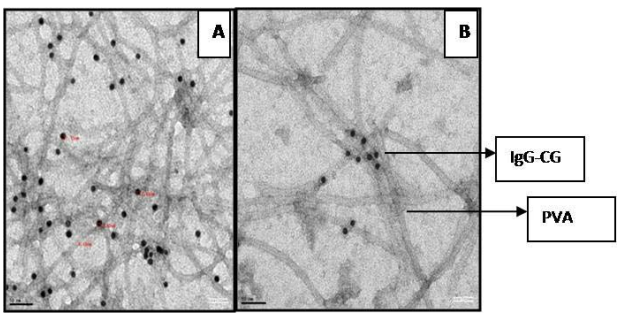


Fig. 26: *Immuno-gold electron microscopic detection of Potato virus A: PVA coupled with IgG-CG complex (A) & magnified view of the same (B)*

Development of triplex LFIA for simultaneous detection of PVX, PVA and PVM

Triplex lateral flow immune assay (LFIA) for simultaneous detection of PVX, PVA and PVM was standardized and validated using forty randomly collected field samples (**Fig. 27**). DAS-ELISA was performed for the same samples and the results were comparable to LIFA strip results.

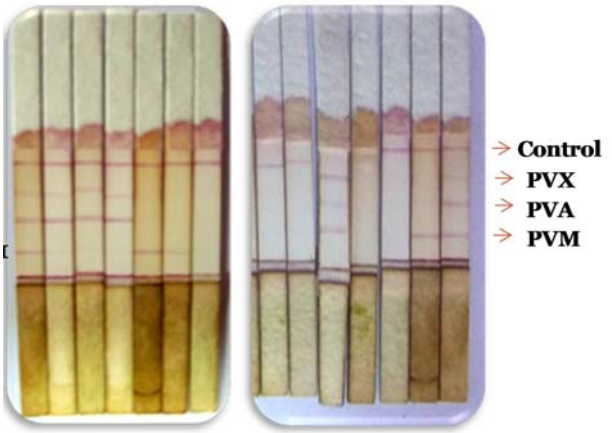


Fig. 27: *Lateral flow immune assay detection of three potato viruses using single strip*

RT-PCR assay for detection of potato viruses

Four sets of primers targeting coat protein and replicase gene of CMV and TMV were designed and used for RT-PCR protocol standardization at different annealing temperatures. Primer sets, which showed a single specific amplified band in positive control and without any non-specific amplification in healthy control (**Fig. 28**) were selected for further use in detection.

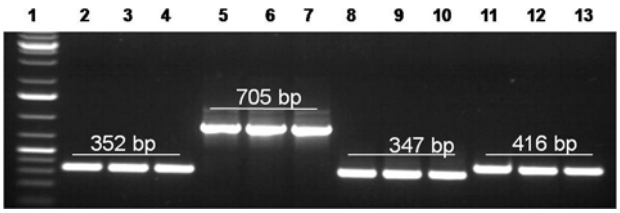


Fig. 28a: *Optimization and standardization of uniplex RT-PCR for TMV detection using cDNA of positive control. Lanes 1=100bp DNA ladder, 2-4= TMV 1F &1R, 5-7= TMV 2F & 2R, 8-10= TMV 3F & 3R, 11-13= TMV 4F & 4R at three annealing temperatures (53, 56, 59^{0}C)*

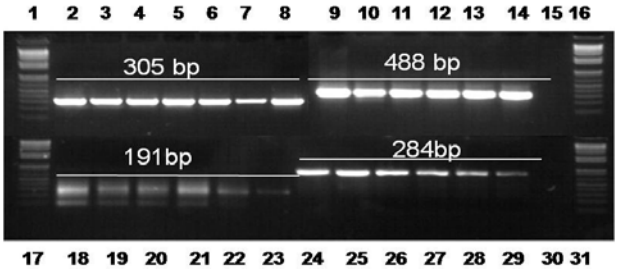


Fig. 28b: *Optimization and standardization of uniplex RT-PCR for CMV detection using cDNA of positive control. Lanes 1&16= 100bp DNA ladder, 2-7/8= CMV 1F & 1R, 9-14= CMV 2F & 2R, 18-23= CMV 3F & 3R, 24-29= CMV 4F & 4R at six annealing temperatures (52, 54, 56,58, 60, 62^{0}C)*

Multiplex RT-PCR for simultaneous detection of potato viruses

A multiplex RT-PCR protocol was also developed to detect five viruses simultaneously. Five pairs of specific primer were designed for single and multiplex RT-PCR amplification of conserved areas within the coat protein gene. The specific primer sets produced amplicon of 305, 363, 408, 452 and 565 bp representing PAMV, PVS, PVM, PLRV and PVX, respectively in multiplex RT-PCR (**Fig. 29**). The protocol was validated using field samples (leaves and tubers) collected from different parts of India.

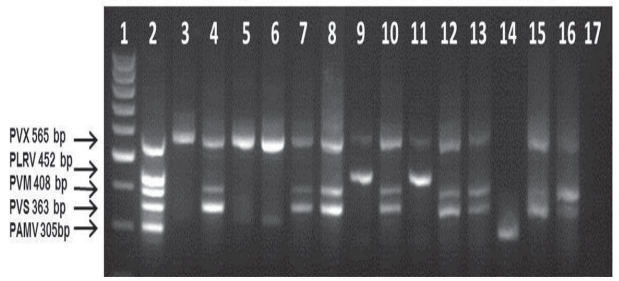


Fig. 29a: *Simultaneous detection of multiple potato viruses from field samples (tubers) using multiplex RT-PCR. Lanes 1=100 bp DNA ladder, 2= positive control, 3-16= field samples, 17= water control*

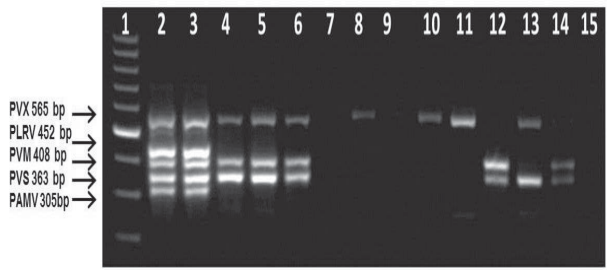


Fig. 29b: *Simultaneous detection of multiple potato viruses from field samples (leaves) using multiplex RT-PCR. Lanes 1=100 bp DNA ladder, 2= positive control, 3-14= field samples, 15= water control*

Real Time PCR for detection of potato viruses

Two sets of primers-probes were designed from the coat protein gene region of *Potato virus X* and both Sybr green (**Fig. 30**) and Taqman based qPCR assays were standardized for detection and validated.

Standardization of Real time PCR protocol for specific detection of PVA has been completed with respect to its primer concentration, annealing temperature and master mix along with generation of standard curve has been completed (**Fig. 31**).

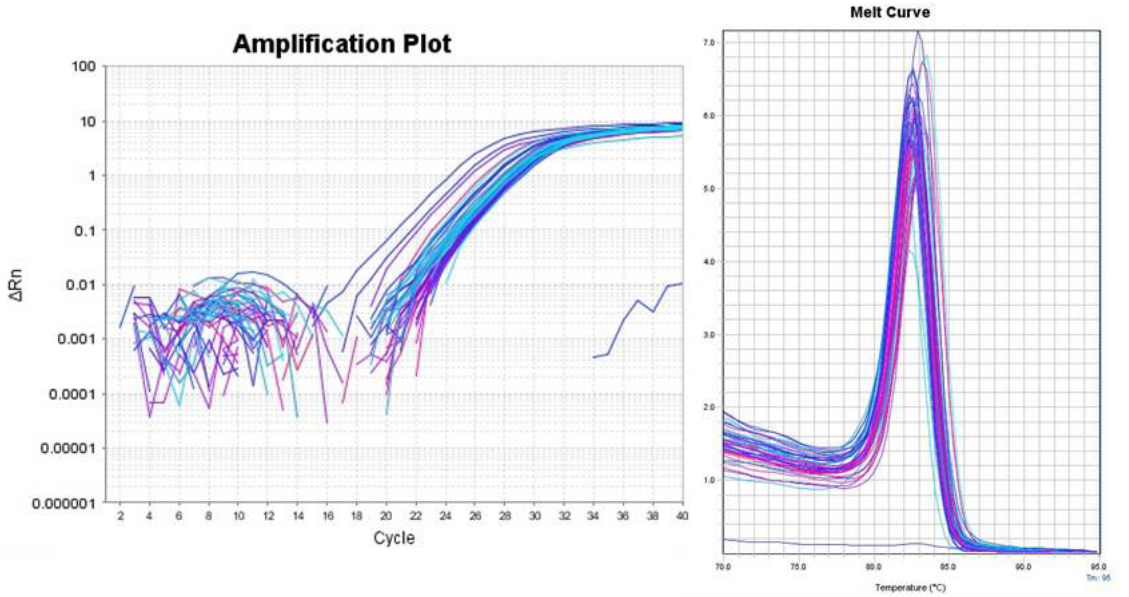


Fig. 30: *SYBR green based qRT-PCR detection of Potato virus X – Amplification plot and melt curve analysis showing the specific melting peak of amplicons in infected samples*

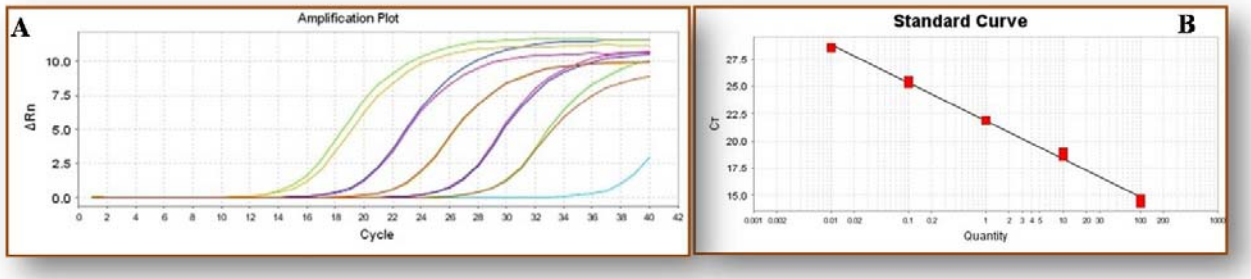


Fig. 31*: Amplification plot (A) and standard curve (B) of qRT-PCR of PVA*

Transgenic for virus resistance

The replication-associated protein gene (*AC1*) of the virus is being used for engineering pathogen derived resistance against ToLCNDV-potato in two popular potato cultivars Kufri Pukhraj and Kufri Badshah. Transgenic lines of Kufri Badshah (2 lines- GTLC2-90, GTLC2-127) and Kufri Pukhraj (4 lines -KPLC2-13, KPLC2-37, KPLC2-53 and KPLC2-54) lines carrying hairpin replicase constructs which were found resistant to ToLCNDV-potato were planted in containment facility and the tubers have been harvested for studying the tuber characters. Southern blot analysis was carried out for these six lines and copy number was determined (**Fig. 32**). All the PVY transgenic lines were multiplied and maintained under glasshouse facility (**Fig. 33**) and in tissue culture facility as well.

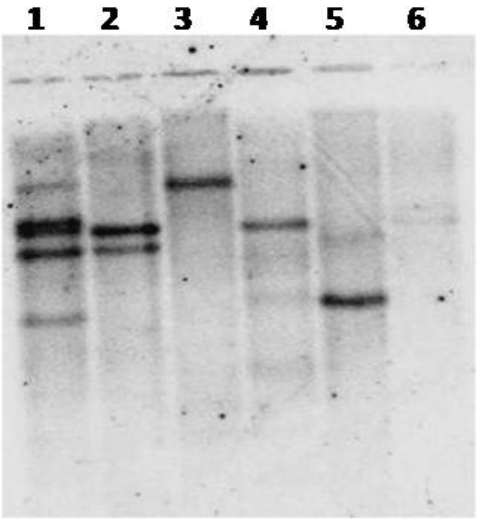


Fig. 32: *Southern blot analysis of selected ToLCNDV-potato resistant transgenic lines; lanes 1= GTLC2-127, 2= GTLC2-90, 3= KPLC2-13, 4= KPLC2-37, 5= KPLC2-53, 6= KPLC2-54*

Fig. 33: *PVY transgenic lines under glasshouse conditions*

Comparative genome analysis of potato viruses

Total one hundred and twenty samples collected from different potato growing regions were tested in DAS-ELISA using conventionally raised polyclonal antibodies. Fifty three positive PVX samples were selected for further coat protein gene characterization. These isolates had 94.8-100.0% similarity in coat protein gene sequence at nucleotide sequence level. In a phylogenetic analysis, most of the isolates (34 isolates) were grouped with the isolate sam-15 (GU144351) and sam-13 (GU144353) from Scotland. Out of remaining nineteen isolates, thirteen of them were found in a separate cluster with two Indian isolates reported earlier (GU256064 and FJ643623). Six isolates from Shillong and Bihar were grouped with the isolates from China, Australia and Russia. A 496 bp region of coat protein (CP) gene of five PVS isolates was amplified, cloned in TA cloning vector and sequenced. Nucleotide sequence of CP genes of these five isolates shared 93 to 97% homology with the sequences already reported in GenBank database. Complete genome of two isolates of PVS were amplified (one each from Jalandhar and Shimla) cloned in TA vector, sequenced. Comparison of Indian isolates of PVS with other PVS isolates (Andean and Ordinary) showed that our PVS isolates are quite distinct (89-93% similarity with ordinary strains and 79-81% similarity with Andean strain) from available PVS strains in NCBI database.

Investigations on prevalence of *Potato virus Y* (PVY) strains were carried out by drawing samples from different locations of India. The results of ELISA and RT-PCR revealed the existence of PVY^{O}, PVY^{C}, PVY^{N} PVY^{NTN} in many of the states (**Fig. 34**). The nucleotide sequence of the amplicons had a nucleotide homology of 98 % with reported PVY^{NTN} sequences. ELISA and RT-PCR assays revealed the existence of different PVY strains in India. Helper component gene, P1 protein and coat protein gene of PVA has been amplified, sequenced and assembled. Sequencing of the remaining fragments or genes of PVA is in progress.

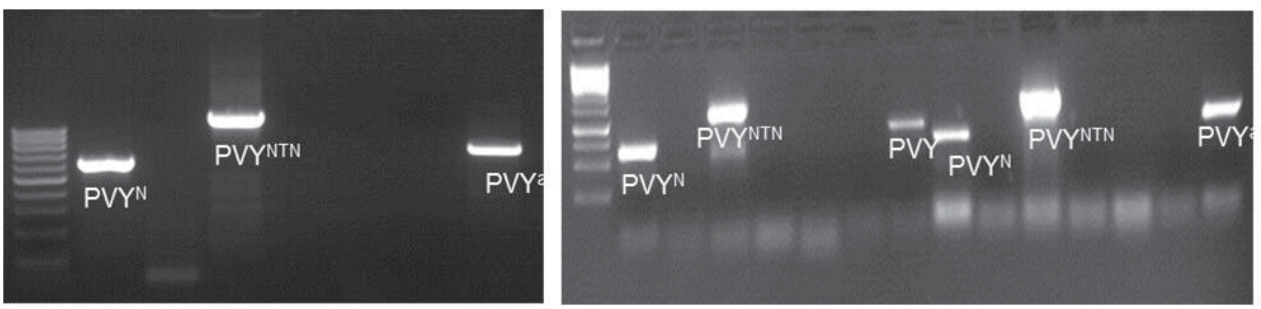


Fig. 34: *A representative gel image of RT-PCR amplification of PVY strains (PVY^{O}, PVY^{N} and PVY^{NTN}) from samples collected from different locations of India*

Programme 3: Characterization, detection and management of major soil and tuber borne pathogens of potato

Common scab (*Streptomyces* spp.) and black scurf (*Rhizoctonia solani*) are major tuber diseases of potato prevalent in large area especially where potato is grown year after year in the same fields without following recommended seed tuber treatment and crop rotations. Bacterial wilt and brown rot is another major soil and tuber borne disease prevalent in certain parts of the country. This disease is likely to increase with global warming. Understanding diversity in pathogen population is the foundation of successful disease management programme. Therefore, attention was paid to study in detail the genetic diversity prevalent in *R. solanacearum*, *Streptomyces* spp. and *R. solani.* A large number of isolates of *R. solanacearum* from Meghalaya and Uttarakhand were analysed for their biovars and phylotypes. A total of 34 *Streptomyces* strains collected from different parts of the country were studied with respect to their pathogenicity and analysis of 16s rRNA gene. Irrigation starting from tuber initiation stage onward is known to control common scab but this recommendation is not working at many locations. Therefore, the pathogenicity of different strains of *Streptomyces* species at different levesl of moisture in soil was studied so as to understand the role of soil moisture for control of the disease and revise the recommendation, if necessary. Identification of suitable seed and soil treatment to manage the major tuber diseases is of paramount importance. Field trials were carried out to manage bacterial wilt, common scab and russet scab diseases of potato and the best treatments identified. Management of storage rots in seed stocks prone to rotting during and after cold storage was investigated and the best chemical treatments to minimize the rots identified.

Characterization and detection of tuber borne pathogens of potato

Collection of isolates

Collected 47 isolates of *Ralstonia solanacearum* from West Khasi hills in Meghalaya, and 34 isolates of *Streptomyces* species from scab infected tubers obtained from Shillong, Raipur, Indore, Sunderban and Chhatisgarh during the current year. These isolates were purified and maintained in the laboratory for further study.

Biovar determination of *Ralstonia solanacearum* isolates

The strains of *R. solanacearum* isolated from wilt infected plants and tubers of potato (**Fig. 35**) collected from West Khasi hills of Meghalaya during 2013 and 2014 were characterized into biovars on the basis of their ability to utilize disaccharides and to oxidize hexose alcohols. The study revealed that out of 47 isolates, 23 (48.9%) belonged to biovar 2T, 21 (44.7%) to biovar 2 and 3 (6.4%) to biovar 3.

Fig. 35: *Symptoms of bacterial wilt (A) and brown rot (B) disease of potato*

PCR based identification and characterization of *R. solanacearum* isolates

Phylotype specific multiplex PCR (Pmx-PCR) confirmed all the isolates to be *R. solanacearum* as expected 280-bp fragment resulted in all the isolates following PCR amplification using the *R. solanacearum* specific universal primer 759/760. Pmx-PCR also revealed that three phylotypes namely phylotype I (Asian), phylotype II (American) and phylotype IV (Tropical) are prevalent in Meghalaya (**Fig. 36**). In Meghalaya, majority of strains belonged to phylotype IV (48.9%), phylotype II (44.7%) and only 6.4% belonged to phylotype I**.**

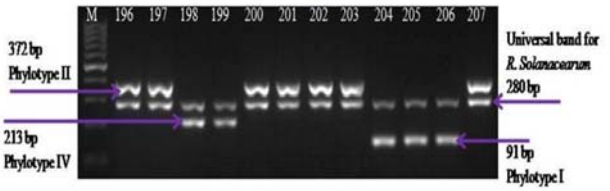


Fig. 36: *PCR based identification and phylotype affiliation of representative R. solanacearum strains from West Khasi Hills of Meghalaya*

Phylogenetic analysis of *egl* gene sequences of 114 *R. solanacearum* isolates from East Khasi hills and West Khasi hills districts of Meghalaya clustered all 41 phylotype II strains with reference strains IPO1609 (II-1), three phylotype I strains with reference strain GMI8254 (I-47), three phylotype I strains with reference strain MAFF211479 (I-45) and 59 phylotype IV strains closely clustered with references strain MAFF301558 (IV-8). However, eight phylotype IV strains did not cluster with any known sequevar reference strain (**Fig. 37**).

Identification and molecular characterization of *Streptomyces* species strains isolated from potato scab lesions

Pathogenicity test

Pathogenicity of all 34 *Streptomyces* strains, isolated from various types of scab symptoms on tubers (**Fig. 38**) was examined through tuber slice assay as described by Hao *et al*. (2009). All the strains were found pathogenic as necrosis was visible within 36 hours after inoculation on potato tuber disks. No necrosis or any colour changes of the tuber disks were observed when agar plugs without *Streptomyces* culture were used.

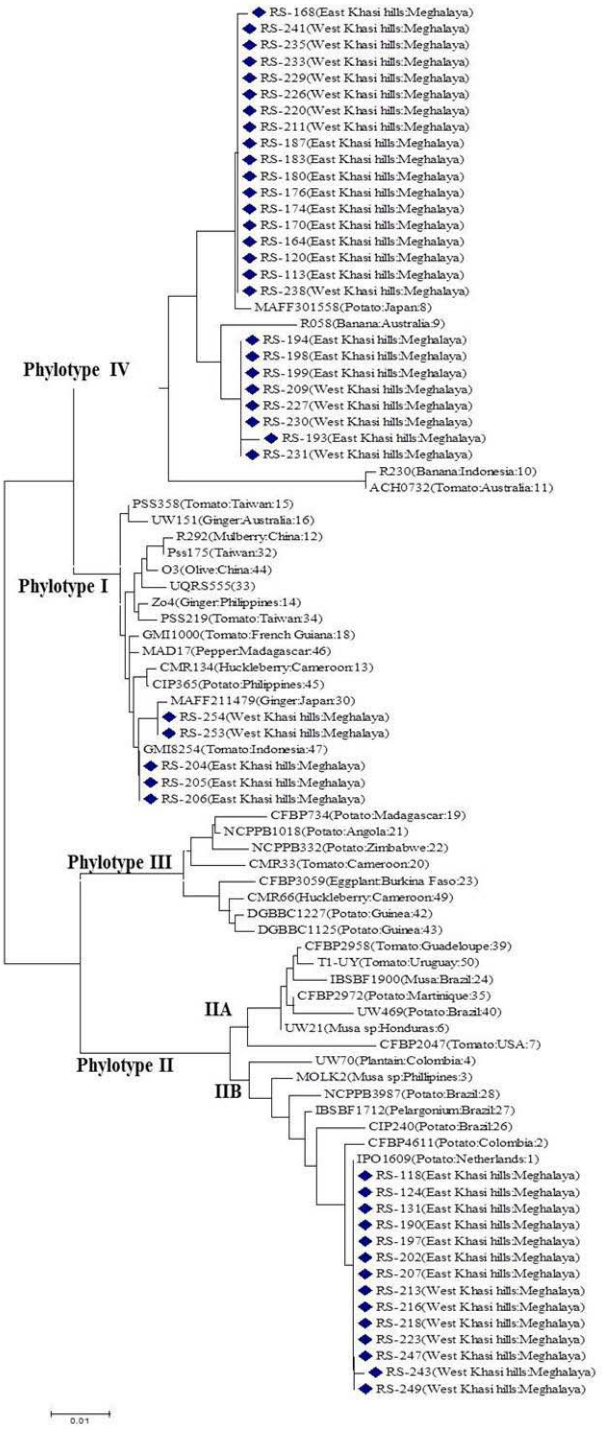


Fig. 37: *Phylogenetic neighbour-joining tree based on the partial egl gene sequences of strains from Meghalaya (NEH region of India) (blue circles) and Ralstonia solanacearum species complex reference strains, generated using MEGA-5 software. The number at each node is the bootstrap value (1000 replications). Scale bar represents 1 nucleotide substitution per 100 nucleotides. The phylotype branch includes representative strains from each location out of 114 strains during present investigation*

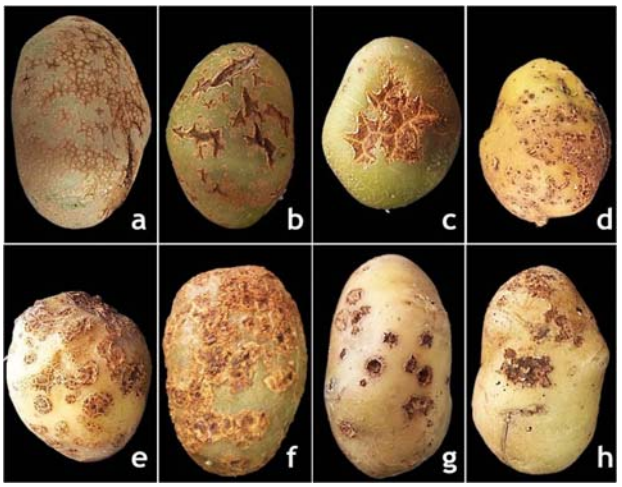


Fig. 38: *Various types of scab symptoms caused by Streptomyces species on potato tubers*

Molecular characterisation

The 16S rRNA gene was amplified from DNA of all 34 *Streptomyces* strains by PCR using the primers 16S-1F and 16S-1R. An expected size of 1500bp was obtained in all the cases. Of the thirty three *Streptomyces* strains tested by PCR using specific primers TxtAB1 and TxtAB2 to the txtAB operon, only twelve were found positive as revealed by the presence of expected 385bp txtAB amplicons.

Characterization of *Rhizoctonia solani* isolates into anastomosis groups

DNA of 26 *R. solani* isolates (collected from Himachal Pradesh, Madhya Pradesh, Arunachal Pradesh, Bihar etc) was extracted and their ITS region amplified through PCR using primers ITS 1/ ITS 4. An expected amplicon of 740bp resulted in all the isolates. The PCR products were further purified using Fermentas PCR purification kit and sequenced using both primers strands.The phylogenetic analysis grouped all the 26 *R. solani* isolates with AG-3 (potato) group.

Analysis of the genetic variability of selected *R. solanacearum* isolates through AFLP technique

Thirteen isolates of *R. solanacearum* (RS-2, RS-66, RS-132, RS-139, RS-146, RS-25, RS-53, RS-50, RS-135, RS-148, RS-206, RS-75 and RS-127) were selected based on diversity in virulent genes, phylotype and biovar for genetic variability studies through AFLP technique. Restriction digestion analysis was performed using *EcoRI* enzyme and restriction pattern was checked through agarose gel.AFLP analysis with 20 primer combinations (*EcoRI*-A/C/G/T with *MseI*-A/C/G; *EcoRI*-TG/AA/AC/AG/AT/TC/TT/TA with *MseI*-A/O) showed polymorphic bands which can be further used as a marker to identify phylotype or biovar.

Management of major soil and tuber borne pathogens of potato

Development of common scab by *Streptomyces* secies under different moisture regimes

Four strains of *Streptomyces* spp. isolated from deep pitted common scab (Str-8, *S. stelliscabies*, Str-17, *S. aureofasicns*), russet scab (Str-31, S. *europascabies*) and corky scab (Str-46, *S. scabies*) were evaluated at Jalandhar for development of the disease under three different moisture regimes. Observations recorded at harvest on potato tubers revealed that two strains *viz*. the strain 8 and 17 developed maximum disease incidence (15.4, 10.9%) and disease severity (6.4, 2.5%) under high moisture regime wherein the soil was kept always wet by irrigation every third day as compared to the low disease incidence (5.8, 7.1%) and disease severity (0.9, 1.7%) in plants subjected to minimum soil moisture *viz*. where the plants were irrigated only upon showing sign of temporary wilting. Similar results were obtained in a trial carried out at Patna. Incidence of the common scab was 76% in plants provided irrigation @ 750 ml for six times as compared to 33.3% in plants provided irrigation @ 250 ml for six times. The results revealed that the recommendation of providing excess irrigation from tuber initiation stage onward followed for control of common scab may not work for some strains of *Streptomyces* and alternate strategies need to be developed to manage the disease.

Evaluation of *Trichoderma viride* for management of common scab in farmers' field

Application of *T. viride* (A7) @ 150 kg/ha over the seed tubers in furrows at planting significantly reduced incidence and severity of common scab. Common scab disease incidence was reduced to 6.0% by application of the *T. viride* as compared to 12.0% observed in the untreated control. Similarly, the disease severity was reduced to 1.6% by application of *T. viride* as compared to 3.2% in untreated control.

Evaluation of chemicals for management of russet scab

Seed treatment with mancozeb @ 3kg/ton, application of ferrous sulphate @ 25 kg/ha, aluminium sulphate 25 kg/ha, Krosin AG (Streptomycine Sulphate IP 90%w/w + Tetracycline Hydrochloride IP (10%w/w) 100 ppm over seed in furrows or soil application of stable bleaching powder @ 300 kg/ha did not reduce significantly incidence and severity of the russet scab over the untreated control plots.

Combined management of black scurf and common scab

A combined treatment of *T. viride* + boric acid could reduce mean black scurf disease severity to 22.3% and common scab severity to 0.72% as compared to 70.9% severity of black scurf and 2.98% severity of common scab observed in the control plots. Results of the trial revealed that application of *T. viride* and boric acid seed treatment together was effective for the management of both common scab and black scurf diseases of potato.

Evaluation of chemicals for management of tuber rots in seed potato

Prevention of rotting in rot affected lots was studied employing spray treatments involving use of boric acid, Bavistin (carbendazim 50%WP), Krosin AG (Streptomycine Sulphate IP 90%w/w +Tetracycline Hydrochloride IP, 10%w/w) in different combinations. A combined spray of 0.2% Bavistin + 100ppm of Krosin AG on the seed tubers was the best since it reduced rotting of the seed tubers to 9.2% as compared to 17.7% observed in the unsprayed control.

Management of bacterial wilt in disease affected fields

A field trial on management of bacterial wilt was carried out at Bhowali, Uttrakhand and East Khasi hills of Meghalaya. None of the six seed and soil treatments evaluated during the current year was effective. However, the use of seed from brown rot free area exhibited minimum incidence of disease at both the locations.

Programme 4: Population dynamics and management of potato pests

Mapping of Aphid species complex infesting potato in India using molecular and conventional taxonomy approaches

Aphids are economically important polyphagous pests known to cause damage to many crops directly by sucking the plant sap, affecting yields and indirectly by transmitting the infectious plant viruses affecting both quality and yield. The seriousness of aphids demands the quick identification of aphid species infesting potato and their viruliferous nature for their timely management. An extensive field survey was carried out throughout Uttar Pradesh (16 districts) for collection of aphid samples for their identification at species level. Beside, yellow water traps were installed at four locations for collection of aphid species in the vicinity of Meerut. Collection of aphid species was also carried out at Raipur, Damtari, Kankar and Jagdalpur (Chhattisgarh), Gwalior (Madhya Pradesh) and Kanpur, Bijnor and Muzaffarnagar (Uttar Pradesh). *Myzus persicae* and *Aphis gossypii* were the most common species and high population (31-255/100 compound leaves) of these aphids were recorded on potato during first week of February, 2014 in different districts of UP. *Aulacorthum solani* (Kaltenbach) and *Brachycaudus helichrysi* (Kaltenbach), two new species of aphids were identified on potato through taxonomic identification in Faizabad region.

The aphids were identified using species specific primers and universal primers (658bp) specific to cytochrome oxidase I gene. All the steps required for total genomic DNA extraction, PCR amplification, gel elution, cycle sequencing, purification and sequencing was carried out. The sequences obtained were BLAST analysed for their identification. A total of seven species were identified from various potato growing regions of India. The green peach aphid, *Myzus persicae* from Gonda and cotton aphid, *Aphis gossypii*, from Gonda, Mashoda and Faizabad (UP) while black bean aphid, *Aphis fabae* was identified from Manikpur and Tenda of UP. The aphid samples collected from CPRIC farm, Modipuram (UP) during October to December were identified as green citrus aphid, *Aphis spiraecola*, Oleander aphid, *Aphis nerii* and coriander aphid, *Hydaphis coriandri* (**Fig. 40**) apart from *Myzus persicae* and *A. gossypii*. However, rice root aphid, *Rhophalosiphum rufiabdominalis, A. gossypii* and *A. spiraecola* were identified from Jalandhar samples (**Fig. 41**). Aphids from Meghalaya (Shillong, Makrial hills and Nangkynrih), Arunachal Pradesh, Nagaland and Sikkim were identified as *M. persicae* and *A. gossypii* while that from Kufri and Solan were identified as *M. persicae*. *M. persicae* and *A. gossypii* were found in all regions probably they could tolerate fluctuations in the abiotic factors.

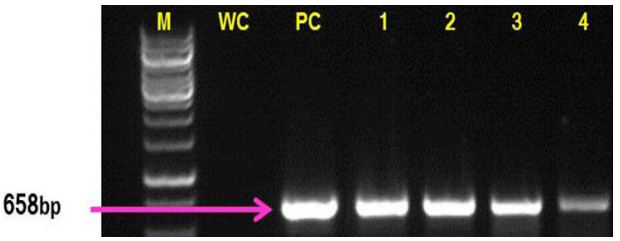


Fig. 40: *M: 1kb Marker, WC: Water control, PC: Positive control, Lane 1& 4: Hydaphis coriandri, Lane 2: Aphis spiraecola and Lane 3: Aphis nerii*

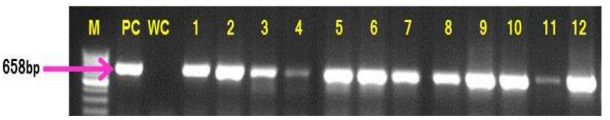


Fig. 41: *M: Marker, PC: Positive control, WC: Water control, Lane 1-4: Aphis gossypii, Lane 5: Aphis spiraecola, Lane 6, 11 & 12: A. gossypii, Lane 7-9: A. spiraecola and Lane 10: Rhophalosiphum rufiabdominalis*

Whiteflies infesting potato in India

Whitefly has become a real threat to the potato seed production due to its ability to transmit apical leaf curl virus, hence its molecular identification to manage it efficiently is essential. Whiteflies were collected from few locations for their molecular identification. They were identified using universal primers (658bp) specific to cytochrome oxidase I gene. The sequencing results revealed that whiteflies from Modipuram and Jalandhar were identified as *Bemisia tabaci* (**Fig. 42**) while glasshouse population from Shimla as *Trialeurodes vaporariorum*. The amplification of the ITS1 rDNA region of the *B. tabaci* population revealed one band of approximately 550 bp from all the individuals analyzed from Meerut area. The results obtained with diagnostic 'B' Biotype specific primer TW81 gave a negative result for Modipuram whitefly when compared to positive control obtained from 'B' population of Bangalore. Therefore, it is confirmed that population at Modipuram whitefly is not B–Biotype. Further investigations

regarding the biotype identification of Modipuram whiteflies needs special attention. The use of specific primers represents an important tool as it helps to identify the introduction of exotic biotypes of *B. tabaci*.

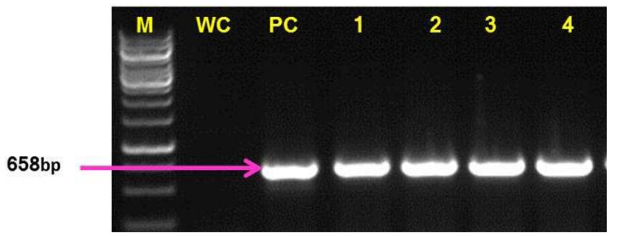


Fig. 42: *M: 1kb Marker, WC: Water control, PC: Positive control, Lane 2-5: Whiteflies, Bemisia tabaci*

Incidence of whitefly on host plants other than potato during off season

The highest population of whitefly (12.16/plant) was recorded on tomato during first week of August followed by urd bean (10.6/plant). Whiteflies from eleven off season plants were tested for presence of PALCV and results revealed that samples from *Phyllanthus niruri, Solanum nigrum*, Cowpea and Black gram were found positive for PALCV (**Fig. 43**).

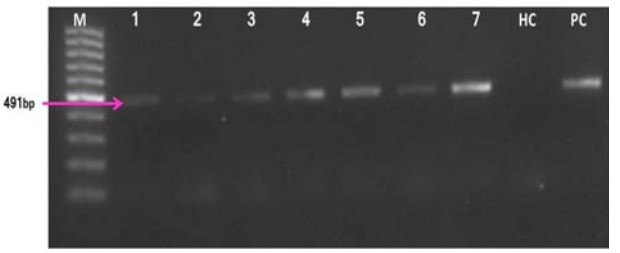


Fig. 43: *M: 1 kb ladder, Lane 1, 2 & 3: Phyllanthus niruri, Lane 4 & 5: Solanum nigrum, Lane 6: Cowpea, Lane 7: Blackgram , HC: Healthy control and PC: positive control*

Transmission of apical leaf curl virus in potato by whitefly

Disease free tissue culture potato plants free from PACLV were grown in covered cages for white fly transmission using wooden cages. White flies (1, 2, 3, 5 & 10) were released on PALCV free potato plants for 24h and 48h. It was observed that even a single viruliferous whitefly can transmit the disease efficiently in potato plants.

Efficacy of plant product extracts against whiteflies and aphids on potato under field condition

A field study was carried out to assess the effect of plant products extracted in hexane, methanol and ethyl acetate on mortality of whitefly (*Bemisia tabaci*) and aphid (*Aphis gossypii*) to confirm the laboratory results. All the plant product extracts were slow and moderately effective against white fly and aphids. The lowest activity of whitefly (0.71-2.55/10 plants) was recorded in methanol bark extract of dalchini (*Cinnamon zeylanvium*) followed by hexane bark extract (1.05-2.62/10 plants) of jatamansi (*Nardostachus jatamansi*) and methanol extract (1.48-2.77/10 plants) of coriander (*Coriander sativus*) during crop growth with 7 sprays at weekly interval. Similarly, the lowest activity (1.05-4.59/10 plants) of aphids was recorded in ethyl acetate seed extract of malkangni (*Celastrus peniculatus*) followed by (1.56-4.86/10 plants) methanol extract of dalchini and methanol extract of jatamansi (1.17-5.10/10 plants). The check insecticide imidacloprid was recorded lowest incidence of whitefly and aphids.

Efficacy of non-edible seed oils against whitefly (*Bemisia tabaci*) and leafhopper (*Empoasca fabae* Harris) under field condition

Field studies on potato cultivar Kufri Pukhraj with non-edible oils- neem, mahua, karanj, eucalyptus and castor oils indicated minimum incidence of leafhopper in the neem oil treated crop (2.39- 4.16/10 plants) during second week of October to first week of December followed by castor oil treated crop (2.61 to 4.51/10 plants). Similarly the minimum incidence of whitefly was also recorded in neem oil treated plots with mean incidence 1.0–2.47/10 plants during the same period followed by eucalyptus oil (1.25-3.13/10 plant), karanj oil (1.64-2.80/10 plant), castor oil (1.80-2.83/10 plant) and mahua oil (2.20-3.19/10 plant). Neem oil was found to be most effective and yielded highest among all the treatments with maximum C: B ratio 1:5.43.

Population fluctuations and management of potato pests

Severe hopper burn (70-85%) infestation was recorded in late planted cv Kufri Bahar in Kanpur. Mite and

whitefly population was very high in Meerut area in both early (September planted) in Muzaffarnagar and main crop (October planted) in Meerut area. A new antifeedant, flonicamid tested at 3 & 4 gm/10 litres of water was effective against both whitefly and aphids. Chemical insecticides tested against white grub indicated carbofuran 3G, Imidacloprid 70 WG and bifenthrin were best.

Evaluation of potato cultivars against sucking insect pests of early potato crop

Field studies on the incidence of leafhopper and whitefly on ten potato cultivars (Kufri Sutlej, Kufri Sinduri, Kufri Bahar, Kufri Garima, Kufri Pukhraj, Kufri Khyati, Kufri Anand, Kufri Puskar, Kufri Arun, and Kufri Gaurav) resulted in maximum mean incidence of whitefly (3.84/plant) on K. Sutlej when crop was 45 days old followed by Kufri Bahar (3.27/plant) and Kufri Gaurav (3.16/plant) under unprotected condition. Red cvs Kufri Arun (2.44/plant) and Kufri Sinduri (2.61/plant) were least preferred by leafhopper while maximum population (4.03/plant) was recorded on potato cultivar Kufri Sutlej, when crop was 35 days old; the same trend was recorded throughout the crop growth as per the order of preference by leafhoppers. Leafhopper population varied (1.39-4.19/plant) during crop growth.

Potato Tuber moth damage in Indore/ Malwa region and Himachal Pradesh

Seven potato cvs viz., Kufri Chipsona-3, Kufri Chipsona-1, Kufri Himsona, Kufri Jyoti, Kufri Lauvkar, Lady Rosetta and Hermes were examined at the time of harvest and no damage by PTM was observed in Malwa region. Potato tuber moth incidence in hot spot areas at five locations (stores) in Kangra valley (Himachal Pradesh) during June and July-2013 was monitored. The highest infestation was in Malan (15.75%) followed by Pathiar (11.25%) and Menjha (10.40%) while lowest was in Nagri (5.75%). For PTM monitoring, pheromone traps were installed at four locations under field conditions namely Samula (Pharade), Malan, Palampur and Nagrota Bagwan. The highest population was observed in Samula (7-8 moths/trap/day) followed by Malan (5-6 moths) and lowest from Palampur and Nagrota Bagwan (one moth each) and was below threshold level in all four locations.

Programme 5: Management of Potato Nematodes

Potato cyst nematodes (PCN) *viz., Globodera rostochiensis* and *G. pallida* are dangerous pests of potato in the Nilgiris and are very difficult to be eradicated from infested fields. Late blight (LB) disease caused by *Phytophthora infestans* is one of the major plant protection problems that seriously affect the sustainable production of potato in The Nilgiris. The occurrence of three pathotypes in each species of PCN and more virulent strains of LB organism calls for continued research activities for developing potatoes having combined resistance to these major biotic constraints. The programme aims at development of an integrated nematode management package including host resistance and various management options for PCN combined with suitable agronomic practices to increase the potato production in the Nilgiris.

Breeding for combined resistance to late blight and potato cyst nematodes

During the year, 53,000 hybrid TPS were produced from 49 bi-parental crosses involving selected late blight and potato cyst nematode resistant parents. In the F_1 generation about 15,000 true seeds belonging to 7 cross combinations were sown in boxes. Nine thousand four hundred seedlings were transplanted in field/poly house, screened under natural conditions of late blight and 567 selections were made. In initial evaluation trials, 1423 hybrids were evaluated in observational rows/single hill along with Kufri Girdhari and Kufri Swarna as check varieties. Of these, 777 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, 52 hybrids were selected on the basis of agronomic traits and resistance to potato cyst nematodes and late blight. Two promising advance generation hybrids were assessed in 4 replications along with check varieties Kufri Swarna, Kufri Girdhari and Kufri Jyoti. OS/94-I-126 (16.9 t/ha) and OS/01-161 (16.2 t/ha) recorded more yield than control varieties Kufri Jyoti (7.8 t/ha) and Kufri Swarna (14.2 t/ha). They were found resistant to both species of potato cyst nematodes and field resistant to late blight. However, Kufri Girdhari recorded the maximum yield (25.9 t/ha).

Marker assisted selection (MAS) for resistance to PCN

Advanced generation breeding materials generated through conventional breeding programme (58 breeding lines) were screened along with five varieties (Kufri Jyoti, Kufri Giriraj, Kufri Girdhari, Kufri Swarna and Kufri Neelima) for presence of genes conferring resistance to *Globodera* spp. using the specific markers. Among them, marker TG689 linked with the gene *H1* was amplified for 38 out of 63 accessions and varieties. Nearly 59% of the breeding lines and varieties tested possessed *H1* gene. However, no accession was positive for the *Gro1*-4-1 marker. Specific primer TG432 associated with QTL conferring resistance to *G. pallida* gave the expected product for 24 accessions and was not amplified in the tested varieties. The SNP marker HC was amplified for 44 accessions and varieties. For *G. pallida* Pa2, marker SPUD 1636 associated with the QTL Gpa5 and Gpa6 was evaluated. Among the 63 breeding lines, marker SPUD 1636 amplified in 4 breeding lines and variety Kufri Swarna (**Fig. 44**).

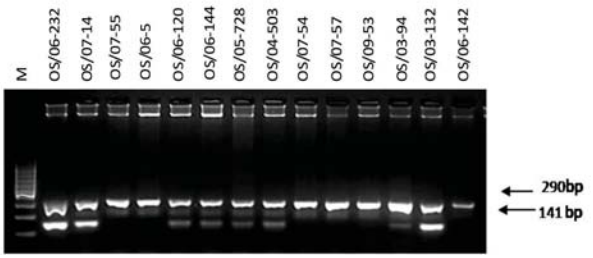


Fig. 44: *H1, TG 689 (141 bp) PCR detection of SCAR marker TG 689 linked to H1 gene with an internal control PCR – BCH marker. Lane M contains 100 bp DNA ladder*

Integrated management of potato cyst nematodes

Effect of various management options *viz.*, physical, cultural, chemical and biological measures on PCN

Trap cropping for all three seasons *viz.,* summer, autumn and spring with susceptible potato Kufri Jyoti recorded 35.33% reduction in cyst population followed by trap cropping in summer and autumn (32%). The yield of succeeding crop Kufri Girdhari was the highest when grown after three trap crops (27.21 t/ha) (**Fig. 45**).

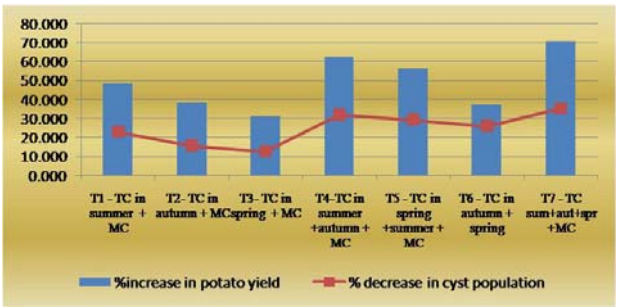


Fig. 45: *Evaluation of trap crops on PCN and succeeding potato crop yield*
[TC – trap crop; MC – main crop]

As potato cyst nematodes prefer solanaceous crops (potato, tomato, brinjal) for feeding and multiplication, various non-solacaneous crops *viz.,* cabbage, carrot, radish, beet-root, cauliflower, garlic, marigold and French-beans were evaluated on survival of PCN. Among the crops tested, radish recorded 19.6 % reduction in number of cysts and 14.5% reduction in number of eggs per cyst. It was followed by garlic which recorded 17.8% and 12.3% reduction in number of cysts and eggs, respectively (**Fig. 46**).

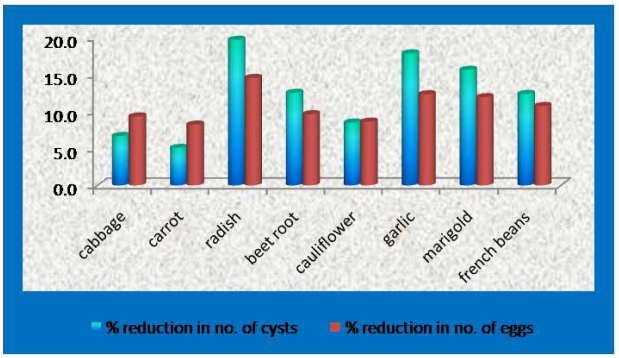


Fig. 46: *Effect of non-host crops on PCN cysts and eggs*

In evaluation of various management options for eradication of PCN in resistant variety Kufri Neelima, integration of trap crop, soil solarization, furadon application followed by organic amendment and biocontrol agent recorded the maximum yield (24.34 t/ha) and minimum reproduction factor (Rf-0.93) (**Fig. 47**). It recorded 20.11% reduction in nematode reproduction.

For management of PCN by cropping systems approach, two intercrops were tested. Among them, radish was found more effective than marigold in PCN control because, the Rf value of PCN in the plots intercropped with radish was lower in comparison to

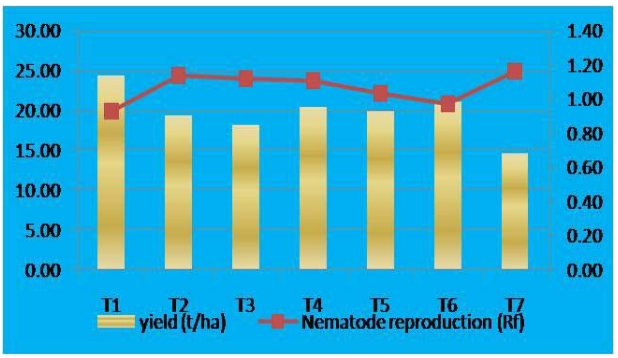


Fig. 47: *Evaluation of various management options for eradication of PCN*
[T1: trap crop + soil solarization + furadon + biocontrol agent + organic amendment; T2: T1- Trap Crop; T3: T1 – solarization; T4: T1- furadon; T5: T1 – biocontrol agent; T6: T1 – organic amendment; T7 – untreated control]

marigold intercropped plots. However, marigold in 2:1 row proportion was effective in bringing down PCN population in Kufri Jyoti, a susceptible variety from Rf value of 1.92 to 1.21 (**Fig. 48**).

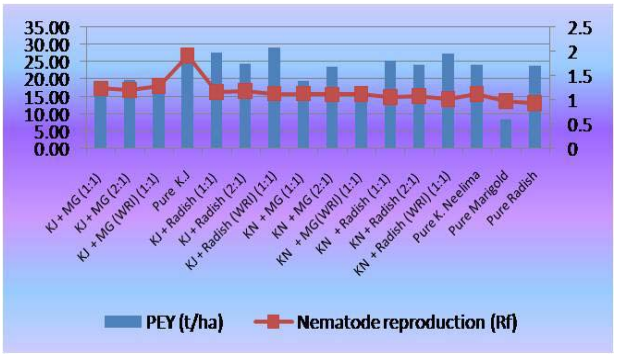


Fig. 48: *Effect of potato based intercropping systems on PCN dynamics*

Molecular identification of *Globodera rostochiensis* and *G. pallida*

PCR analysis was performed to fifteen *G. rostochiensis* and *G. pallida* populations from various potato fields of Nilgiris District using species specific primers designed by Fullando *et al.* (1999). Primers generated expected size of bands i.e. 315 bp amplicon for the *G. rostochiensis* and 798 bp amplicon for *G. pallida* (**Fig. 49**). Comparable bands were found in amplification assays of different *G. rostochiensis* and *G. pallida* populations. However, the fragments will further be sequenced and confirmed.

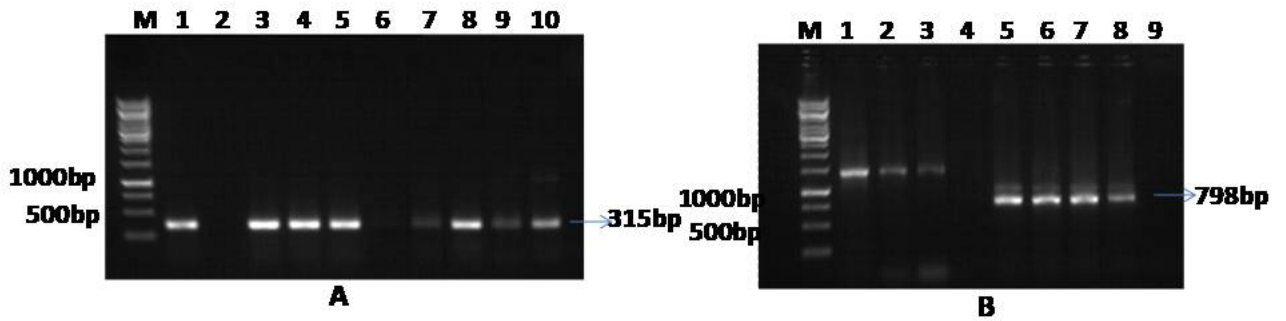


Fig. 49: *Species identification of Globodera populations using PCR assay Amplification products for G. rostochiensis (A) and for G. pallida (B)*

Survey for assessment of PCN dynamics in different crop seasons

A survey was conducted in the four taluks (Ooty, Kundha, Kotagiri and Coonoor) of The Nilgiris district during the spring crop season. Kookalthorai area of Kotagiri taluk recorded nil population of PCN while maximum population (177 per 100 ml soil) was recorded from Gandhikandi of Kundha taluk. In Ooty and Coonoor taluks, the population ranged from 4 to 62 per 100 ml soil. The cysts collected from various locations will be subjected to further molecular characterization at species and pathotype level.

Division of Crop Physiology, Biochemistry and Post-harvest Technology

Increasing potato production in the country has resulted in greater utilization of potatoes. For diversified utilization of potatoes, establishment of its nutritional value is essential. The programme aims at ascertaining the nutritional quality of potatoes and potato products and development of potato based products with improved nutritional quality.

Analysis of flavouring compounds (AMP+GMP) in potato tubers

Potato flavour depends on the level of umami compounds as well as volatiles. The significant umami compounds present in potatoes are amino acids *viz*. Glutamate, Aspartate and 5' nucleotides *viz.* Adenosine Monophosphate (AMP) and Guanosine Monophosphate (GMP). The umami compounds generally enhance the flavour and mouthfeel and give the impression of viscosity to the food. Till date no flavouring compounds have been determined from Indian potatoes, therefore, an HPLC method was standardized to estimate AMP and GMP (5' nucleotides) in Indian potato cultivars. (Fig. 1).

The concentration of 5'-nucleotides (AMP+GMP) was low in raw tubers of all the 44 Indian potato cultivars tested. In raw tuber tissue concentration of 5'-nucleotides ranged from 1.70µg/ g FW (Kufri Jawahar) to 6.68 µg/ g FW (Kufri Muthu). Microwave cooking increased the concentration of flavouring compounds as well as flavour in all the tested cultivars and the 5'-nucleotide contents ranged from 2.97 µg/g FW (Kufri Jawahar) to 9.54 µg/g FW (Kufri Himalini), which ranged from 0 to 272% (Fig 2). Maximum increase after microwave cooking was reported in Kufri Lalima (272%) followed by cultivars Kufri Arun(225%), Kufri Himalini (177%), Kufri Chandramukhi (164%) and Kufri Pushkar (144%).

Utilization of potato starch for preparation of biodegradable films

To enhance the utilization of potato starch, a method for preparation of potato starch based biodegradable film was standardized using casting method. Method was standardized using 1.5g potato starch mixed with varying concentrations of plasticizer. Films prepared with 0.4% plasticizer were brittle. Those prepared with 0.6% and 0.8% plasticizer were soft and flexible. The films prepared from starch showed poor mechanical properties, therefore, to improve the mechanical properties starch is blended with polyvinyl alcohol (PVA) - a biodegradable synthetic material. Different blends were prepared varying the concentration of starch and PVA. Films prepared with pure starch lack flexibility and clarity and were brittle. Flexibility improved with increasing the concentration of plasticizer. Films made of PVA were more flexible, soft and transparent than films made of pure starch and different ratio of starch and PVA (Fig 3). Starch and PVA in 1:3 ratio showed good results, with soft, flexible and semi-transparent films. Once the properties of starch based films are improved, it can be a good replacement for plastic based packaging and can be used as biodegradable packaging material.

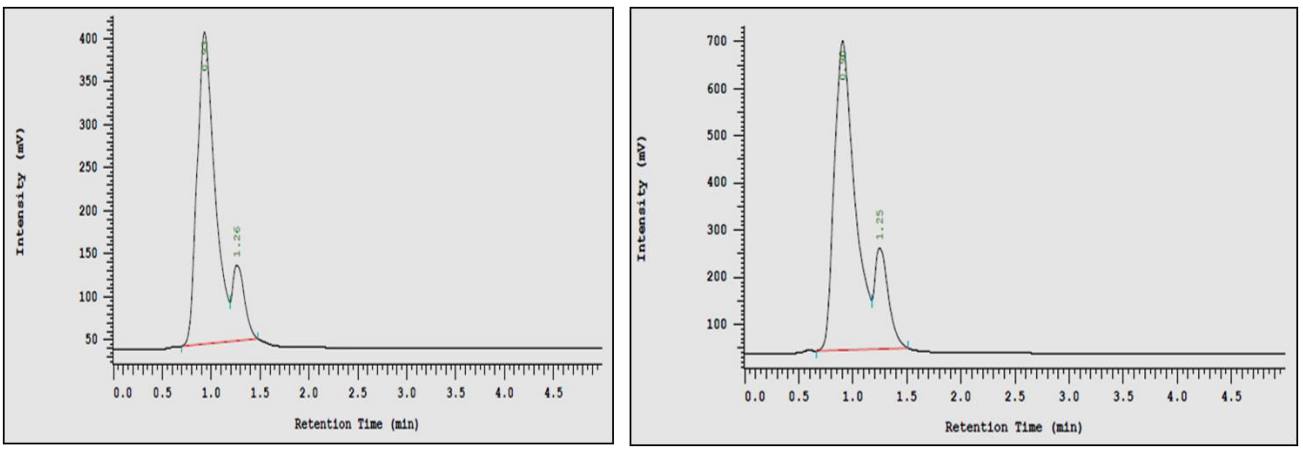


Fig 1. HPLC chromatogram of AMP+GMP in raw and microwave cooked potatoes

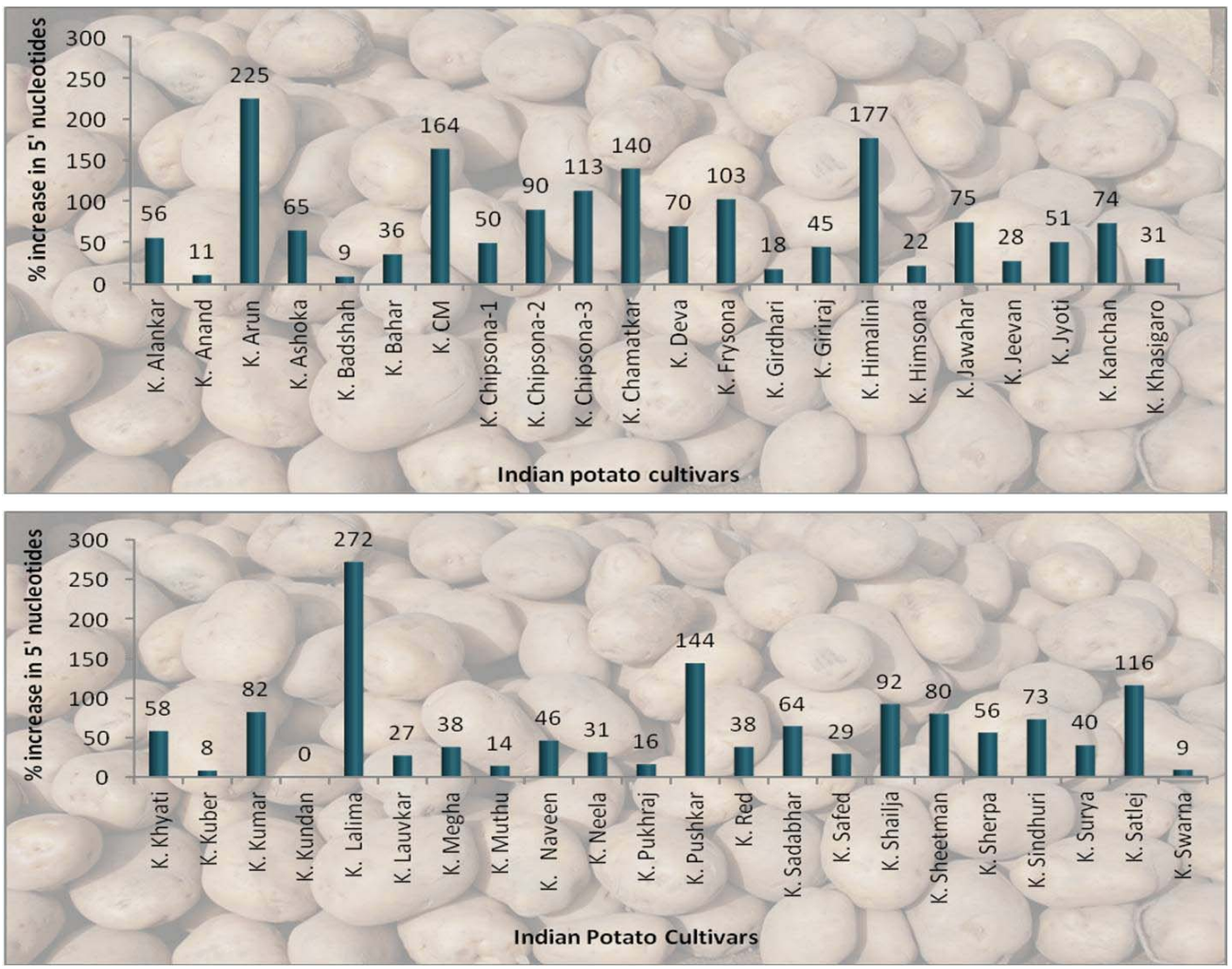


Fig.2. Per cent increase in the level of 5' nucleotides (AMP + GMP) after microwave cooking in Indian Potato Cultivars

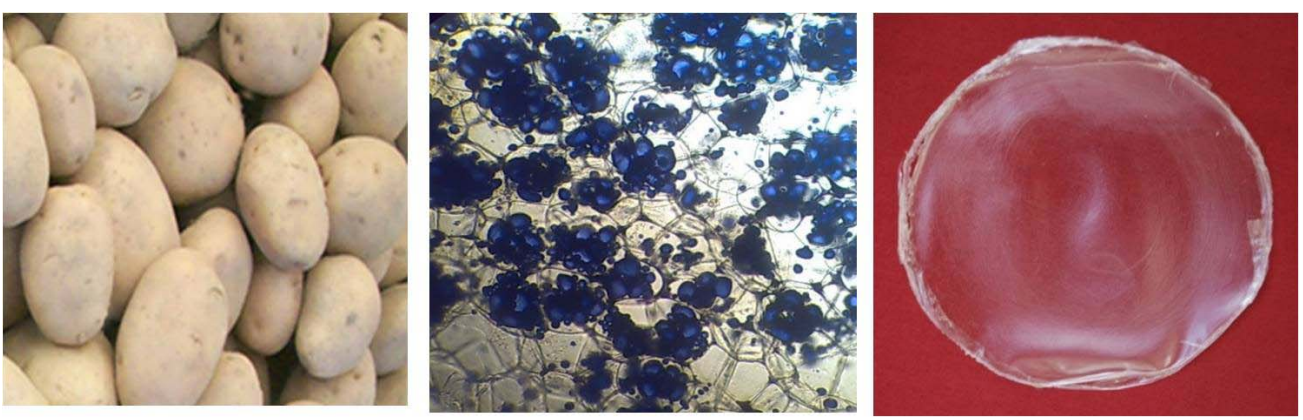


Fig. 3. Potatoes, starch granules trapped in amyloplast and potato starch based film

Resistant Starch from Fresh and Stored potatoes and products

Potato tubers: Total starch content was determined from 44 Indian potato cultivars procured from CPRIC, Modipuram. The starch content ranged from 39 to 78 g/100 DW. From nutritional point of view low content of digestible starch (DS) is desirable in starchy foods. In raw tubers of 44 Indian potato cultivars, DS content ranged from 38% (Kufri Naveen) to 77% (Kufri Khasigaro). High content of resistant starch (RS) provides various health benefits. RS content in Indian potato cultivars ranged from 0.79 mg/100mg DW (Kufri Neela) to 1.74 mg/100mg DW (Kufri Chamatkar). Cultivars such as Kufri Sutlej (1.71 mg/100mg DW), Kufri Ashoka (1.69 mg/100mg DW), Kufri Chandramukhi (1.66 mg/100mg DW), Kufri Muthu (1.66 mg/100mg DW) and Kufri Frysona (1.64 mg/100mg DW) also contained high content of RS, these results indicate that high resistant starch containing cultivars will have better nutritional value.

Resistant starch in French fries: To determine the values of resistant starch in processed products, its contents were estimated in French fries without freezing (after par frying) and with freezing. Resistant Starch (RS) content was the maximum in the finish fried French fries prepared without freezing from Kufri Chipsona-1 (1.45%), followed by Kufri Chipsona-3 (0.90 %) and Kufri Frysona (0.70 %) (Fig 4). RS content increased in French fries with increase in storage duration (at -20°C) from 24h to 180d. Increase in RS content was significant after 60 DOS. French fries prepared after 180DOS contained highest RS content and the increase was 9.49, 9.66 and 8.25 % in Kufri Frysona, Kufri Chipsona-1 and Kufri Chipsona-3, respectively.

Cellulose content was the maximum in finish fried French fries prepared without freezing from Kufri Chipsona-1 (3.33 %), followed by Kufri Chipsona-3 (2.13%) and Kufri Frysona (1.82%) (Fig 4). The results showed that the dietary fibers (resistant starch and cellulose) are higher in French fries prepared from Kufri Chipsona-1 and the minimum in Kufri Frysona.

Analysis of Nutritional and Anti-nutritional Compounds in Potatoes

Antioxidants: The freshly harvested potatoes were analysed for anti-oxidants *viz.* ascorbic acid, anthocyanin and total carotenoids. The ascorbic acid content was found to be the highest in Kufri Gaurav followed by Kufri Surya. The Anthocyanin content was the maximum in Kufri Gaurav, followed by K. Chandaramukhi whereas, the carotenoids were the highest in Kufri Surya followed by Kufri Chipsona-3 (Fig. 5).

Ascorbic Acid and protein as affected by storage: Ascorbic acid decreased from the beginning till 180 days of storage. Percent decrease was more prominent 10°C than at 4°C storage. Maximum decrease (48.71%) was observed in K. Pukhraj at 10°C as compared to storage of tubers at low temperature (36.90%) at 90th day (Fig. 6). This was followed by variety Kufri Jyoti, where decrease was 42.02% at higher temperature. Among the varieties, lowest decrease was of 9.15 per cent in variety Kufri Chipsona-1 at 10 °C (CIPC) followed by variety Kufri Chipsona-3 (16.29%). Similar behavior was observed at 180 days of storage. Again storage of tubers at 10°C had more pronounced effects. Ascorbic acid content decreased by 67.20, 55.13, 53.65, 52.61 and 50.92 per cent in Kufri Pukhraj, Kufri Himsona, Kufri

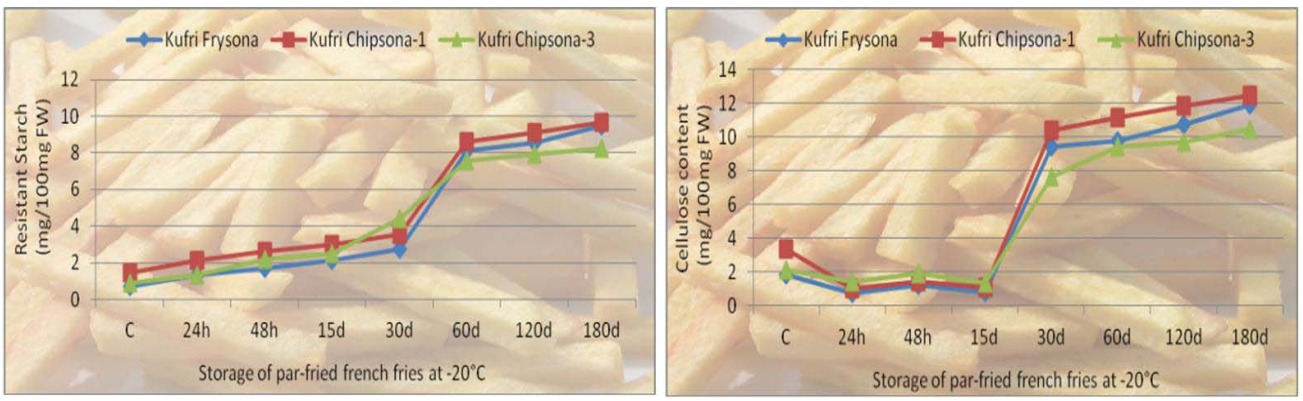


Fig.4. Effect of storage duration on RS and Cellulose of par-fried French fries

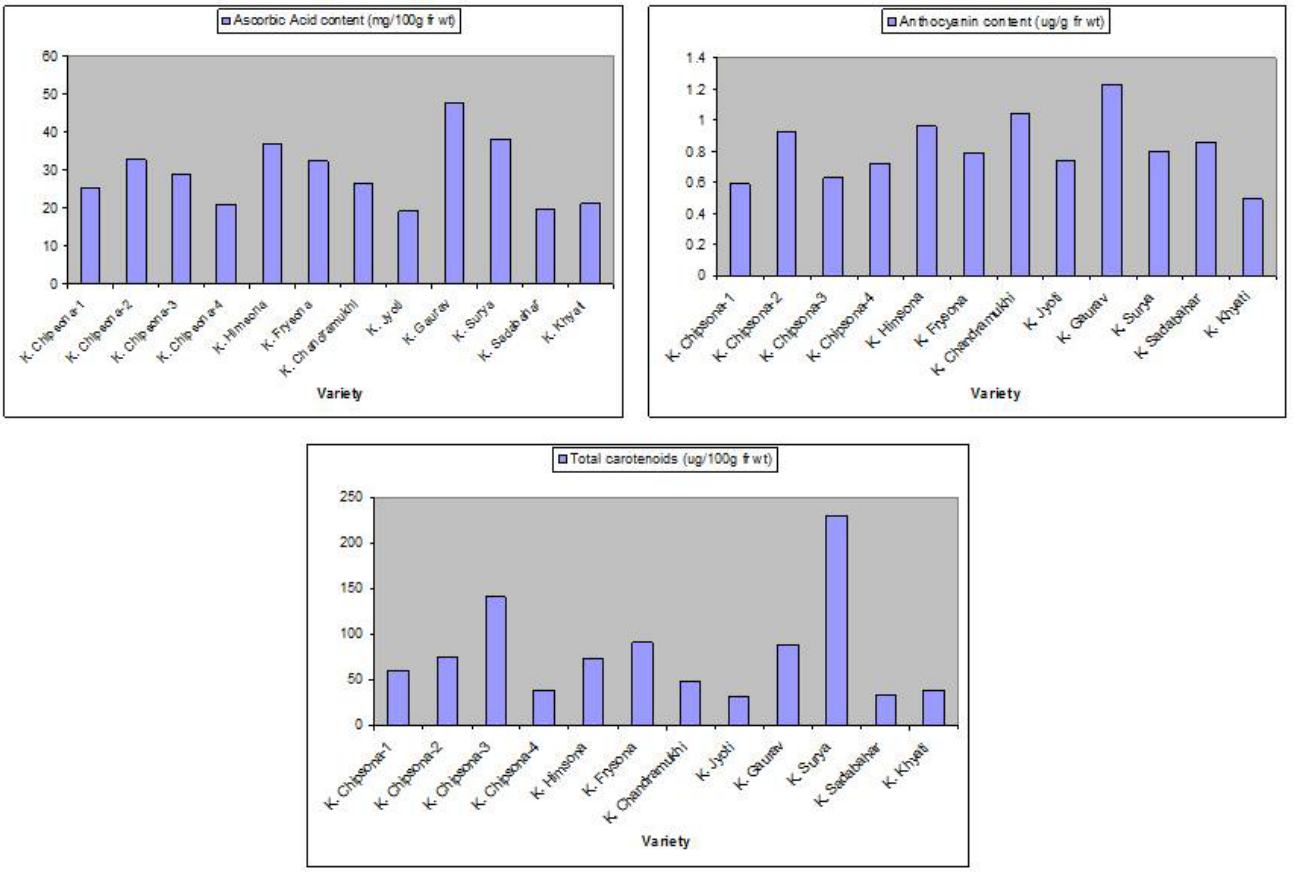


Fig. 5. Ascorbic acid, Anthocyanin and Total carotenoids in potato tubers

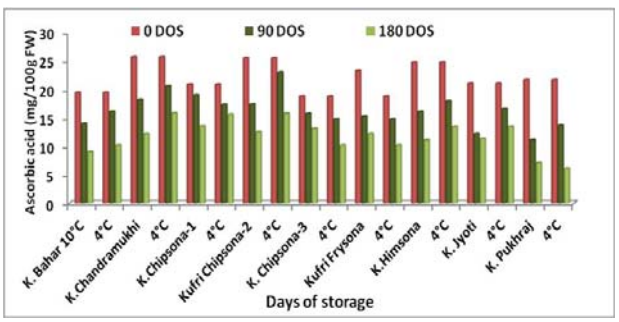


Fig. 6. Effect of storage temperature on ascorbic acid content

Bahar, Kufri Chanramukhi and Kufri Chipsona-2 respectively.

Protein content also showed variation due to storage. Kufri Bahar retained more protein among all the varieties as the decrease was minimum (1.75 %) at 10°C and decrease almost doubled at 4°C (3.89 %). Maximum decrease was observed in variety Kufri Pukhraj (24.21%) at low temperature followed by Kufri Jyoti (23.69%).

Glyco-alkaloids: The potato tubers contain nitrogenous steroidal glycosides, called glyco-

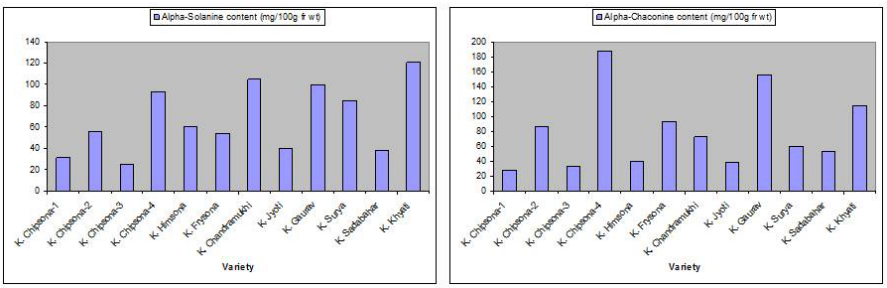


Fig. 7.Glycoalkaloid contents (mg/100g fresh wt) in potato peels of tubers

alkaloids. These are unwanted potato constituents for consumers because of their toxicity and bitter taste. The potato glyco-alkaloids solanine and chaconine were detected in peels of freshly harvested tubers. The maximum concentration of solanine was observed in *cv*. Kufri Khyati followed by Kufri Chandramukhi, whereas, the minimum concentration was observed in Kufri Chipsona-3 (Fig. 7). The chaconine content was the highest in Kufri Chipsona-4 and the lowest in Kufri Chipsona-3.

Evaluation of minimal frying/ microwaveable frozen potato products

An experiment for making French fries after osmotic dehydration (OD) with different treatment combinations of NaCl, Sucrose, KMS, Sodium citrate and ascorbic acid was conducted. On the basis of last year's results, treatments with only acceptable quality of French fries were included. Freshly cut fries were dipped in different solutions (sample: solution ratio 1:4) for 4 hrs, washed in water, extra moisture was blotted off, frozen for 24 hrs and fried for 1.5 minutes at 180°C. Colour of French fries of all the treatments was acceptable. Organo-leptic evaluation by panel of 5 untrained judges showed that taste was acceptable in treatments from T4-T8 with better taste (sweet and sour) in treatments in combination with ascorbic acid (T6-T8) and there was no need to add salt as top dressing. These fries also recorded low oil content (3.43-4.32% v/s 16.75%) and higher vitamin-C contents (48.0-128.3 v/s 14.75 mg/100g fresh weight) as compared to normal frozen French fries.

The fried samples were analysed for sodium and chloride content by Atomic Absorption Spectrophotometer to see whether the contents are within the tolerable intake level. Sodium is a nutrient found in table salt and many other foods. Our body needs some sodium to function, but too much may lead to high blood pressure. Healthy adults need only 1500 mg of sodium each day. Healthy children need only 1000-1500 mg of sodium a day. Sodium contents in French fries increased from 0.16% in raw tuber to 1.24% with OD treatments.Sodium values in best treatments (T6-T8, 1.10-1.24 %) were about 50% lower than the tolerable upper intake level and hence were safe for consumption even if 100 g of French fries are taken in a day.These fries with low oil content (4.32% v/s 16.75%) were enriched with Vitamin -C (48-128 mg/ 100 fresh weight) as compared to normal French fries (14.75 mg/100g fresh weight).

Programme 2: Potato Storage: Efficient and eco-friendly methods for improved quality

Studies on physiological and hormonal changes associated with dormancy release during storage under different temperatures were continued for better understanding of the underlying processes in potato tubers. Besides efforts were made to provide alternative method for sprout inhibition using compounds of plant origin which are naturally occurring and have low mammalian toxicity.

Keeping Quality Indicators

Peroxidase activity: Peroxidase activity was maximum in Kufri Chipsona-1 (0.754 µmoles/min/g FW) and minimum in Kufri Pukhraj (0.093 µmoles/min/g FW) before storage (Fig. 1). The activity increased during storage up to 180 days at both the temperatures (4°C and 12°C) in three cultivars. Peroxidase activity remained high in Kufri Chipsona-1, medium in Kufri Jyoti and low in Kufri Pukhraj up to 90 days at both the temperatures and up to 180 days of storage (DOS) at 4°C.

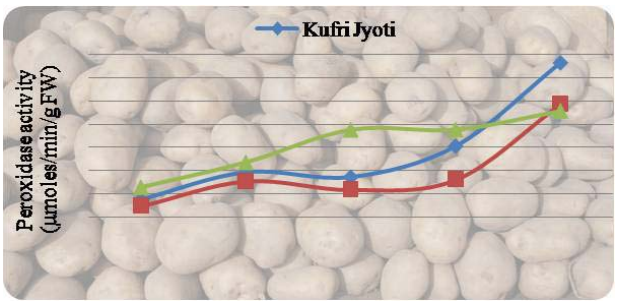


Fig. 1. Effect of storage temperature and duration on peroxidase activity

DPPH inhibition: 2,2-diphenyl-1-picrylhydrazyl (DPPH) is a stable free radical, when acted upon by an antioxidant is converted into diphenyl-picryl hydrazine with a colour change. Per cent DPPH inhibition indicates the antioxidative potential of a cultivar to scavenge free radicals. DPPH inhibition was measured at 4°C in three potato cultivars varying in storability. Before storage, DPPH inhibition was the maximum in Kufri Jyoti and low in Kufri Chipsona-1 and Kufri Pukhraj (Fig. 2). DPPH inhibition decreased during storage and maximum inhibition was recorded in Kufri Chipsona-1 (33.88%) and least in Kufri Pukhraj (14.69%) at the end of the storage.

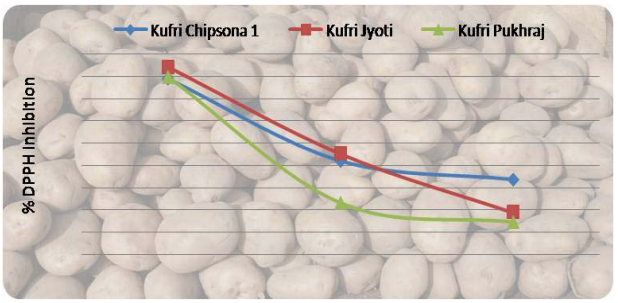


Fig. 2. Effect of storage duration on DPPH inhibition

H_2O_2 scavenging activity: Hydrogen peroxide (H_2O_2) scavenging activity, a measure of the capacity to remove the H_2O_2, was the maximum in Kufri Jyoti (33.43%), followed by Kufri Pukhraj (31.73%) and least in Kufri Chipsona-1 (11.61%) at 0 day (Fig. 3). The scavenging activity remained high in Kufri Chipsona-1 and low in Kufri Pukhraj at both the storage temperatures with higher activity recorded at 12°C compared to 4°C.

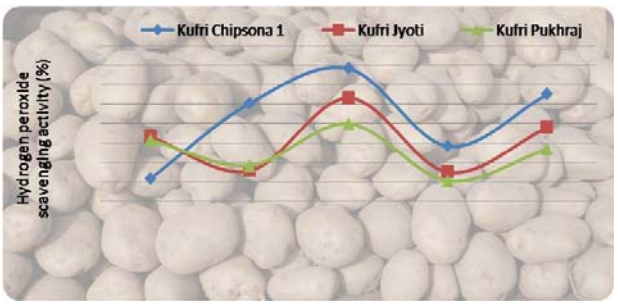


Fig. 3. Effect of storage duration and temperature on H_2O_2 scavenging activity

In terms of antioxidative potential (peroxidase, catalase, DPPH scavenging activity and H_2O_2 scavenging activity), Kufri Chipsona-1 was superior to Kufri Jyoti and Kufri Pukhraj during storage. These attributes may be responsible for the good keeping quality of this cultivar over the other two cultivars.

Anti-oxidant system: Activities of anti-oxidant enzyme system, namely ascorbate peroxidase (APx) was studied along with ascorbic acid (AsA) levels during storage at two temperatures. The activity of APx decreased with storage duration and the level was higher at lower temperature as compared to 12°C (Fig. 4). Contents of AsA also decreased during storage with

lesser decrease recorded at 4°C compared to 12°C. Higher AsA content associated with higher activities of APx at 4°C compared to 12°C shows greater formation of active oxygen species at relatively lower temperatures of storage.

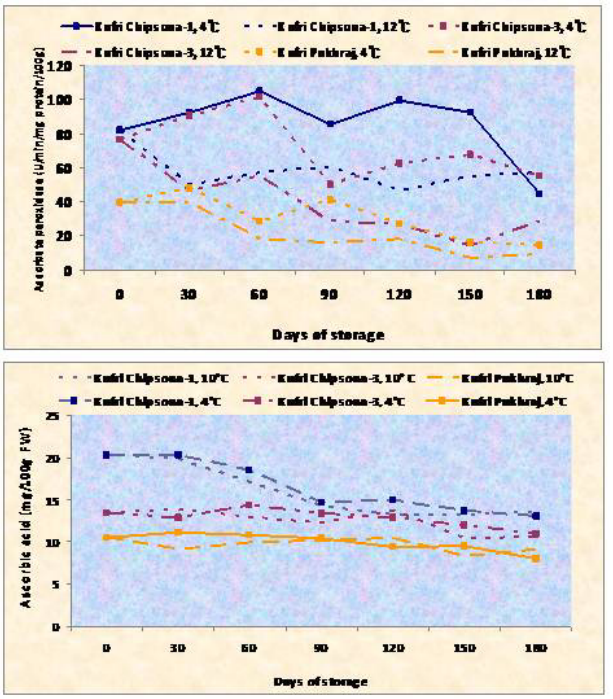


Fig. 4. Effect of storage temperatures onascorbate peroxidase activity and AA content

It is speculated that greater formation of active oxygen species at lower temperatures result in changes in membrane transport properties leading to more accumulation of free sugars. Higher APx activity and higher AsA contents were recorded in cvs. Kufri Chipsona-1 and Kufri Chipsona-3 as compared to Kufri Pukhraj along with low sugar accumulation during storage up to 180 days.

Gibberellins during dormancy and sprouting:

A method was developed and standardized for the estimation of Gibberellic acid (GA) content from potato tubers using DAS-ELISA and was applied for its estimations in dormant, chitted and sprouted potato tubers of three varieties differing in dormancy duration *viz.*KufriGiriraj, KufriJyoti and KufriGirdhari. GA content ranged from 2.84 pmol/ml to 4.51 pmol/ml in dormant tubers, 3.58 pmol/ml to 4.96 pmol/ml in chitted tubers and 2.97 pmol/ml to 3.19 pmol/ml in sprouted tubers (Fig. 5). In Kufri Jyoti and Kufri Girdhari, GA content was low in dormant and sprouted tubers and high in chitted tubers i.e at the end of dormancy.

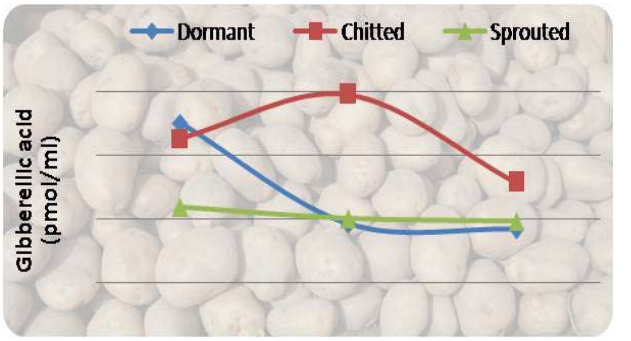


Fig. 5. GA content in tubers of three potato cultivars

Effect of growth retardants

Foliar spray of cycocel (1500-3000 ppm) and paclobutrazol (1000-1400 ppm), 4 and 6 weeks before harvest did not affect the tuber yield at harvest and storage behaviour of potatoes in heaps. Spray of cycocel 6 weeks before harvest improved the processing quality of potatoes at harvest as was observed last year with foliar spray of paclobutrazol. It increased the dry matter, reduced the reducing sugar

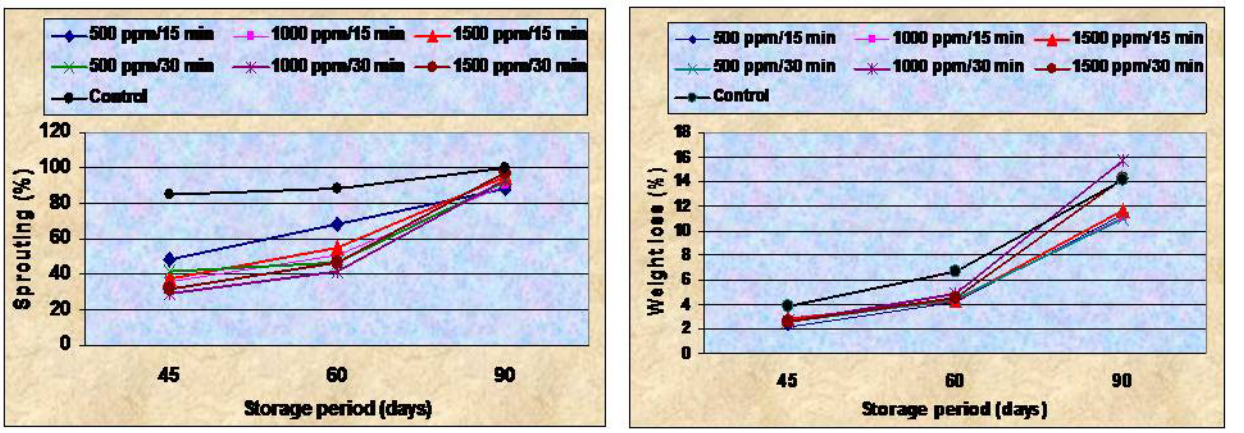


Fig. 6. Effect of dip treatment with paclobutrazol on storability of potatoes during storage in heaps(19-34°C, 46-86% RH)

content and improved the chip colour of potatoes as compared to control at harvest in cv. Kufri Lauvkar

Dip treatment of potatoes with paclobutrazol (500-1500 ppm) for 15/30 minutes reduced the sprouting and weight loss in potatoes up to 60 days of storage (DOS) in heap (Fig. 6). Treatment for 30 minutes was found more effective than for 15 minutes with no adverse effect on processing quality of potatoes during storage. However, dip treatment with other growth retardants *viz.* cycocel (100-2000 ppm) and ethrel (250-2000 ppm) did not record any effect on sprouting behaviour of tubers under heap storage.

Sprout suppression with organic compound

Presently, the sprout inhibition in table and processing potatoes is achieved with the use of CIPC (isopropyl N-3-chlorophenyl carbamate). The MRL in Europe for CIPC has been reduced to 10 ppm since it is a carbamate compound, debate is on for its use in potatoes being consumed. Therefore, efforts were made to search for an alternate non-toxic compound for use on table potatoes. The organic compound named AF1 developed at IARI was tested on dormant potatoes of Kufri Jyoti and Kufri Giriaj at four concentration (25, 50, 100 and 200 ppm) for bio-efficacy as sprout suppressant during storage at 12°C. The control (untreated) tubers started sprouting within 30 days of storage. In comparison, the treated tubers sprouted after about 60 days (at 25 and 50 ppm dose). No sprout initiation was observed in tubers treated with 100 and 200 ppm for up to 90 days of storage (Fig. 7).

Sprout suppression using plant essential oils

Preliminary screening experiments were conducted for evaluation of ten plant essential oils for sprout suppression of potatoes at 24±2°C. Vapour treatment with Dill seed (*Anethumsowa*) oil (500-1250 µl/l) recorded complete sprout inhibition without any increase in rotting in potatoes up to 65 days of storage. The rotting in potatoes however increased later. The control (untreated) potatoes recorded 100 per cent sprouting after 30 days with an average sprout weight of 4.7 g/kg tuber weight.

Estimation of 1,4-DMN on tuber skin

Contents of 1,4-dimethyl naphthalene (1,4-DMN) in tuber peels were analysed in forty potato cultivars after harvest to find any correlation with the dormancy duration. DMN contents ranged between 0.034 (Kufri Frysona) to 4.402 µg/kg tuber (Kufri Sherpa), but no correlation could be established between the dormancy duration and the DMN contents. However in earlier studies, DMN residues were well related with the end of dormancy in three potato cultivars.

Fig. 7. Sprout suppression in potatoes treated with organic compound

Programme 3: Physiological and genetic approaches in managing heat and water stress under sub-tropical environment in potato

The objectives of this programme aim at basic and strategic research for management of heat and water stress in potatoes including development of cultivars having tolerance to these traits for sub-tropical environment.

Hybridization and evaluation of clones for heat tolerance

Sixty five crosses were attempted at Kufri between suitable parents having heat tolerance and earliness, out of which 33 were successful and yielded 34114 seeds. During winter, 58 successful crosses at Modipuram yielded 150175 seeds. Seedlings were raised from 34110 seeds of 18 crosses and 165 selections were made based on tuber characters like size, color, shape, synchrony, eye depth etc. Maximum selections were obtained from the cross Kufri Khyati x HT/7-321 (33) followed by Norchip x Kufri Pukhraj (30) and A 98-98 x KufriPukhraj(23). At Shimla 5273 seeds from 14 crosses were screened in a heated glass house and 459 selections were made (Fig. 1). At Modipuram F_1C_1 to F_1C_3 were multiplied and evaluated during normal planting season and F_1C_4 to F_1C_6 were evaluated during early planting conditions under heat stress.

Confirmation of heat tolerance in advanced hybrids under controlled conditions

Five advanced hybrids were tested for their ability to tuberize at 24C night temperature by leaf bud cutting technique. At 24C night temperature, the tuber formation was observed only in HT/07-1105 and HT/07-804, whereas, sessile tuber was formed only Kufri Surya. At 20C night temperature, the best performance was obtained in HT/07-804.

Effect of night temperature and photoperiod on tuberization

Effect of night temperature was studied in K. Surya and Kufri Chandramukhi using leaf bud cuttings at 24/20 and 24/24 C day/night temperature. Four hours of dark period was sufficient for tuberization at 24/20 C day/night temperature in both the varieties. At 24/24 C day/night temperature there was no tuberization in Kufri Chandramukhi however in Kufri Surya 4 hr dark period was sufficient for tuberization.

Evaluation of paclobutrazol for dwarf plant architecture

Controlled release technology has been accepted globally as a potent tool for agrochemicals delivery.

Fig. 1. Glass house screening of seedlings and a tuberizing seedling

Two controlled release formulations (PP-10 and PS-10) developed in collaboration with IARI were evaluated during early crop. The farm grade plant growth regulator (CULTAR having Paclobutrazole 25%W/V) was also used along with CRFs. Kufri Surya was planted on 15th September 2013 during heat stress conditions (temp: 36.3/23.8 ^{0}C, D/N and RH: 84/21%) and foliar spray treatments were given at 3-4 leaf stage at 35 DAP. The treatments were 2.5 and 5 ppm spray of CRFs and 5 and 10 ppm spray of paclobuterazole. Five ppm concentration of both the CRFs (T2 and T4) was most effective and improved yield of marketable tubers as well as total tuber yield significantly (Fig. 2). CRFs increased yield by increasing the total biomass production and harvest index remained unaffected. Paclobuterazole increased harvest index at 10 ppm concentration.

Performance of Kufri Surya during early planting

Kufri Pukhraj is the predominant variety grown during early planting in Jalandhar and surrounding areas. Since CPRI has released heat tolerant variety Kufri Surya, which is suitable for early planting in NW plains, this experiment was designed to evaluate performance of Kufri Surya *vis-a-vis* Kufri Pukhraj. Treatments consisted of three dates of planting *viz.*, 2nd, 10th and 21st September and three dates of harvesting 60, 75 and 90 days after planting. Plot size was 3 X 3.5 m and spacing was 60 X 20 cm. Recommended fertilizer dose and other cultural practices were followed for raising the crop. Design was split plot with three replications. Tuber yield increased in both the varieties with advancing date of planting as well as date of harvesting. Kufri Surya out-yielded K. Pukhraj at first date of planting and 60 and 75 day harvesting only. On all other planting dates Kufri Pukhraj out yielded Kufri Surya. The proportion of small non-marketable tuber was low in Kufri Surya at first date of planting and 60 and 75 day harvest only. Kufri Surya had yield advantage over Kufri Pukhraj if planted early in September and harvested before 75 days. As the planting and/or harvesting is delayed this advantage is reduced and ultimately lost during mid and late September planting.

Performance of advance stage genotypes at Pune (Maharashtra) under early planting

At Pune (Maharashtra), 4 advanced hybrids were evaluated along with three control varieties in replicated trial (three replications & 40 tubers in each replication) under *Kharif* planting season. At 90 DAP significantly higher tuber yield was obtained in the advanced hybrid HT/7-1105 (22 t/ha) followed by HT/7-804 (19 t/ha) and K. Jyoti (18 t/ha) (Fig. 3).

Calcium application improves processing quality during early planting

An experiment was carried out to study the effect of calcium application on tuber yield and processing quality in processing varieties. Calcium application improved tuber yield and as well as chip colour in all the tested varieties (Fig. 4).

Tuber yield in PP10 5 ppm | *Tuber yield in PS10 5 ppm* | *Tuber yield in control*

Fig. 2. Plants showing effect of CRF on tuber yield

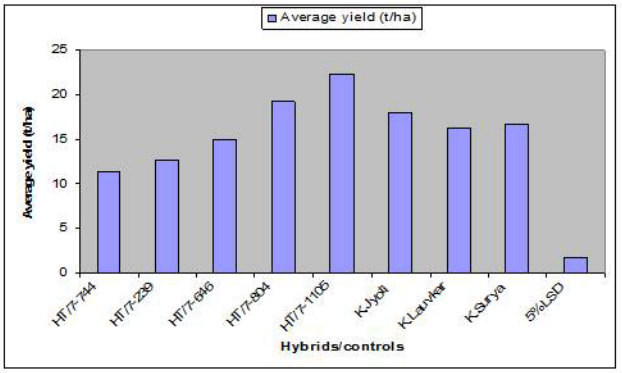


Fig. 3. Evaluation advanced hybrids at CSRI Padegaon, Pune under Kharif season

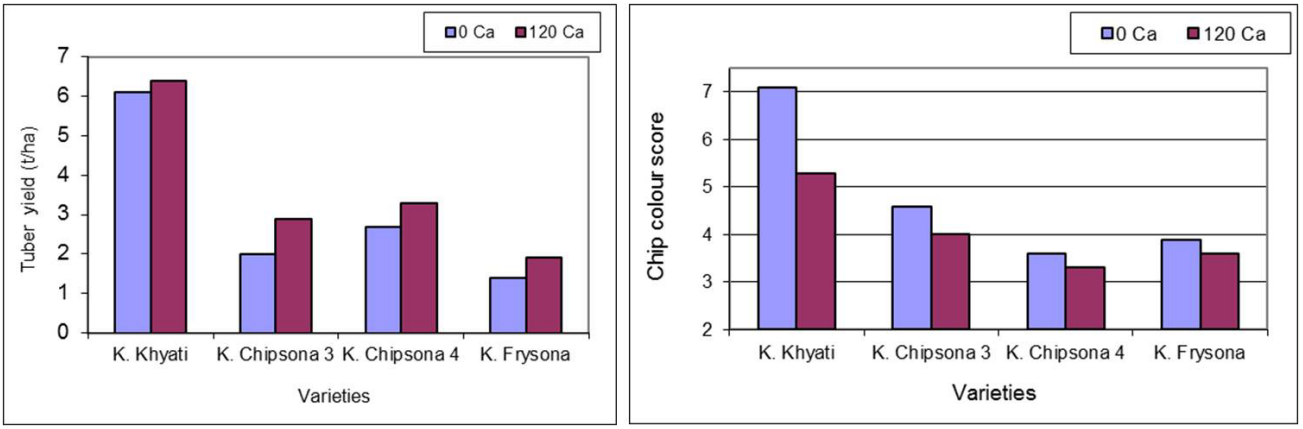


Fig. 4. Effect of Calcium on tuber yield and chip colour

Fertilizer requirement of advanced drought tolerant hybrids

Advanced hybrid WS/2005-146 produced significantly higher yield than Control variety Kufri Bahar. NPK dose at 75% was sufficient for full yield potential of the hybrid. (Fig. 5)

Leaf hopper and mite burn resistant hybrid

Twenty eight heat tolerant hybrids of series HT/10 were screened for mite and leaf hopper burn. Under sprayed (2 sprays of insecticide & miticide) conditions also few genotypes were attacked by mite such as

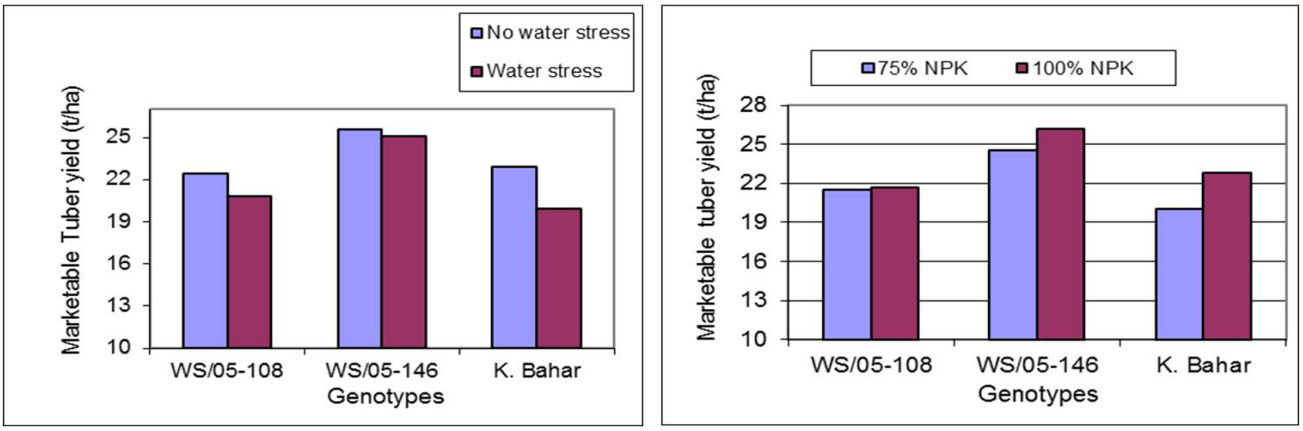


Fig. 5. Effect of water stress and fertilizer dose on tuber yield in drought tolerant hybrids

HT/10-1540, HT/10-1007, HT/10-1928 and HT/10-2901 and hopper burn was highest in HT/10-1920. Three genotypes *viz.* HT/10-1559, HT/10-1912, HT/10-2405 showed resistance to both hopper burn and mite under unsprayaed conditions.

Screening for drought tolerance

About 34000 seed from 28 crosses were used for raising seedlings and successful crop was managed. On the basis of morphological characters like tuber shape, color, depth of eyes etc., 559 clones each with 3-5 tubers were selected in WS 2013 series. Genotypes of different series tabulated below were planted for initial evaluation and selection.

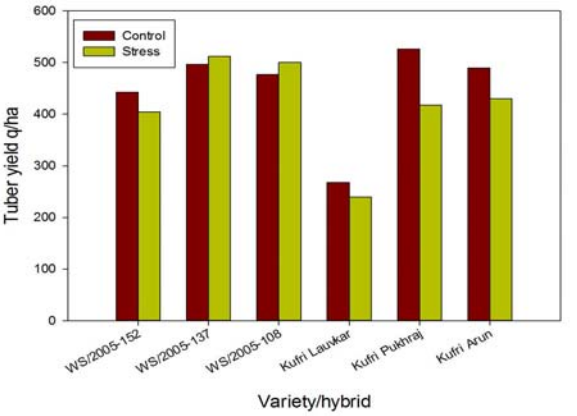


Fig 6. Tuber yield of drought tolerant hybrids under control and drought stress

Water stress series	No. of genotypes Planted	Selected	Status/ Details	Number of tubers for each selected genotype
WS/2011	132	69	Multiplication 2nd	60
WS/2012	880	270	Multiplication 1st	8-10

Evaluation of potato hybrids for drought tolerance

WS/2005 series: Three hybrids (WS/2005-108, WS/2005-152, and WS/2005-137) selected for drought tolerance were evaluated along with three control varieties viz., Kufri Lauvkar, Kufri Pukhraj, Kufri Arun under water stress. Control plots (T1) were irrigated when evaporation in the open pan reached 20 mm. The reduction in yield due to water stress was upto 20% in Kufri Pukhraj. Two hybrids WS/2005-108 and 137 yielded better than all the three controls under stress treatments. Yield reduction due to stress in these hybrids was negative to 9% compared to 10-20% for controls (Fig 6).

Fig 7. Tuber shape, skin color and external appearance of hybrid WS/05-108 and WS/05--146

Two hybrid *viz.* WS/05-108 and WS/05-146 were evaluated for storability. Both hybrids are good keepers and comparable to Kufri Bahar at room temperature. Total weight loss ranged from 4 to 5% at 45 days after storage (DAS) and remained below 10% at 60 DAS. Physical attributes of these hybrids are shown in Fig 7.

WS/2006 and WS/2007 Series: A total of 11 hybrids were evaluated. There were total four irrigations in control while last two irrigations were withheld in stress treatments. Yield data was subjected to exhaustive analysis and indices for drought susceptibility and stress tolerance were developed as follws: Drought susceptibility index (DSI) = (1-Yst/Ypt)/DI and DI=1-Ys/Yp, Modified stress tolerance index (MSTI) = k{(Ypt*Yst)/(Yp)2}, where : $k=(Yst)^2/(Ys)^2$,Y_{st} -yield of cultivar under moisture stress condition, Y_{pt} -yield of cultivar under irrigated condition, Y_s -mean yield of all cultivar under moisture stress condition and Y_p- mean yield of all cultivar under irrigated condition. Hybrid WS/07-131 had highest TY (28.4 t/ha) under stress and found superior as compared to targeted control cv Kufri Bahar (25.4 t/ha). Computation of MSTI showed highest tolerance in WS/07-131 (2.607) among hybrids, followed by WS/07-138 (1.860) and Kufri Bahar (1.728 . DSI values hybrid in hybrids WS/07-131, 113,138, 145 were lower than Kufri Bahar while in WS/06-128 it was slightly higher than the control (Fig. 8). Considering the MSTI, DSI, root pulling force, leaf RWC, crop vigour, tuber shape and tuber yield a total of 5 Nos. namely WS/06-128, WS/07-113, 131, 138 and 145 were selected for further evaluation and selection.

The thirteen water stress advance numbers along with two popular varieties Kufri Bahar & Kufri Pukhraj were evaluated for higher yield and water use efficiency. The results showed that the two advance numbers of 2005 series *viz.* WS/05-108 & WS/05-146 alongwith five new water stress numbers WS/06-72, WS/06-109A, WS/07-113, WS/07-131 and WS/07-160 produced 34.6 to 41.6 t/ha compared to 35-39t/ha for controls. These advance numbers were also found promising for higher water use efficiency.

Variety specific minimum thresh-hold water requirement of potato

Experiment was conducted with eight potato cultivars. The treatments comprised of four irrigation levels *i.e.* 15, 20, 25 & 30 mm CPE water level in main plots (6, 5, 4 & 3 irrigations, respectively and 35.5 mm effective rainfall during entire crop period), The results showed that the effect of irrigation levels and varieties was significant on yield and tuber numbers. All potato cultivars produced significantly higher yield (average 36.4 t/ha) at 15 mm CPE when 335.5 ha-mm total water was applied in comparison to 20, 25 & 30 mm CPE water levels (28t/ha at 30mmCPE). However, the

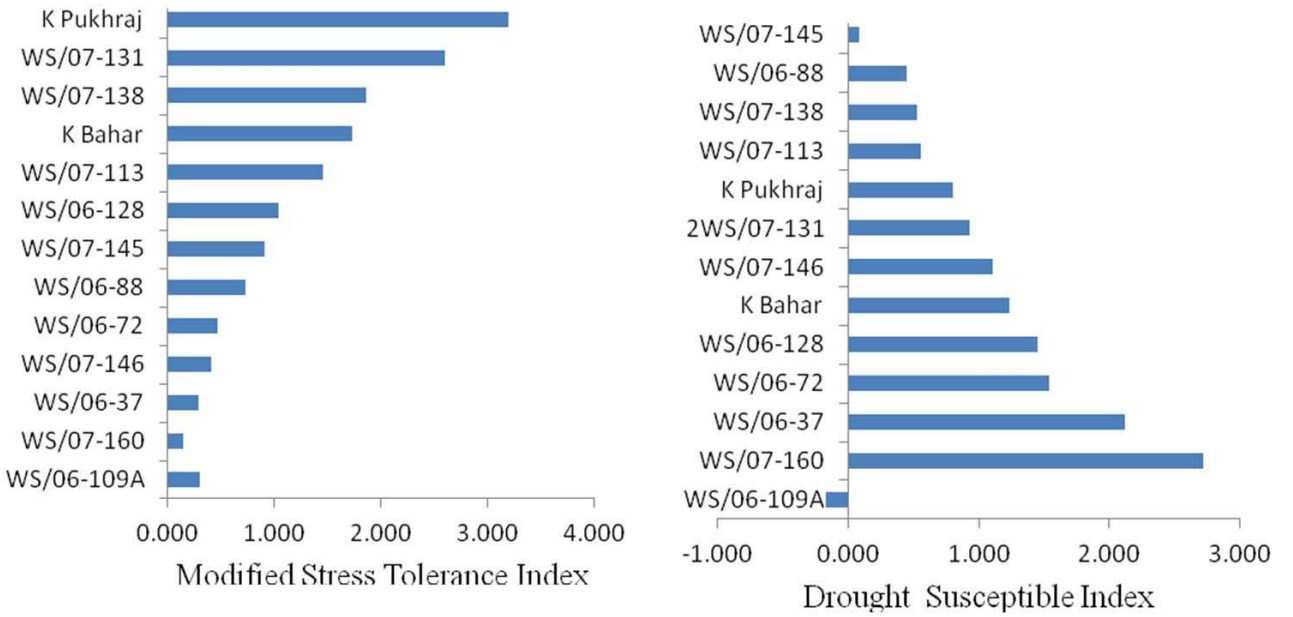


Fig.8. Drought Susceptibility Index (DSI) and Modified Stress Tolerance Index (MSTI) in selected potato genotypes (WS/06 and WS/07 Series) under water stress

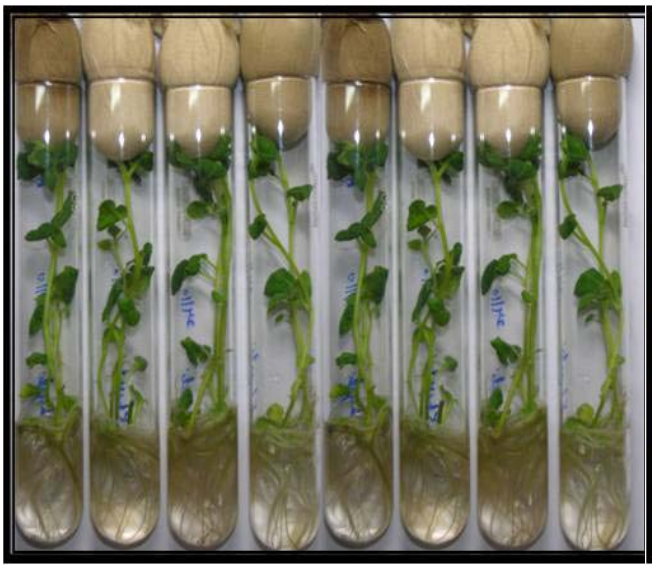
total yields decreased with the decrease in water levels from 15 to 30 mm CPE, the significant differences in yields being observed when irrigation applied at 30 mm CPE water level. The similar trend was also observed in case of large and medium grade tuber yields and numbers. However, the small size tuber yield was non significant under all irrigation levels. The water use efficiency (WUE) was also higher in case of Kufri Khyati (1.605 q tubers), Kufri Sadabahar (1.463 q tubers), Kufri Pukhraj (1.428 q tubers) and Kufri Anand (1.413 q tubers) in comparison to others varieties. The water requirement of Kufri Khyati (0.623 mm/q tubers), Kufri Sadabahar (0.683 mm/q tubers), Kufri Pukhraj (0.698 mm/q tubers) and Kufri Anand (0.708 mm/ q tubers) was less than other potato varieties.

Evaluation of dwarf transgenic lines for plant height and tuber yield

Eleven selected transgenic lines were multiplied in the net house at CPRS Jalandhar. Plant height and no. of stems was measured at 50, 70 and 90 days after planting. Tuber number and weight was recorded at harvest. All the transgenic lines were shorter than the control plants in Kufri Surya (Fig 9). Tuber number per plant was similar in both transformed and untransformed plants. Three out of seven transgenic lines of Kufri Surya yielded better than control with KS 11 and 13 yielding 285 g/plant compared to 185 g/plant for untransformed controls. In Kufri Himalini two transgenic lines KH.79 and KH 90 had plant height similar to control plants. The third transgenic line KH.65 was shorter than the controls till maturity. Tuber number was higher in KH.65 than the control and other two transgenic lines. None of the transgenic lines of Kufri Himalini yielded better than untransformed controls.

Fig 9. Dwarf transgenic lines of Kufri Surya along with control

Division of Seed Technology



Programme: Production of breeder seed of potato through conventional and hi-tech system

Introduction

Potato seed tuber is vegetatively propagated and is the most essential input in successful potato cultivation as it accounts for about 50% of the total cost of cultivation. Degeneration of potato seed stocks due to viral diseases is the most limiting factor in potato seed production. Therefore, seed stocks should be free from viral and other seed-borne diseases. To maintain high productivity, it is essential to have a scientific seed production mechanism through which high degree of health standard of the seed potato crop can be maintained. In this context, Seed Technology Division of the institute has been set up with the mandate "to produce disease-free basic seed of notified varieties developed by the institute". Therefore, a programme entitled "Production of breeder seed through conventional and high-system" was started under Revolving Fund Scheme (RFS). The nucleus and breeder seed production is being monitored by the scientists of the division at five different regional stations located in different regions of the country. The division has also started several research activities on emerging problems in conventional and high-tech seed production to increase the availability of quality and quantity of nucleus and breeder seed in the country. The seed production and supply status of breeder seed for hills in 2013-14 and supply of plains during 2012-13, while seed research of current year is summarized as below.

A. Seed Production

1. Conventional Seed Production System

i) Tuber indexing: A total no. of 13696 tubers of different commercial potato varieties were indexed at Modipuram (5528), Gwalior (6184), Patna (924) andKufri /Fagu (1060).

ii) Stage-I: A total production of 17.40 quintals was achieved in stage-I from an area of 0.12 hectare in hills (Table1). During 2013-14, the average yield was145 q/ha at Fagu.

iii) Stage-II: A total production of 52.60 quintals was achieved in stage-II from an area of 0.36 hectare in hills (Table 1). During 2013-14, the average production was 146.11 q/ha at Fagu.

iv) Stage- III: A total production of 124.50 quintals was achieved in stage-III from an area of 0.86 hectare in Kufri hills (Table 1). The average production was 144.77 q/ha in stage-III at Fagu.

v) Stage-IV: A total production of 352.25 quintals of breeder seed was achieved in stage-IV from an area of 2.89 hectares in hills. The average production in stage-IV was 121.89 q/ha at Kufri (Table1).

Table 1. Variety wise area and production in conventional seed production system at CPRS, Kufri/ Fagu

	Variety	Stage-I		Stage-II		Stage-III		Stage-IV		Total	
		Area (ha)	Production (q)	Area (ha)	Production (q)	Area (ha)	Production (q)	Area (ha)	Production (q)	Area (ha)	Production (q)
1	Kufri Jyoti	0.050	7.75	0.15	18.50	0.30	48.50	1.31	145.65	1.810	220.40
2	Kufri Himalini	0.020	3.35	0.08	14.50	0.18	37.50	0.45	64.40	0.730	119.75
3	Kufri Kanchan	0.008	1.05	0.05	4.80	0.08	10.50	0.21	30.00	0.348	46.35
4	Kufri Shailja	0.013	1.60	0.02	3.50	0.03	7.15	0.26	33.00	0.323	45.25
5	Kufri Giriraj	0.005	0.50	0.006	1.00	0.01	1.50	0.16	15.00	0.181	18.00
6	Kufri Girdhari	0.018	2.60	0.05	9.80	0.24	18.50	0.45	61.30	0.758	92.20
7	Kufri Himsona	0.006	0.55	0.004	0.50	0.02	0.85	0.05	2.90	0.080	4.80
	Total	0.120	17.40	0.360	52.60	0.86	124.50	2.89	352.25	4.230	546.75

2. Hi-Tech Seed production System

Production and supply of microplants: A total number of 13,325 *in vitro* culture tubes of 23 varieties and 1,750 bottles were produced while 900 flask of liquid culture of 11 varieties were transferred for microtuber induction at Shimla. A total of 1,173 *in vitro* culture tubes of 10 varieties were supplied to different regional stations for further multiplication.The details of microplants production of different potato varieties and supplied to regional stations is given in the fig1.A total of 136 microplantsof twelve cultivars viz., Kufri Jyoti, Kufri Badshah, Kufri Pukhraj, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Lauvkar, Kufri Bahar, Kufri Chandramukhi, Kufri Khyati, Kufri Frysona and Kufri Kanchan were supplied to 14 private seed companies from CPRI, Shimla.

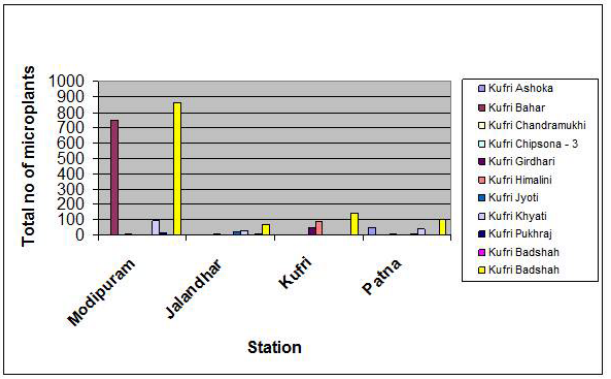


Fig 1. Microplants supplied to seed centers from CPRI, Shimla

Production and supply of microtubers: A total number of 17,109 microtubers (3.46 kg) of 21 varieties were produced in the division at Shimla (Fig. 2). Out of which 12,810 microtubers were supplied to different

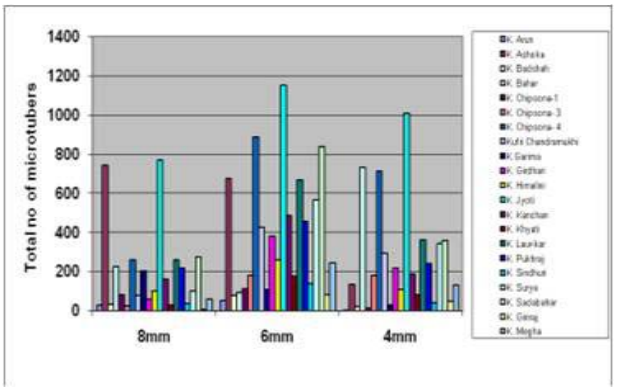


Fig. 2. Production of microtubers

regional stations during the year 2013 for the production of minitubers. Details of production of microtuber of different potato varieties and supplied to the different stations is given in fig. 3.

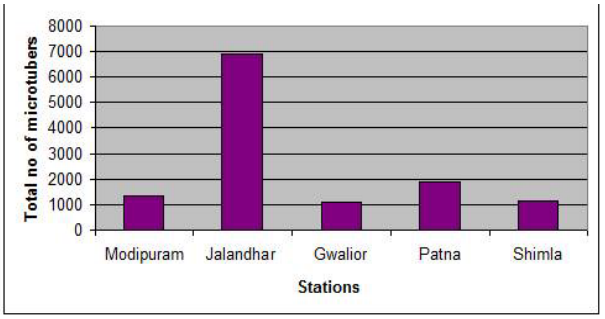


Fig. 3. Microtuber supplied from Shimla

Production of minitubers: A total number of 68,688 minitubers and tubers have been produced from microplants, microtubers and < 3 g minitubers. Total number 82,145 (282.96 kg) of aeroponic minitubers comprising of CPRS, Patna and CPRI, Shimla (Table 2).

Table 2: Production status of microplants, microtubers, <3 grams and aeroponic minitubers

Station	Planting material(Type)	Planted (No.)	Establishment (No.)	Minituber produced (No./wt. in kg)
Kufri	Microplants	345	290	792 (21.99)
	Minitubers (<3 g)	4794	4590	9100 (187.36)
Modipuram	Microplants (Aeroponic)	2610	——	71247 (204.59)
Patna	Microplants (Aeroponic)	782	—-	23,349 (70.53)
Shimla	Microplants (Aeroponic)	6015	5435	58,796 (212.43)
Total Microplants		345	290	792 (21.99)
Total Minitubers (<3 g)		4794	4590	9100 (187.36)
Total Aeroponicminitubers		9407	—-	1,53,392 (487.55)

Table 3. Area and production in high-tech system at CPRS, Kufri/Fagu

VaVarities	Generation-I		Generation –II		Total	
	Area (ha)	Production (q)	Area (ha)	Production(q)	Area (ha)	Production (q)
Kufri Jyoti	0.02	1.85	0.05	9.00	0.07	10.85
Kufri Girdhari	0.03	2.10	0.20	17.00	0.23	19.10
Kufri Himalini	0.05	3.20	0.30	57.50	0.35	60.70
Kufri Shailja	-	-	0.04	5.73	0.04	5.73
Kufri Kanchan	-	-	0.04	6.55	0.04	6.55
Kufri Giriraj	-	-	0.04	4.25	0.04	4.25
Total	0.10	7.15	0.67	100.03	0.77	107.18

ii) Generation-1: A total production of 7.15 quintals was achieved from six varieties in generation-1 from an area of 0.10 hectare in hills (Table 3). The average production in this generation was 71.50 q/ha at Fagu.

iii) Generation-2: A total production of 100.03 quintals was achieved from six varieties in generation-2 from an area of 0.67 hectare in hills. The average production in G-2 was 149.30 q/ha at Kufri (Table 3).

3. Production and supply of nucleus and breeder seed from Shimla hills during 2013-14

A total production of 653.93 quintals of nucleus and breeder seed was achieved in both conventional and hi-tech seed production system from an area of 5 hectares in hills. This provided 452.28 quintals breeder seed produced in 3.56 ha area. A total quantity 447.18 quintals of breeder seed was supplied from Kufri hills during the current season of 2013-14 (Fig. 4). Presently, 83.6% nucleus and breeder seed was produced from 84.60% area in conventional system and 15.40% area in hi-tech system and the percentage of breeder seed from conventional system was 77.88% while 22.12% through hi-tech system for hills.

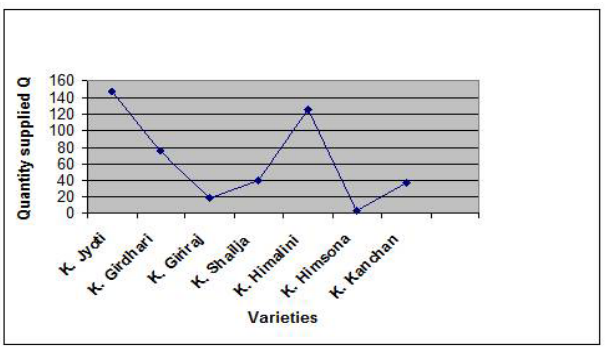


Fig 4. Varieties wise supply of breeder seed from CPRS, Kufri

4. Total supply of breeder seed during 2012-13 cropping season:

A total of 23,955.37 quintals breeder seed were supplied to various government and private agencies during 2012-13 (Table 4) from plains and hills which include both pre-cold store (21,646.79 quintal) and post-cold storage (1,898.36 quintal). The supply was 410.22 quintals from Kufri for hill states of the country during 2012-13.

5. Maintenance and multiplication of virus free buffer stocks:

A total no. of 104 individual tubers of 23 varieties viz., Kufri Arun, Kufri Ashoka, Kufri Badshah, Kufri Bahar, Kufri Chandramukhi, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Frysona, Kufri Giriraj, Kufri Girdhari, Kufri Himalini, Kufri Himsona, Kufri Jyoti, Kufri Kanchan, Kufri Khyati, Kufri Lauvkar, Kufri Pukhraj, Kufri Pushkar, Kufri Sadabahar, Kufri Shailja, Kufri Sindhuri and Kufri Surya were separately planted and 94 plants were tested against 29 viruses by ELISA and 8 viruses by PCR and aseptically produced 453 basic tubers of 20 varieties by maintaining four different lots in net house. Out of this material, virus infected and phenotypically different plants were discarded. About 80 individual tubers of 20 varieties of virus free, true to type, uniform in size and genetically pure tubers were selected and aseptically maintained at 4ºC as basic material. A total of 21 nodal cutting from virus-free plants of basic material of 17 varieties were carried out aseptically for microplant generation and further multiplication.

Table 4: Variety and agency wise supply (quintal) of breeder seed during 2012-13

State/agency	K. Bahar	K. Jyoti	K. Pukhraj	K. Chip-3	K. Chip-1	K. Badshah	K. Sindhuri	K. Surya	KCM	K. Anand	K. Himsona	K. Kanchan	K. Lauvkar	K. Chip-4	K. Sadabahara	K. Arun	K. Sutlej	K. Himalini	K. Ashoka	K. Girdhari	K. Pushkar	K. Shailja	K. Giriraj	K. Khyati	K. Frysona	K. Jwahar	K. Chip-2	Total
UP	2624.5	-	300	403	250	162	-	1000	-	100	-	45	-	100	154.5	-	43.5-	-	-	-	-	-	-	133	100	-	-	5445.5
Punjab	50	180	120	80	-	70	100	-	205	-	-	-	100	-	-	40		-	-	-	-	-	-	50	-	-	-	995
Haryana	-	-	112	-	-	-	-	-	-	-	28	-	-	-	-	-	-	-	-	-	25	-	-	107	-	-	-	272
H.P	-	720	-	-	-	-	-	-	73	-	-	-	-	-	-	-	-	35	-	20	-	-	15	-	-	-	-	863
M.P	90	-	130	40	25	-	-	10	70	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	390
W.B	-	238.5	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	298.5
J&K	-	566	704	-	16	-	-	-	130	-	-	-	-	-	-	-	-	45	-	2	-	-	-	130	5	-	-	1598
Bihar	-	45	915.5	-	-	-	15	-	-	-	-	-	-	-	-	145	-	-	55	-	-	-	-	-	-	-	-	1175.5
Chattisgarh	-	-	-	70	-	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230
Kamataka	-	17	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-	34.6
Gujrat	-	-	-	-	-	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110
Arunachal Pradesh	-	16	-	-	-	-	-	-	-	-	-	4		-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
Sikkim	-	5	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	30
Uttaranchal	-	67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	20	-	10	5	-	-	-	-	122
Meghalaya	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
NSC	5	205	50	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	310
SFCI	90	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	132
NHRDF	350	35	40	-	-	-	-	150	-	-	-	-	100	-	-	20	-	-	35	-	-	-	-	45	-	-	-	775
FOC/ICAR	2.1	64.50	40.50	42.40	1.14	8.72	-	61.05	-	0.1	17.21	0.5	0.5	4.9	5.1	-	0.1	19.48	-	9.5	5	3.5	0.5	87.6	63.1	-	-	437.50
University	-	8.5	216.50	-	-	-	0.1	51.34	5.2	-	-	-	5.3	0.2	-	0.2	-	2	-	2.5	1	2	-	10	-	0.2	0.21	305.25
Pvt/ Farmers	457	1589.51	745.9	124.09	1200.6	134.63	1282.25	692.6	277.7	274	108	9.4	507.25	380.35	-	135.4	-	14.55	6.25	19.5	16.8	8.95	2.7	341.62	238	3.65	53.52	8624.22
Auction/ Market	781	-	184.3	130.1	40.2	39.8	-	129.5	-	97.1	11.8	-	-	79	106.2	-	10.7	4.2	-	-	-	-	-	90.9	62.5	-	-	1767.3
Total:	4479.6	3789.01	3603.7	889.59	1532.94	685.15	1397.35	2161.49	760.9	471.2	165.01	78.9	713.05	589.45	265.8	340.6	54.3	140.23	111.25	73.5	41.8	29.45	23.8	970.12	498.6	3.85	53.73	23955.37

6. Revenue generated in Revolving Fund Scheme (RFS)

During the financial year 2012-13, a total of Rs. 5,04,29,602 as per unaudited balance sheet was generated from the sale of breeder seed of potato. The sale of potato breeder seed was worth Rs. 2,72,50,387; 91,95,437; 94,60,358; 38,94,980 and 6,28,440 at Modipuram, Jalandhar, Gwalior, Patna and Kufri respectively. The total expenditure was Rs.2,89,83,376 under RFS and the centre wise expenditure was 1,60,13,061; 58,15,609; 46,73,543; 8,85,112 and 15,96,051 at Modipuram, Jalandhar, Gwalior, Patna and Kufri respectively. Excessive expenditure of about more than two times of revenue generated has been made by CPRS Kufri.

7. Production and supply of quality seed

A total production of 891.20 q was achieved from 9.18 ha area at Ooty with the average productivity of 97.08 q/ha and a total of 539.30q quality seed was supplied (Table-5). The revenue generated from sale of potato was as Rs 11.78 lakhs as compared to approximately Rs. 20.28 lakhs during last year. The total production and average productivity has drastically reduced in this year as compared to last year. A total production of 337.23 q was achieved from 3.31 hectare (94.50 q from 1.20 ha under conventional system and 242.73 q from 2.11 ha under hi-tech seed production system) at Shillong with average productivity of 101.88 q/ha which was comparatively better than last year. A total of 256.30 q quality seed have been supplied and the revenue generated was Rs 5.95 lakhs at CPRS Shillong.

8. Supply of indexed tubers to RPF, Mao, Imphal, Govt. of Manipur

As per the MoU between CPRI, Shimla and Government of Manipur, regarding the breeder seed production at Mao farm, Manipur. A total of 1360 indexed tubers (600 tubers of Kufri Jyoti, 240 tubers of Kufri Himalini, 240 tubers of Kufri Kanchan and 280 tubers of Kufri Girdhari) were supplied in clonal form for further multiplication in subsequent cycles to augment seed potato production in Manipur and supply chain in NE regions. The quantity and quality of seed production was observed to be very good at RPF, MoU during monitoring of the crop. Two senior research fellows were trained in division of Seed Technology on tissue culture, PCR techniques, ELISA techniques, microtuber production and other techniques to further strengthen seed production programme through High-tech system in Manipur.

B. Seed Research

1. Effect of priming with biopesticides, micronutrient, fungicides and its integration on germination, vigour and weight loss of different grades of microtuber

Freshly harvested microtubers of Kufri Lauvkar were dipped for 30 minutes in the commercial formulation suspension of *Trichoderma viride, Pseudomonas fluroscence* as biopesticide, carbendazim, captan and pencycuron as seed treatment fungicides, tracel as blended micronutrient, air dried at ambient laboratory conditions of Shimla. Results revealed that percent loss in weight of microtubers was periodically

Table 5. Quality seed production details of different crop season during 2013 at Ooty

Sl. No.	Varieties	Summer season			Autumn season			Spring season		
		Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)
1.	Kufri Swarna	2.40	37.15	15.5	0.60	8.56	14.27	0.26	1.46	5.62
2.	Kufri Girdhari	2.64	29.93	11.3	0.60	6.93	11.55	0.40	0.95	2.38
3.	Kufri Himalini	0.64	1.29	2.02	0.16	0.55	3.44	0.06	0.09	1.50
4.	Kufri Jyoti	0.70	0.75	1.07	0.16	0.43	2.69	0.20	0.07	0.35
5.	Kufri Neelima	0.12	0.38	3.17	0.16	0.32	2.00	0.08	0.26	3.25
	Total	6.50	69.5	10.70	1.68	16.79	9.99	1.00	2.83	2.83

increased from 35 days to 130 days of storage in all the three grades as well as the treatments with maximum in 4 mm followed by 6 mm. It varied from 48.1 to 58.3% in 4 mm grade, 34.9 to 44.0% in 6 mm grade and 27.2 to 31.4% in 8 mm grade microtubers. Carbendazim priming was best for reduction of weight loss in 4 mm grade of microtuber (48.1%) followed by tracel alone (51.1%) in comparison to control (58.3%). However the minimum weight loss was in *T. viride* (34.9%) closely followed by *T. viride*+ *P. fluorescence* + tracel integration (35.4%) in comparison to control (41.9%) for 6 mm grade of microtubers (Fig.5). The vigour was tremendously increased in most of the treatments in both the grade of microtubers. The highest percent vigour increase was 171.4% in carbendazim, pencycuron as well as tracel over control in 6 mm grade of microtubers. The vigour was also very high in captan (114.3%) and tracel+carbendazim (100%). Percent increase in germination over control in 6 mm grade varied from 13.3 to 33.3% with maximum in *T. viride* and pencycuron. In 4 mm grade of microtubers, the maximum increase in germination was 29.6% in carbendazim, penycuron and tracel (Fig.6). The non-germinated/rotted/dried microtubers was 12.5% in carbendazim, pencycuron and tracel in comparison to control (32.5) in 4 mm grade microtubers. It was concluded that all the treatments improved the germination and vigour of microtubers in comparison to control and can be successfully utilized as wet priming by integrating these micronutrient/ fungicides /bioagents (Fig.7). It was very apparent that weight loss/driage and rottage can also be minimized by the wet priming of the above chemicals in all three grades of microtuber.

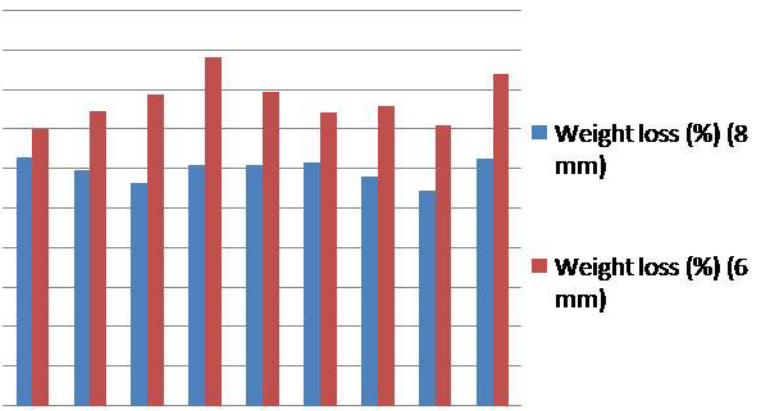


Fig. 5: Priming effect on weight loss

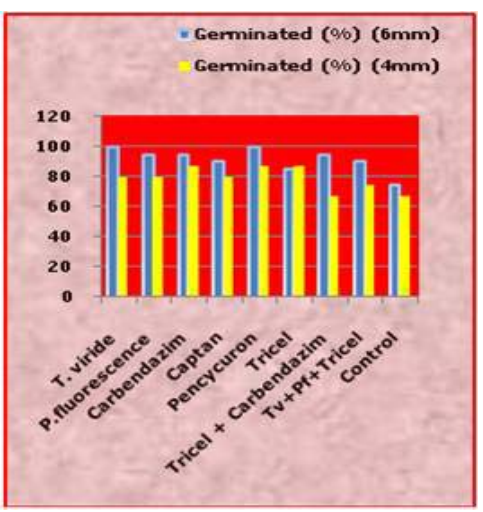


Fig. 6: Priming effect on germination

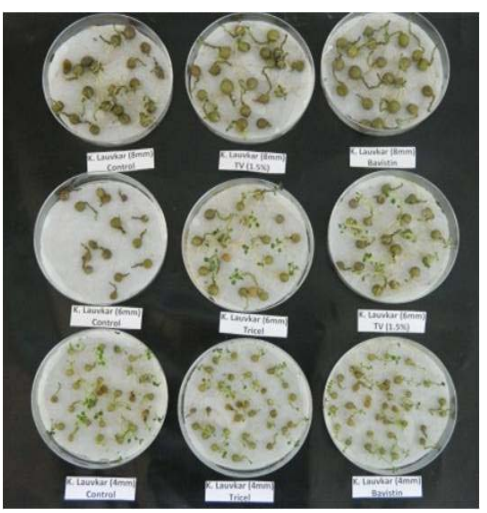


Fig. 7: Priming effect on germination & vigour

2. Effect of packing material as well as different priming on weight loss and vigour of aeroponic minituber

Aeroponic minitubers of Kufri Girdhari harvested in the month of April, 2013 was used for wet priming by bioagents, fungicides, tracel (micronutrient) and its integration. The minintubers were kept in four different types of packing bags and stored in upper culture room for about 11 months. Periodical weight loss was taken at monthly interval while germination was taken in last month. There was no significant difference dueto different treatments on weight loss. However, yellow cloth bag seems to be better over other three packing bags. The weight loss varied from 46.35 to 74.04% during the course of experimentation. Cloth bag and biopriming was comparatively better for increasing the sprouting vigour. Sprout viability was maximum in biopriming, captan and monceron.

3. Development of encapsulation techniques for microtuber storage

Freshly harvested microtubers in the month of February 2014 of varieties Kufri Bahar, Kufri Sadabahar, Kufri Girdhari and Kufri Surya (6 &4 mm) were encapsulated using different concentration of sodium alginate (2%, 3%, 5%, 7% and, 9%) by dipping for 10 minutes and then transferred in 2.5% calcium chloride for 30 minutes. After encapsulation it was stored at 4°C (Fig.8). Good coating was observed with proper agitation but cracking was observed after 2 weeks of storage at 7 and 9%. Lowest rate of cracking was observed in 2 and 3% in all grades. Calcium alginate at any concentration was not suitable for encapsulation. Among the varieties, the best coating without any cracking was noticed in Kufri Surya, Kufri Girdhari and Kufri Bahar after 50 days of storage at 4°C temperature.

4. Refinement in MS culture media for multiplication of recalcitrant potato cultivar Kufri Jyoti

The modified MS culture media was developed earlier with higher concentration of ammonium nitrate, gibberellic acid (GA_3) and naphthalene acetic acid (NAA) over the normal standard MS media cannot be used now due to restriction on growth hormone as policy decision in high-tech seed production. Therefore the present study was conducted to find out a hormone free media for satisfactory growth of microplant of recalcitrant variety Kufri Jyoti. Observation of different vegetative growth parameters like microplant height, number of leaves, nodes, root, root length and fresh weight revealed that the media freshly prepared from stock solution was better than readymade synthetic media when supplemented with carbencillin (100 ppm). However, fresh weight was more in synthetic media when supplemented with cefotoxime (100 ppm). Microplant height, number of nodes and root length was comparatively high in growth hormone-free media irrespective of antibiotic selection. Among the antibiotics, carbencillin was comparatively better than cefotoxime for most of the growth parameters. However, cefotoxime was much better for restriction of most of the endophytic bacteria. It was concluded that MS media freshly prepared from stock solution and devoid of all the growth hormone supplemented with 100 ppm cefotoxime or carbencillin can be successfully utilized for optimum growth of recalcitrant variety Kufri Jyoti. Alternatively both types of the above

Fig. 8. Encapsulation of microtubers

MS culture media with antibiotic and without growth hormone should be used for satisfactory growth.

5. Occurrence of *Sclerotinia sclerotiorum* and its mode of infection on potato in hills and plains of North India

Seed potato crop is observed to be infected by white rot disease in Shimla hills and plains of Jalandhar and Gwalior. Close inspection of seed crop revealed that the flowers and its petals were infected with white cottony fungal growth. The infected petal of flowers was also found fallen on lower base of stem and leaves. The infected flowers and petals were brought to Shimla and isolated the pathogen. It clearly revealed the pathogen *S. sclerotiorum*. Here it is necessary to understand the mode of potential primary infection on potato. The pathogen is monocyclic and its sclerotia survive in soil for several years which formed apothenia in cool, cloudy, wet and shady conditions. The mode of primary infection is only through ascospores developed in apothecia from fallen sclerotia in soil. The short lived ascospores forcibly released from ascus and fall on flowers as well as all parts of the plants and germinate but can cause infection only on petals. All the germinating ascospores on leaves, stem, fruits cannot penetrate hard cuticle and waxy layers but easily infect delicate petals and colonize. Now the infected petals have enough inoculum potential to create infection on other plant parts whichever comes in contact for subsequent infection (Fig.9). In absence of potato flowers it infects flower of weeds available in vicinity of potato plant and the infected flower of weeds leads to infection in potato plant. It is also clear that the disease must have appeared in seed potato field at these locations much earlier and accordingly sclerotia have fallen in the soil few years back for subsequent infection. It is concluded that *S. sclerotiorum* is spreading rapidly in seed potato and the source of primary inoculums is ascospores and site of primary infection is flower.

6. Study on endophytic bacteria in different types of planting materials of potato:

Various types of seed planting materials comprising of seed tubers of GO, G-1, G2, Basic plant, microplants, microtubers, nodal cuttings etc. were used for isolation of endophytes. The bacteria were aseptically isolated on Nutrient Agar medium. The isolation was made from tubers, leaves, stem and root. All the culture was purified and about 30 pure cultures were maintained aseptically. The colony characters' was studied on six media Potato Dextrose Agar (PDA), Oat Meal Agar (OMA), Czepak Dox Agar (CDA), Richard's synthetic Agar (RA), Murashige and Skoog Media (MS), Nutrient Agar (NA) revealed PDA, CDA and OMA plates having best bacterial growth of all types of isolates. Colony characters were highly variable and varied from bright red to dull light red, bright white to dull white, dark yellow to light yellow, crusty to mucilaginous, radiating to smooth, slimy, erumpent with whitish semisolid colony. The colony growth in these medium was scanty to profuse. Kufri Chandramukhi, Kufri Sadabahar and Kufri Badshah were the varieties which have red bacterial growth with maximum incidence in Kufri Chandramukhi. The red bacteria were most dominant in most of the seed planting materials and it was tentatively identified as *Methylobacterium* species (Fig.10). Some of the dominant isolate may be *Pseudomonas* and *Bacillus* spp. Few isolates of fungal colony was also observed from the inner core of tubers. Intermixed bacterial colony with radiating hyphae type was also observed. The culture of few isolates changed their colony colours during subsequent culturing on NA.

Fig. 9. Sclerotinia on seed potato

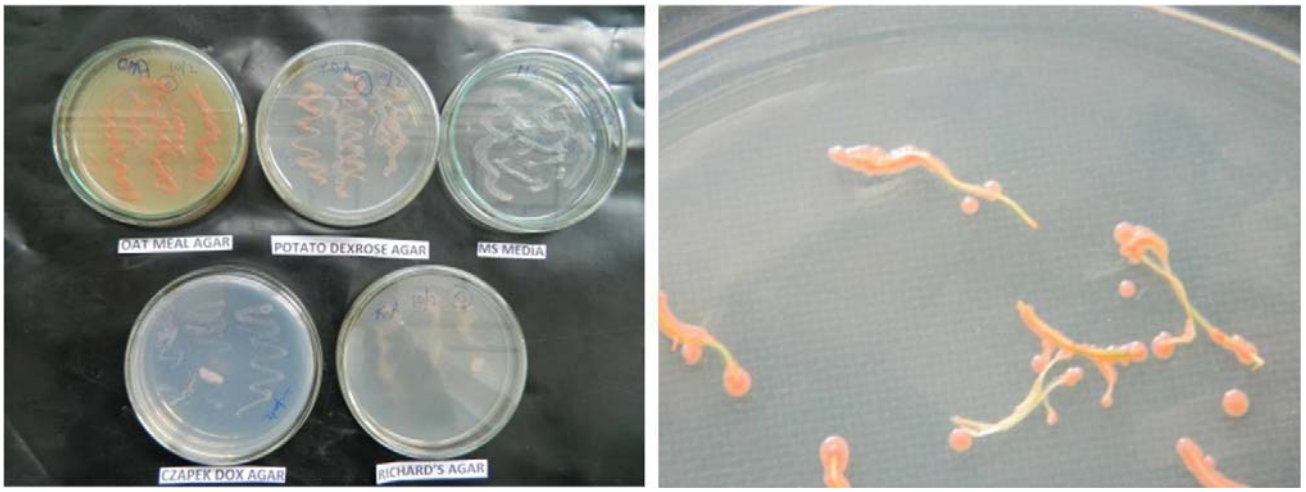


Fig. 10. Endophytes in seed potato

7. Monitoring of health and quality of basic seed by virus and genetic fidelity test

Different types of basic planting material used for breeder seed production was periodically inspected and monitored for virus freedom, quality and health standard through PCR and ELISA. A total of 267 samples comprising basic leaf samples (67) mericlones (139), nodal microplants (42), old microplnts (19) were tested by PCR against different viruses. Similarly a total of 1605 samples comparising of above materials were tested by ELISA against all the viruses. Based on PCR and ELISA testing, the quality was checked and monitored. A total of 52 leaf samples of nucleus and breeder seed planting material were tested by molecular marker for genetic fidelity and compared with DUS material as well as germplasm gene bank and accordingly the genetic purity was checked and monitored.

8. Management of black scurf and common scab disease in seed crop under lower hill conditions of Shimla

The experiment was conducted in experimental field of lower laboratory in summer season. The black scurf and common scab incidence was significantly reduced in all the treatments in comparison to control. Maximum reduction of black scurf was observed in *T. viride,* mancozeb, monecron and boric acid+ *T. viride* and statistically at par to each other. The black scurf incidence in these treatments varied from 11.2 to 13.9% whereas in control it was 36.3%. Common scab incidence was minimum in *P. florescence,* boric acid and *T. viride* which varied from 14 to 15.2% in comparison to control (37.14%). It was clear that intensity of black scurf and common scab in the field of lower laboratory at Shimla is very high and can be managed by application of biocontrol agents also (Fig. 11).

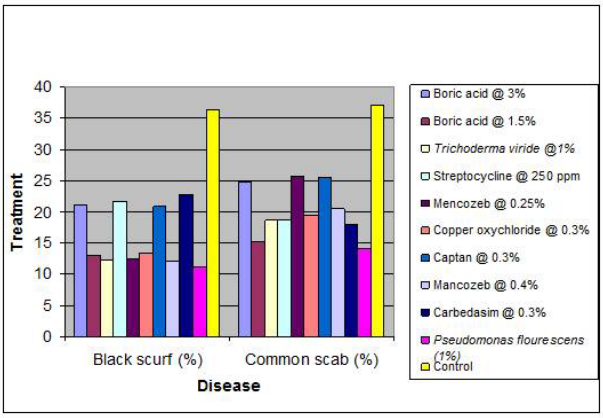


Fig. 11. Incidence of black scurf and common scab

9. Comparison of crop raised with conventional seed tubers vs tissue culture tubers:

The experiment was planted at lower laboratory in summer season with Stage-IV, Stage-III, G2 and G1 of two varieties *viz.* Kufri Jyoti and Kufri Girdhari and compared for plant growth and productivity. The germination did not vary among the different stages of two production system and it was maximum (100%) in Kufri Girdhari (G1) and minimum (97.40%) in Kufri Jyoti (G2). The numbers of leaves and plant height at 50, 70 and 90 days after planting were found to be affected with cultivars and different stages. Mean total number of tuber per plot varied among the different stages and varieties. In G2 of Kufri Jyoti produced 72.13% oblong shape tuber while in G1 Kufri Girdhari

produced 51.51% phenotypic changes oblong shape tuber. The experiment conducted with three varieties Kufri Jyoti, Kufri Himalini and Kufri Girdhari and four stages *viz*. Stage IV, Stage V, G2 and G3 at Kufri. Percent ground cover at 75 DAP was not found to be affected neither with the cultivars nor the different stages. Plant height (75 DAP) revealed a non-significant difference between the different stages, however, among the cultivars plant height was significantly more in Kufri Girdhari than others. Haulm weight was found to be comparatively high in G2 and G3 than Stage IV and V, although the differences were statistically non-significant. Low haulms weight in Stage IV and V at 120 DAP indicates early maturity of the crop raised from conventional seed in comparison to hi-tech grown seed. At Patna seed size tuber yield was maximum in stage-III, G1 and G2 as compared to stage-IV with in varieties Kufri Pukhraj and Kufri Jyoti. The over size tuber yield was maximum in stage-IV in both varieties. The visual as well as ELISA test result showed hi-tech seed were more healthy than conventional system.

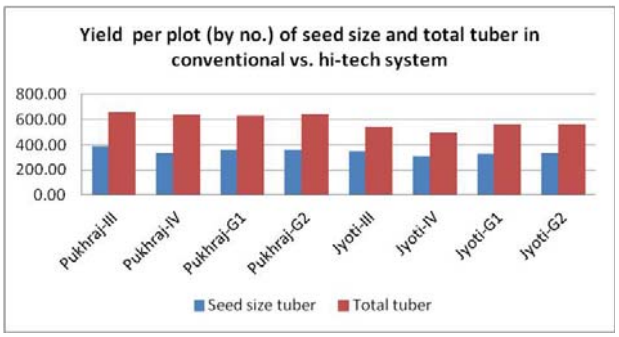


Fig. 12. Comparative yield performance in two system

10. Study on phenotypic changes during hi-tech seed potato production system

The experiment was conducted with planting of elongated tubers and round tubers from G-2 of *cv*. Kufri Jyoti and Kufri Girdhari in pots in autumn season for phenotypic changes during hi-tech seed potato production system. The germination ranged from 99 to 100%. In Kufri Jyoti, round shaped tuber planted material produced 69.50% round shape tuber and 30.45% oblong shape tubers while oblong shape tuber planted material produced 67.76% rounded shaped tuber and 32.23% oblong shape tubers. In Kufri Girdhari round planted tuber produced 55.33% round and 44.66% oblong tubers. The oblong planted material produced 35.67% round and 64.32% oblong tubers in G-2 raised by microplants (Table 6).

Plant phenotype at Fagu in G1 and G2 stages was not observed in Kufri Girdhari and Kufri Himalini. However, the phenotype was slightly different in Kufri Jyoti in both the stages. It may be the carry over effect of the seed tubers obtained from similar type of plants grown during last year in G0 and G1. These plants were having upright growth with small leaf laminas and inward rolling of leaves. Such plants were also dark green, remained young and vigorous with profuse white flowering for longer period than the plants of Stage III and IV under conventional system of seed production. With advancing crop age *i.e.* after about 70 days of planting, upright growth habit of these plants started changing towards normal with open and enlarged leaf laminas. Proportions of phenotypically elongated mini-tubers grown from different sources *viz.* (micro-plants, aeroponic tubers and recycling of <3g mini-tubers) varied within different grades of mini-tubers as well as among the varieties. The proportions of deformed tubers was maximum (14.5%) in the mini-tubers produced from re-cycling of <3g mini-tubers and minimum (11.5%) in those obtained from micro-plants. Proportion of such elongated tubers increased gradually with the increasing size of mini-tubers.

11. Virus profiling in potato growing regions of Shimla

A survey was conducted in the Shimla district of Talai, Bakhati, Gallu, Kufri, Sarog and Theog area, a total

Table 6. Effect of phenotypic change tuber performance on yield and number of tuber

Sl.	Varieties	Pheno-typic change tuber	No. of tuber planted	Germin-ation (%)	Total no. of tubers	Total wt. of tubers (kg)	Total no. of round tubers	Round shaped tuber (%)	Total no. of oblong tubers	Oblong shaped tuber (%)
1	Kufri Jyoti	Round	64	99	220	1.451	153	69.50	67	30.45
		Oblong	20	100	121	0.570	82	67.76	39	32.23
2	Kufri Girdhari	Round	21	99	103	0.346	57	55.33	46	44.66
		Oblong	30	99	171	0.540	61	35.67	110	64.32

of 38 farmer's field leaves samples revealed that mild mosaics were most predominant being prevalent in 25% farmer fields, Virus testing of the collected leaf samples was done through ELISA for the twenty six potato viruses. the virus profile 40% infected with PVS in Talai village, 100% infected with PVS, PVY in Bakhati village, 80% infected with PVS, PVY in Gallu village and 40% infected with PVS, PVY in Kufri. In Sarog & Theog area, maximum infection was of PVS (33.3%), followed by PVX & PVY (16.6% each). No sample was found to have PVA& PLRV.

12. Aeroponics technology-A new approach for tomato, capsicum and brinjal production

The study was conducted at Central Potato Research Institute, Shimla during summer season from March-August to evaluate the performance of tomato, chilli and brinjal crop under small indigenously designed experimental Aeroponics box. A total of six tomato and capsicum seedlings were planted in the aeroponic unit on 26th March 2013. However, brinjal seedlings were planted quite late in another aeropnic box on 8th May, 2013. During the first 30 days of tomato crop growth, nutrient solution of before potato tuberization was supplied and then solution of after tuberization was supplied in the unit with maintaining 5.8 pH using 30 and 300 second cyclic interval The root was initiated between 4-5 days after transplanting in tomato and capsicum crop while after 9-10 days in brinjal. All three crops were successfully raised with maximum growth in tomato. The plant was hanged using bower system and excessive lower leaves were removed to intercept more light, and to increase aeration, transpiration as well as photosynthesis. Naphthalene Acetic acid (NAA) was sprayed @20 ppm at full bloom stage on capsicum and brinjal for fruit setting. The tomato crop performed very well under the above aeroponic system. The flower initiation in tomato started after 49 days of transplanting and fruit bearing in 59 days. Tomato ripening was started in 75 days old crop with indeterminate behaviour. All the tomato fruits were harvested after 120 days of transplanting. A total of 109 number of tomato ripe fruits weighing 5.245 kg were harvested from six plants in the aeroponic system. An average number of 18.1 ripe tomato fruit weighing about 878 gper plant was produced in the aeroponic system during the season. Successful fruiting was also observed in capsicum during the season. The flowers in brinjal were fertilized and fruit setting was observed after 91 days of transplanting but could not be established and all dropped out at buttoning stage. Based on the present study it is concluded that the aeroponic technique can be successfully utilized for the production of tomato and capsicum however the season and planting time need to be standardized for brinjal.

Fig. 13. Aeroponics for vegetable crops

13. Effect of bower system of planting on yield of different varieties in Aeroponic system

Refinement in various production technologies is going on particularly on date of planting, method of planting and nutrient solution to take round the year production of aeroponic minituber in hills of Shimla for long day as well as short as day condition using most of the important varieties under seed production. A total of 15 varieties viz., Kufri Himalini, Kufri Girdhari, Kufri Kanchan, Kufri Shailja, Kufri Giriraj, Kufri Jyoti, Kufri Khyati, Kufri Badshah, Kufri Pukhraj, Kufri Bahar, Kufri Sindhuri, Kufri Chipsona-3, Kufri Arun, Kufri Ashoka and Kufri Sadabahar were evaluated during August 2013 to January 2014 at Shimla. An experiment was conducted with aim to increase production potential in aeroponic system by using bower system to intercept more light, to increase aeration, transpiration as well as photosynthesis area and compared with conventional system of planting. The data revealed that significantly very high yield (number & weight) was recorded in most of the varieties in bower system as compared to conventional system (normal) of planting. The increase in number and weight of aeroponic minituber was recorded in all types of varieties irrespective of long day, short day and day neutral. The maximum 275% increase in yield by weight was

recorded in Kufri Jyoti, 260.3% in Kufri Badshah under bower system of planting over normal planting. More than two times additional yield was recorded in variety Kufri Sindhuri, Kufri Khyati, Kufri Pukhraj, Kufri Sadabahar and Kufri Himalini. The yield increase in bower system was not recorded in Kufri Bahar and Kufri Shailja both by number and weight. In Kufri Arun and Kufri Ashoka the number wise yield increased but total yield by weight decreased. The yield performance was also increased during each harvest.

Fig. 14. Aeroponics in bower system

14. Performance of minitubers production through aeroponics system in different seasons at Shimla:

Planting of microplants of six potato cultivars viz. Kufri Himalini, Kufri Lauvkar, Kufri Sindhuri, Kufri Girdhari, Kufri Jyoti and Kufri Khyati was done in April (summer) at Shimla. Rooting was initiated within 12 to 22 days and the establishment varied from 93.36 to 99.4% after 30 days of planting. The number of minituber per plant varied from 5.60 in Kufri Lauvkar to 13.77 in Kufri Sindhuri. The maximum mean weight of minituber per plant produced in Kufri Sindhuri with 48.36 g and lowest mean weight of minituber in Kufri Chipsona-4 with 15.64 g. A total of 12144 numbers of minitubers were produced with weight of 41.30 kg. Microplants of six varieties viz. Kufri Bahar, Kufri Badshah, Kufri Chandramukhi, Kufri Khyati, Kufri Lauvkar and Kufri Pukhraj was planted in the second week of July (Kharif). The establishment ranged from 95.42 to 98%. Tuber initiated in 38 to 42 days in Kufri Bahar and a total number of tuber harvested was 10,067 with weight of 37.22kg. The plant establishment varied from 61.22 to 100% after 30 days of planting. The number of minituber per plant varied from 7.17 in Kufri Chandramukhi to 31.34 in Kufri Chipsona-3. The maximum mean weight of minituber per plant was in Kufri Chipsona-3 with 103.67 g and lowest mean weight of minituber in Kufri Chipsona-4 with 20.32g. A total of 15,795 numbers of minitubers was produced and the weight was 56.34 kg. Further the planting of microplants of fifteen potato cultivarsin the last week of October (Rabi) was done. Rooting initiated within 4 to 9 days in all the varieties irrespective of season. The plant establishment varied from 66.23 to 100% after 30 days of planting. The number of minituber per plant ranged from 1.1 in Kufri Girdhari to 16.6 in Kufri Jyoti. The maximum mean weight of minituber (g) per

Fig. 15. Minituber production in Aeroponics at Shimla

plant produced in Kufri Jyoti with 47.67g and lowest in Kufri Girdhari (2.09g). A total of 9,920 numbers of minitubers was produced with total weight of 22.3 kg.

15. Production of minitubers through aeroponics seed production system

A total number of 58,796 minitubers with weight 212.43 kg were produced through aeroponics at Shimla. Out of that a total number of 35,782 minitubers and total weight 115.87 kg were produced during rabi crop season while a total number of 23,014 minitubers with total weight 96.56 kg were produced during summer crop season through aeroponics system. A total number of 71,247 minitubers weighing 204.59 kg were produced through aeroponics at Modipuram. Maximum number of minitubers was produced ofKufriBahar.A total of 23,349 numbers of minitubers was produced with total weight 70.53kg at Patna.

16. Performance of aeroponic tubers of different harvesting dates G-0 at Shimla

Germination per cent was higher in >3-10 g in all the dates of harvest than <3g tubers (Fig.16). Single stem per plant was recorded in both the size of tubers. Average number of compound leaves of different dates of harvest for <3g tubers was 9.2 and 11.3 while 12.7 and 14.0 for >3-10 g tubers at 50 and 75 days respectively. Average plant height of different dates of harvest for <3g tubers was 22 cm and 31 cm while 31 cm and 35 cm for for>3-10 g tubers. Average tuber number per plant of different dates of harvest was 5.6-6.2 and 7.3-9.4 for <3g and >3-10 g tubers respectively Average tuber weight per plant of different dates of harvest was 32.7-38.6g and 41.6-48.7g for <3gm and >3-10 gm tubers respectively. Average tuber number and weight per plot was higher in >3-10 g tubers in almost all the dates of harvest than <3g tubers in both the units (Fig 17 and 18)

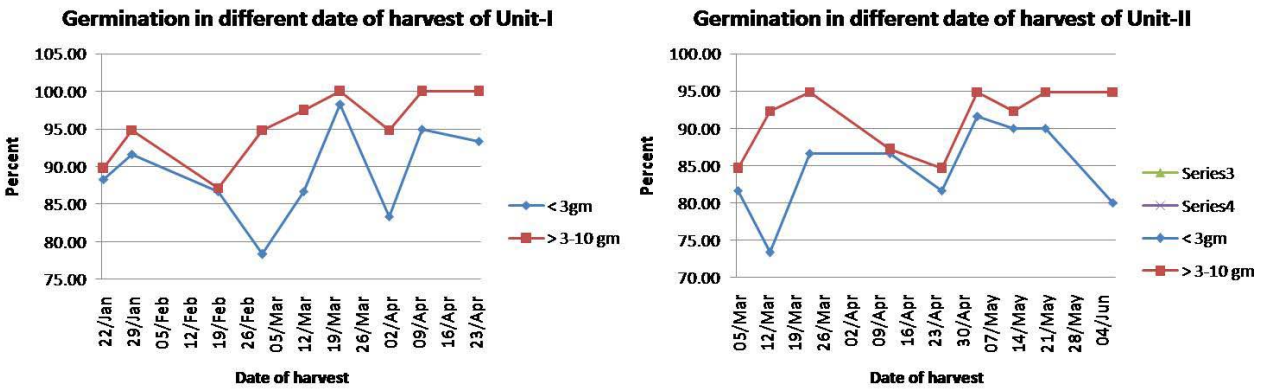


Fig. 16. Germination in different dates of harvest in aerophonic tubers

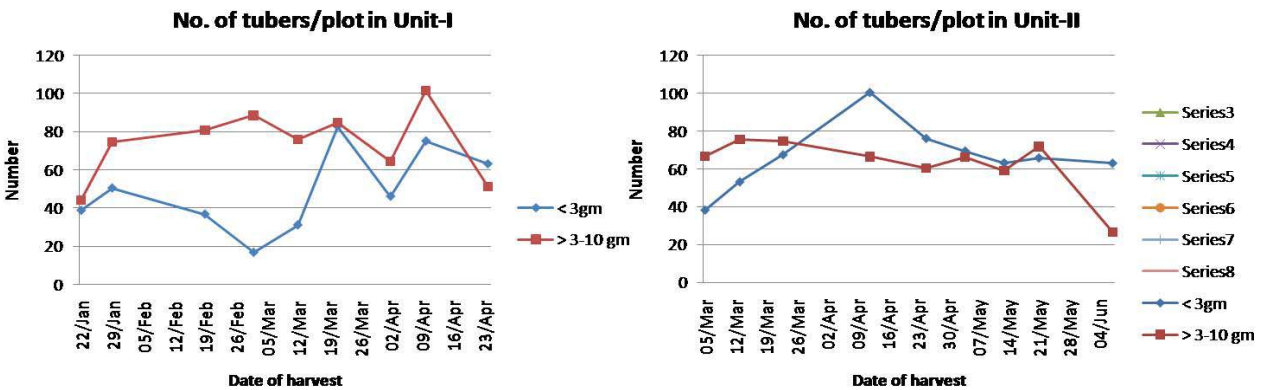


Fig. 17. Number of tubers/plot in different dates of harvest

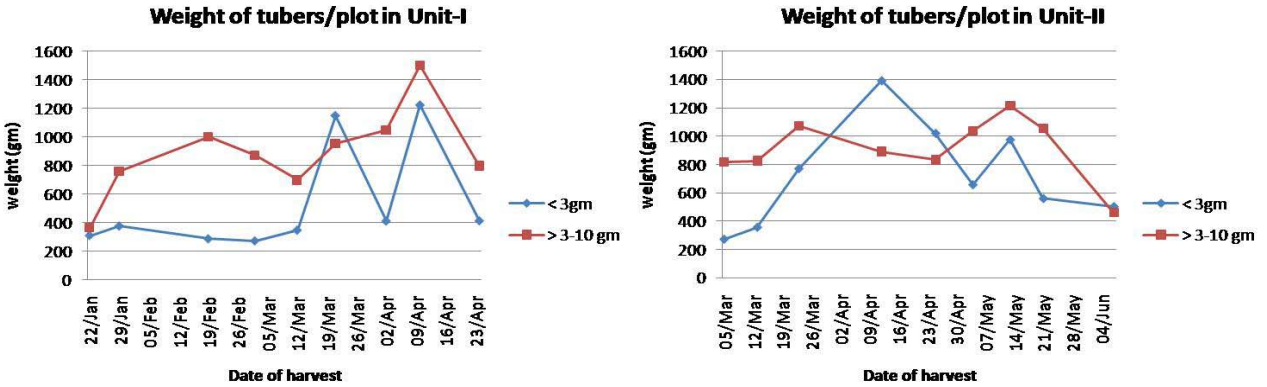


Fig. 18. Tuber yield (gm)/plot in different dates of harvest

17. Performance of different potato cultivars in aeroponic system at Modipuram

Performance of four potato cultivars viz. Kufri Bahar, Kufri Chipsona-3, Kufri Chipsona-4 and Kufri Khyati was evaluated by planting in last week of October. Rooting initiated within 3 to 4 in all the varieties. Sequential harvesting was done at the interval of three days and the mini tubers of 3g or more than 3g were picked. Days taken for first harvest were minimum (38 days) in Kufri Bahar whereas Kufri Chipsona-3 took 57 days to attain the desired size of minitubers for first harvest. However, the mean across the varieties was 46.25 days. Maximum number of 41.45 tubers/ plant was obtained from Kufri Chipsona-4 and minimum 25.68 from Kufri Khyati. Weight 105.28g of tubers/ plant was also maximum in Kufri Chipsona-4. Mean tuber weight was maximum 3.5 g Kufri Khyati.

18. Production of Nucleus/ Basic seed and planting material at Shillong

Potato micro-propagation has been going on under Mini-mission -I since its initiation in CPRS Shillong. A Total of 37,259 micro-plants of Kufri Giriraj (8342), Kufri Jyoti (3151), Kufri Himsona (7203), Kufri Himalini (5532), K Megha (3782), Kufri Girdhari (6674) and Kufri Kanchan (2575) were produced through micro-propagation during the period under report. During the same period, 677 micro-tubers of Kufri Himalini (96), Kufri Himsona (63), Kufri Girdhari (189), Kufri Giriraj (71), Kufri Jyoti (193) and Kufri Kanchan (65) were also produced. A total of 24,273 Kg of quality seed were produced in 7 most promising varieties, Kufri Girdhari (2795 Kg), Kufri Giriraj (5269 Kg), Kufri Himalini (7228 Kg), Kufri Himsona (1274 Kg), Kufri Megha (7438 Kg), Kufri Jyoti (239 Kg) and Kufri Kanchan (30 Kg) of potato for NEH Region.

19. Standardization of Aeroponic system for production of quality seeds under NEH conditions.

The poly house cum Aeroponic system has been constructed in March, 2013 at Shillong. Two crops were taken in the aeroponics system during 2013-14. During summer season microplants of potato varieties Kufri Girdhari, Kufri Megha, Kufri Himalini, Kufri Himsona, Kufri Jyoti and Kufri Giriraj were planted while in autumn microplants of six varieties viz., Kufri Girdhari, Kufri Megha, Kufri Himalini, Kufri Himsona, Kufri Jyoti and Kufri Kanchan were planted. In total, 71665 mini-tubers of different varieties were produced in summer and autumn season.

Fig. 19. Formation of minitubers (K. Megha)

20. Effect of harvesting interval and spacing on aeroponicminituber production at Modipuram

The effect of four harvesting intervals (3, 7, 10 and 14 day's interval) on cv Kufri Bahar under aeroponic system at Modipuram revealed that maximum number of tubers/plant was obtained from minimum harvesting interval (3 days). However maximum weight of tuber 26.46 per plant was obtained from maximum harvesting interval. Mean tuber weight increased from 2.77 g to

4.43 g with the increase in harvesting interval. Kufri Bahar planted in aeroponic system at four different spacing showed that maximum number of tubers/plant and highest tuber yield/plant was obtained in 15x15 cm spacing and minimum in 10x10cm plant spacing. However maximum number of tubers 1597 per m^2 unit area was obtained in treatment with highest plant density (10x10).

21. Performance of different potato cultivars in aeroponic system at Patna

Nine varieties of potato namely Kufri Surya, Kufri Kanchan, Kufri Pukhraj, Kufri Khyati, Kufri Jyoti, Kufri Sindhuri, Kufri Chipsona-3, Kufri Ashoka and Kufri Bahar were evaluated in rabi season and the rooting initiated within 4 to 5 days in all the varieties. Maximum number of 57.5 minitubers was obtained in Kufri Pukhraj while minimum in Kufri Chipsona-3 (1.5) and Kufri Jyoti (4.2).

22. Monitoring of aphid population in seed crop during 2013

Aphid build up in seed potato crop was monitored in sprayed and un-sprayed conditions at Gallu (Fagu) after about 50 days of planting (*i.e.* on 15th June) up to 15th August. Under sprayed conditions, systemic insecticides *viz.*imidacloprid @ 0.004% (two times) and Rogor @1.2ml/litre water (one time) were sprayed alternatively at fortnightly intervals starting from 2nd July onwards. Monitoring revealed that under sprayed as well as unsprayed conditions aphids appeared by mid July. Three different types vector monitoring system was installed in seed crop at Jalandhar with very good trap. Funnel based water trap was very effective for intact catch of vectors for identification purpose and four different types of aphid were identified in seed crop. An experiment was carried out at Patna by growing mustard crop as trap crop in the border side of potato crop grown on larger area in such a manner that flowering coincide with the aphid appearance. Every week spray of insecticide was done on the trap crop to control the adult aphid and its further spread since second fortnight of the December. Six yellow sticky traps of 2' x 2' were also fixed in the experimental field for monitoring of adult aphids (one trap/300 sq. meter area). Up to January 25, there was no infestation of aphid on the leaves of potato crop. The presence of adult ranged from 4-8 on the yellow sticky trap.

23. Standardization of planting date for seed production in Gwalior region

Early planted seed crop (10th Oct) took least time for emergence and 50% emergence (7.6 and 11.1 day respectively) while 7th November planted seed crop took longest time for emergence and 50% emergence (10.0 and 13.2 day respectively). Kufri Sindhuri performed better for growth attributing parameters followed by Kufri Chipsona-1 and Kufri Chandramukhi. There was increasing trend for tuber number and yield with delay in planting (Fig. 20 and 22) except at initial planting where higher tuber number and yield was recorded which is due to 39 mm rainfall just after planting the seed resulting into higher germination than later planting. Among varieties highest tuber number and yield was recorded in Kufri Sindhuri (Fig. 21 and 23).

24. Enhancement of photoautotrophic nature of microplants for *in vivo* establishment

The shoot cuttings of potato propagated vigorously in liquid and solid sugar free nutrient medium supplemented with 0.5% IBA with viable rooting systems (Fig. 24). However, the presence of agar in solid sugar free nutrient medium caused fungal and bacterial contamination while liquid medium was prone to algal growth which strongly restricted the growth of microplants. Experiments were carried out using vermiculite, peat moss, perlite, sand and liquid

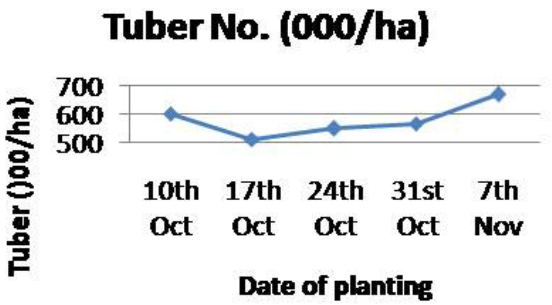


Fig. 20. Tuber number according to DOP (000/ha)

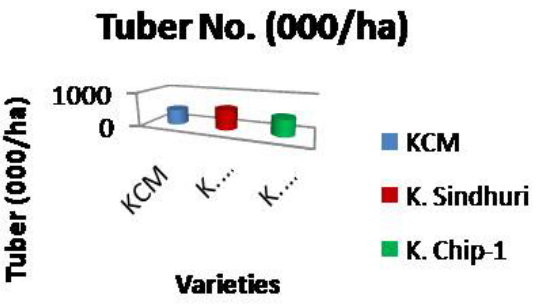


Fig. 21. Variety wise tuber number (000/ha)

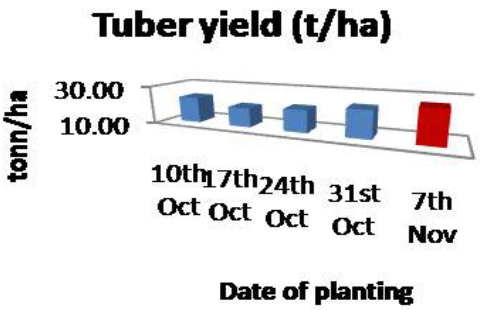


Fig. 22. Tuber weight according to DOP (t/ha)

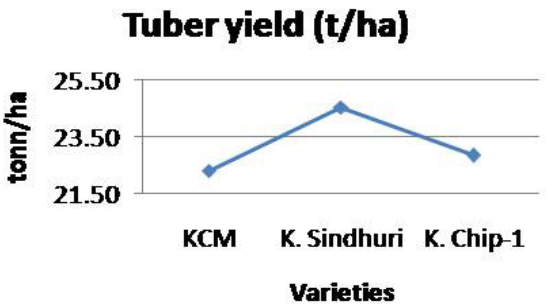


Fig. 23. Variety wise tuber weight (t/ha)

medium (Fig. 25) and survival rates, shoot length, root length and biomass were depicted in (Table 7). Significantly vigorous growth is achieved in peat moss medium as compared to control liquid nutrient medium.

A photoautotrophic chamber (Fig. 26) was designed and the plants grown in chamber showed significantly higher growth rates (Fig. 27) as compared to test tubes and magenta boxes.

Fig. *24. Effect of sugar and non-sugar in nutrient medium*

Fig. 25. Microplants in A:Peat moss; B:Sand; C:Vermiculite; D:Liquid medium; E:Perlite

Fig. 26. Plants grown in photoautotrophic chamber

Fig. 27. Plant vigour from photoautotrophic chamber

Table 7. Growth parameters in different solidifying mediums

Media	Survival (%)	Shoot length (cm)	Root length (cm)	Biomass(g)
Sand	46.67	10.71	7.14	0.39-*
Peat moss	66.67-**	17.00-**	11.80-**	1.21-**
Vermiculite	40.00¯**	11.50	10.17	0.35
Perlite	40.00¯**	5.33¯**	2.67¯**	0.06¯**
Liquid	53.33	11.75	7.13	0.32
CD at 1%	3.97	2.74	2.58	0.209

¯Depicts significantly high; - significantly low; * significance at 5% and; ** significance at 1%

25. Standardization of medium types for use in photoautotrophic micropropagation

Experimentation on different types of solid medium after 40 days of culture revealed 100% survival in all the mediums. The significant differences between treatments for all the characters were observed. Treatment of vermiculite+perlite was observed to rank the best in terms of all characters under study followed by Vermiculite+Peat Moss+Pearlite (1:1:1) and Vermiculite. Fig. 28 shows the different treatments. On pair wise comparison of means resulted pumped air treatment showed significantly higher values for all the characters followed by passive flow and closed photoautotrophic systems (Fig. 29).

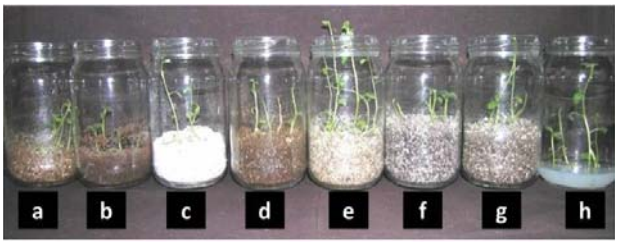


Fig. 28. Growth behavior in (a) Vermiculite, (b) Peat Moss, (c) Pearlite, (d) Vermiculite+Peat Moss, (e) Vermiculite+Pearlite, (f) Peat Moss+Pearlite, (g) Vermiculite+Peat Moss + Pearlite and (h) Agar.

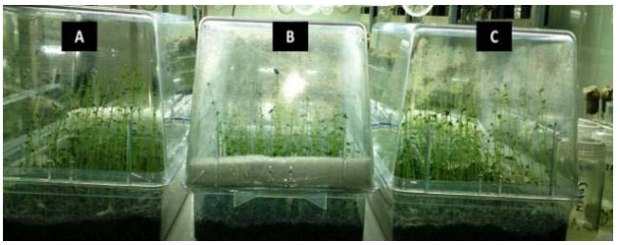
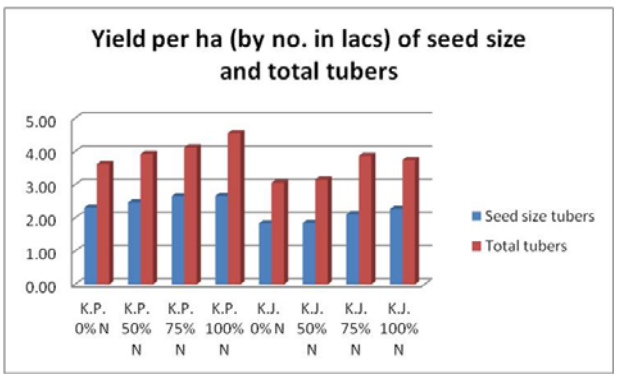


Fig. 29. (a) Passive air flow over, (b) closed and (c) pumped air

26. Experimentation to evaluate nutrient efficiency at Patna

The promising variety Kufri Lalit and Kufri Pukhraj were grown at four levels of nitrogen viz. control (no nitrogen), 25% less nitrogen than recommended dose (RD), 50% less nitrogen than recommended dose (RD), and recommended dose (180 kg N/ha). The phosphorus and potassium were applied @ 80 kg and 125 kg per hectare, respectively. The total and seed size tuber yield was recorded maximum in variety Kufri Pukhraj as compared to KufriLalit at 80 days of harvest.



Division of Social Sciences

Programme: Impact of Potato Production Technologies Developed by the Institute

Project 1: Seed potato marketing system in India and its impact on farmers' profitability

Seed potato utilization in West Bengal and Bihar

West Bengal and Bihar are the second and third largest potato producing states of India. West Bengal produces processing grade and specialty potatoes in addition to the table purpose potatoes while the Bihar state produces quality seed potato in addition to the processing and table purpose potatoes. Availability of healthy seed has largely been reported as the principal cause for concern by the farmers of West Bengal and Bihar. This comprehensive study was conducted to find real problems and seed potato utilization pattern of the potato growers in these two states during 2012-13.

Three districts *viz*. Hooghly, Midnapur West and Bankura were selected as sample districts for assessing the situation in West Bengal. Similarly three districts *viz.*Patna, Bihar Sharif and Muzzaffarpur were selected from the state of Bihar. In total 290 potato farmers, 30 traders and 6 agricultural/ horticultural officers were interviewed from both the states under this survey. Seed potato utilization pattern and constraints of potato growers in selected districts were studied through primary data. Problems of potato growers were quantified in terms of severity, and relative importance (RI) of each problem in overall potato farming situation.

Variety wise potato area

Variety wise potato area was assessed in both the states and it was found that in West Bengal, Kufri Jyoti was the predominant potato variety occupying more than two third area (69%) followed by Kufri Pukhraj (19% potato area), Kufri Chadramukhi (8%) and other potato varieties (4% potato area). However, in Bihar, half of the potato area was covered by Kufri Jyoti followed by Kufri Pukhraj (27%), Kufri Sindhuri (14%) and other potato varieties (9%).

Difficulty level for getting quality seed potato

In West Bengal Kufri Chandramukhi followed by others were the varieties whose seed was difficult to obtain while availability of Kufri Jyoti followed by Kufri Pukhraj was the easiest. Similarly in Bihar, Kufri Sindhuri followed by Kufri Chadramukhi were the varieties whose healthy seed was difficult to obtain while KufriJyoti followed by Kufri Pukhraj were the varieties for which seed was easily available.

Seed potato utilization pattern

It was found that in the state of West Bengal, seed potato purchased from traders was the most commonly used (53% farmers) followed by own farm production retained as seed (24%), purchased from other farmers (16%) and private companies (7%). However, in Bihar, own farm production retained as seed potato (49% farmers) was the most commonly used seed followed by the seed purchased from traders (24%), other farmers (16%), private companies (6%) and government farms (5%). Seed replacement rate was as low as 15% in the state of Bihar while this rate was 48% in West Bengal.

Effect of seed quality on farmers' profitability

Effect of seed potato quality on farmers' profitability was assessed considering expenditure on seed as proxy to its quality. Overall, it was found that 50% respondents with higher seed potato expenditure invariably had higher potato yield, cost of cultivation, net income and benefit-cost ratio compared to the 50% respondents with lower expenditure on seed potato in both the states. In West Bengal, the half of farmers having higher expenditure on seed potato had 36% higher net income, 24% higher gross income and 11% higher B-C ratio (due to higher cost of cultivation). Similarly in the state of Bihar, half of the higher spenders on seed potato had 65% higher net income, 25% higher gross income and 19% higher B-C ratio. Hence, availability of quality seed potatoes to each and every farmer of the country is in the benefit of farmers as well as the nation.

Constraints in seed potato cultivation

Constraints of potato farmers were studied in terms of their severity and relative importance. Expensive seed was found to be the severest problem for potato farmers in the state of West Bengal followed by wide fluctuation of potato prices over different months and

unavailability of healthy seed potato at reasonable prices. However, unavailability of healthy seed potato was the number one constraint in the state of Bihar followed by expensive cold storage and repeated as well as long cuts in electricity supply. Overall, in both the state (collectively), unavailability of healthy seed potatoes was the most important constraint of potato farmers followed by expensive cold storage charges and expensive farm inputs such as pesticides and fertilizers *etc*.

Project 2: Analysis of adoption pattern and technology gap in important potato growing areas

Adoption of improved potato varieties and technology in Bihar

A Survey of 120 potato growers was carried out in three districts of Bihar namely Patna, Nalanda and Muzaffarpur. Analysis of data revealed that on an average, every farmer cultivated potato on 68.3% of its cultivated land holding in Nalanda district. Average potato area out of cultivated land holding was found to be 37.8% in Patna and 31% in Muzaffarpur districts. The varietal adoption pattern was observed in these three district and it was found that Kufri Pukhraj was the most predominant variety in Nalanda occupying more than half area under potato while Kufri Pukhraj and Kufri Sinduri were the major varieties grown in Patna district. In Muzaffarpur district, Kufri Jyoti was the most popular variety followed by Kufri Pukhraj. Farmers applied 5-6 irrigations in Nalanda and 4-5 in Patna district, however, in case of Muzaffarpur, only 2-3 irrigations were applied by the farmers in potato which was far less than recommendations. Application of NPK fertilizers in Patna, Nalanda and Muzaffarpur was found to be 215:210:115, 170:188:120 and 150:166:96 kg/ha against the recommended doses of 180:80:100 kg/ha. So, in all three districts, application of phosphate fertilizers was higher than the recommended dose. The seed rate of potato was the highest in Nalanda (33.6 q/ha) followed by Patna (28.8 q/ha) and Muzaffarpur (20.6 q/ha). Thus, seed rate in Muzaffarpur district was less than the recommended *i.e* 25 q/ha. The average yield of potato recorded in the study area was the highest 33.6 t/ha in Nalanda district while it was 28.8 t/ha in Patna and only 20.6 t/ha in Muzaffarpur district. Lower yield in Muzaffarpur district was due to the use of traditional variety Kufri Jyoti, application of less number of irrigations and very lower seed replacement rate by the farmers.

Assessment of improved potato varieties and technologies

Overall, 25 demonstrations were laid out in different locations of UP and Bihar to assess the performance of potato varieties and technologies at farmers' field.

In Uttar Pradesh, a total of 10 field demonstrations were conducted on farmers' field at various locations of eight districts namely Baghpat, Saharanpur, Hapur, Sambhal, Moradabad, Sahajahanpur, Hathras and Agra. Five demonstrations on late blight management and five on cutworm management were conducted on an area of 200 m^2 each, during the year. The yield of variety Kufri Garima was compared with the existing variety Kufri Bahar while Kufri Khyati was compared with Kufri Pukhraj.

Demonstration on late blight management: During this year, disease appeared in the main crop at all locations in control plots. The first appearance of late blight disease was recorded in second week of January 2014 at farmers field in variety Kufri Bahar in village Khera Afgan of district Saharanpur. No late blight was recorded in sprayed crop in all locations except in village Khera Afgan where 5% foliar damage were recorded with late blight disease in demonstration field in the plot of variety Kufri Pukhraj due to heavy inoculation in this area while 23.4% average disease intensity in demonstration plots was observed due to late blight disease in unsprayed fields. On an average 6.8% of tuber rotting was observed at harvest due to heavy rains during the crop season in demonstration fields at harvest. In Kufri Khyati 25.6 and 5.6% of increase in yield was recorded over control in Baghpat and Sasni demonstration trials when crop was harvested at 90 days.

Demonstration on cutworm management: Five field demonstrations were conducted at villages, Sadikpur (Hapur), Khandoli and Murkia (Agra), Rambalka (Hathrus) and Gamser (Sahajahapur). All the recommended plant protection practices were applied *i.e.* 2 sprays of Chloropyriphos (drenching on ridges) @ 0.20 % at 25 and 50 DAP at all the specified locations along with unsprayed farmers fields. No cutworm damage was recorded in sprayed crop while 1.8% tuber damage was recorded in unsprayed fields. Average 11.2% increase in tuber yield was recorded under recommended practices over the unsprayed field.

Average tuber yield from these 10 demonstrations was estimated as 28.4 t/ha in variety Kufri Garima, 24.9 t/

ha in Kufri Bahar, 31 t/ha in Kufri Khyati and 29.7 t/ha in Kufri Pukhraj.

In Bhojpur district of Bihar, 15 varietal demonstrations were laid out at Farhangpur to show the farmers the superiority of new potato varieties Kufri Pushkar, Kufri Chipsona-3, Kufri Khyati and Kufri Pukhraj over existing C-40. All the recommended package of practices were used in demonstration plots. It was also observed that the occurrence of late blight in experimental plots was only 0.5% while in control plot with farmers practice, it was nearly 1.8%. Farmers used Indofil M-45 for control of late blight but their dose of this chemical was only 1 kg/ha which is very less than recommended dose of 2.5 kg/ha. The average yield of all four demonstrated varieties was found to be higher than the control variety. Among tested varieties, Kufri Pushkar gave the highest yield of 21.5 t/ha followed by Kufri Khyati (19.2 t/ha), Kufri Chipsona-3 (18.7 t/ha) and Kufri Pukhraj (18.5 t/ha). The local variety C-40 gave only 17.7 t/ha yield which was less than all demonstrated varieties.

Impact of training programme: A 21- days Summer School course sponsored by Indian Council of Agricultural Research was organized on "Advances in Quality Potato Production and Post-harvest Management" from July 16 to August 5, 2013. The objective of this training was to enhance the knowledge and skills of trainees regarding latest technologies for scientific potato cultivation and post harvest management. This training course was attended by 21 participants from 11 states. A variety of methods of training such as lecture-cum discussion, practical sessions, field visits and video film shows *etc*. was applied during this programme. To assess the impact of training, pre and post training evaluation was conducted. Majority of the trainees were very well satisfied with the training contents and training delivery mechanism. More than 80% of trainees were well satisfied with 'behaviour and style of teacher' and lab facilities provided during the training. More than 60% of respondents were of the opinion that this training will help in enhancing their work efficiency in the future. The highest gain in knowledge (59.1%) was in the area of "basic knowledge of potato" after training. Gain in knowledge was also found to be higher in Potato Physiology and Post-harvest Technology (39.1%) and Breeding and Biotechnology application in potato (22.9%). In other subjects like Agronomy, Plant Protection, Economics *etc.* gain in knowledge varied from 10-20% only. Thus, average increase in knowledge of trainees before and after training was estimated at 25.7% which shows that training was successful in significantly increasing the knowledge of the respondents. A majority (46.2%) of the trainees graded the training programme as excellent while 53.8% felt that it was of very good quality.

Training of Potato farmers under Mini Mission I: During the year 2013-14, 7 On-farm and 2 on campus trainings were conducted at Kangra, Mandi, Una, Sirmour, Shimla district where about 376 farmers participated. Out of these 258 were male and 118 women farmers. These vegetables growers were trained in commercial cultivation of potato, pea and other vegetables. The data regarding improvement in knowledge and skills before and after training was collected through a comprehensive questionnaire. The analysis of data from training in 5 districts (Kangra, Mandi, Una, Sirmour, and Shimla) showed that there was overall 14 to 17 % increase in knowledge level of farmers after trainings.

Fig. 1. Participants of Summer School at CPRI, Shimla

Fig. 2. Farmers training at CPRI, Shimla

Transfer of Technology

Technology transfer activities organized by CPRI, Shimla

During year 2013-14 many extension activities were organized by CPRI to transfer the improved potato technologies to farming communities and other stakeholders. These technology transfer activities include organization of trainings, *Kisan Mela,* awareness camps and exhibitions, laying out demonstrations on farmers' field alongwith live phone in programmes on AIR and Doordarshan, Shimla. This helps in creating awareness about new potato varieties and production technologies for increasing knowledge of participants.

A. **Organization of trainings**: Many institute and sponsored training programmes for scientists, farmers, extension functionaries and other stakeholders were organized at CPRI Headquarters, Shimla. Almost all the aspects of potato production *viz.* planting operations, intercultural operations, nutrient management, water management, harvesting, processing, storage and marketing were thoroughly covered during these trainings programs. The participants were exposed to a series of lectures as well as practical classes on above mentioned subjects. In these lectures audio-visual aids were used by the faculty with extensive use of photographs and other informative tools like live samples, making learning more interactive and informative. Besides this, field visits to Kufri-Fagu and other important places were also organized. The details of the trainings and other extension activities conducted during the period are given in the table below.

Table 1. Details of training programmes organized at CPRI, Shimla

Sl. No.	Date and duration	Title of training course	No. of farmers/ officers	Sponsoring agency
1.	May 15-17, 2013 (3 days)	आधुनिक तकनीक द्वारा भोज्य एवं विधायन हेतु आलू उत्पाादन	6	Self sponsored by Mr. Devesh Patel, Gujarat
2.	July 16- August 05, 2013 (21 Days)	Summer School on "Advances in Quality Potato Production and Post-harvest Management"	21	Education Division, ICAR, New Delhi
3.	September, 12-14, 2013 (3 days)	आधुनिक तकनीक द्वारा बीज आलू उत्पादन	23	Project Director, ATMA Distt. Khera (Gujarat)
4.	October 30, 2013 (1 Day)	आधुनिक तकनीक द्वारा बीज आलू उत्पादन	70	TSP –Plan (HRD)

Sl. No.	Date and duration	Title of training course	No. of farmers/ officers	Sponsoring agency
5.	November 4, 2013 (1 Day)	आधुनिक तकनीक द्वारा बीज आलू उत्पादन	40	TSP –Plan (HRD)
6.	November 5-6, 2013	आधुनिक तकनीक द्वारा बीज आलू उत्पादन	31	Sub Divisional Magistrate-cum-Project Director, Keylong (L&S)
7.	November 14-16, 2013 (3 days)	आधुनिक तकनीक द्वारा बीज एवं भोज्य आलू उत्पादन	20	Project Director, ATMA, Kadimbagh, Nagpur (Maharashtra)
8.	January 17, 2014 (1 day)	आधुनिक तकनीक द्वारा बीज एवं भोज्य आलू उत्पादन	24	Ambuja Cement Foundation, Darlaghat, Distt. Solan (HP)
9.	February 1-15, 2014 (15 days)	Seed Potato Production Technology	2	State Govt. of Manipur
10.	February 24-26, 2014 (3 days)	Potato Seed Production	20	General Manager NABARD Kolkata (WB)

B. Organization of Awareness Camp/*Kisan Mela* cum Training Programme: The institute organized five *Kisan Melas* and three awareness camp under Tribal Sub Plan (TSP) project for a large No. of farmers to create awareness about new potato varieties and modern techniques of potato cultivation. The list of these programmes is given in the following Table.

Table 2. List of kisan mela and awareness camp organized by CPRI, Shimla under TSP

Sl. No.	Date	Title and Venue of Kisan Mela/awareness camp	No. of Farmers/ participant
1.	October 9, 2013	Training cum awareness Camp on “Modern Techniques for Seed and Table potato production” at Udaipur (Lahaul & Spiti)	127
2.	December 23-24, 2013	*Kisan Mela*-cum Training on “Potato production” in Dindori (Madhya Pradesh)	3500
3.	January 27-29, 2014	*Kisan Mela*-cum Training on “Potato cultivation at East Khashi Hills” in Shillong (Meghalaya)	2200
4.	February 13-14, 2014	*Kisan Mela*-cum Training on Potato production” in Sarguja district (Chhattisgarh)	4000
5.	February 21-22, 2014	*Kisan Mela*-cum Training in Sundergarh district (Odisha)	2000
6.	March 20-21, 2014	Training cum Awareness camp on Potato production at Lohardaga district (Jharkhand)	100
7.	March 21-22, 2014	Training cum awareness camp on “Potato production” at Leh (J&K)	464
8.	March 27-28, 2014	*Kisan Mela*-cum Training at West Khashi Hills Shillong (Meghalaya)	2000

C. Live phone in programme/agricultural talk on AIR and Doordarshan: Expert scientists from different fields of potato research and development from CPRI Shimla participated in various agricultural talk show and live phone in programmes on different topics. They answered the queries from potato growers on aspects like planting, water management, disease and pest management, storage practices *etc.* during *Krishi Darshan*. A list of these programmes is given in Table 3 & 4.

D. Participation in agricultural fair/exhibitions: CPRI participated in many exhibitions and agricultural fairs organized in different parts of the country through ATIC at CPRI, Shimla and other regional stations. CPRI stall was put to showcase new potato varieties and production technologies of potato. A large No. of farmers benefitted from these exhibitions. List of these exhibitions is given in the following Table.

Table 3. Live phone in programme on Doordarshan, Shimla

Sl. No.	Date	Topic	Name of expert
1.	April, 2013	Seed preparation and planting of potato in higher hills of HP	Dr. Vinod Kumar Dr. Ashwani Kumar
2.	May, 2013	Earthing up, fertilizer application and weed management in high hills of HP	Dr. VK Dua Dr. Ravinder Kumar
3.	June, 2013	Harvesting of potato in mid hills and disease management in high hills of HP	Dr. Sanjeev Sharma Dr. Dhiraj K. Singh
4.	July, 2013	Disease and pest management in potato in the higher hills of HP	Dr. Sanjeev Sharma Dr. Ravinder Kumar
5.	August, 2013	Inter culture operations in Seed Potato in higher hills of HP	Dr. VK Dua Dr. Vinod Kumar
6.	September, 2013	Harvesting and post harvest in potato in higher hills of HP	Dr. Ashwani Kumar Dr. Brajesh Singh
7.	October, 2013	Post harvest operation and marketing of potato in higher hills of HP	Dr. NK Pandey Dr. Brajesh Singh
8.	November, 2013	Planting and fertilizer application in lower hills of HP	Dr. Dhiraj K. Singh
9.	December, 2013	Planting and disease management in potato in the hills of HP	Dr. Ashwani Sharma Dr. Sanjeev Sharma
10.	January, 2014	Planting and fertilizer application in potato in mid hills of HP	Dr. SS Lal Dr. Dhiraj K. Singh
11.	March, 2014	Potato varieties and seed preparation for higher hills of HP	Dr. Vinod Kumar Dr. Vinay Bhardwaj

Table 4. Radio talk/ live phone in programme on AIR, Shimla

Sl. No.	Date	Topic	Name of expert
1.	15th April, 2013	आलू की खेती	Dr. SS Lal
2.	1st July, 2013	Disease and pest management in potato in higher hills of HP	Dr. Sanjeev Sharma
3.	9th September, 2013	ऊंचे पर्वतीय क्षेत्रों में आलू की खुदाई एवं रखरखाव	Dr. Vinod Kumar Dr NK Pandey
4.	28th October, 2013	हिमाचल प्रदेश में आलू बीज उत्पादन की तकनीकी जानकारी	Dr. BP Singh

Table 5. CPRI participation in different exhibitions

Sl. No.	Particular	Date	Venue
1	Mushroom Mela at Directorate of Mushroom Research, Solan	10 September, 2013	Solan (HP)
2	*Kisan Mela* organized by Ambuja Cement Foundation	November 15, 2013	Darlaghat, Solan
3	*Kisan Mela* and Farmer's training at Jalandhar	December 15, 2013	CPRS, Jalandhar
4	*Kisan Mela* and Farmer's training at Gwalior	January 22, 2014	CPRS, Gwalior
5	National Agriculture Fair "*Krishi Vasant*" Nagpur	9-13 February, 2014	CICR, Nagpur (Maharashtra)
6	India Potato Expo 2014	20-22 February, 2014	Chandigarh

Extension activities at CPRI Campus Modipuram

- One day training programme on "Improved Techniques of Table and Potato Seed Production for Plains Areas" was organized on 11 February, 2014. A total of 300 farmers from 23 districts of U.P., M.P., Rajasthan, Punjab and Haryana participated in the training programme.
- One day training programme on "Potato Seed Production Techniques for Plains Areas" was organized on 21 March, 2014. A total number of 30 farmers from Etawah district of Uttar Pradesh participated in the training programme
- Total 238 farmers from various districts of UP, Haryana, Rajasthan, and MP and 20 agriculture students visited CPRIC Modipuram to know the potato farming activities at the campus. A total of 25 queries were answered through the phone.
- Exhibited Institute's stalls in All India Farmers' Fair and Agro-Industrial Exhibition held at SVBP University of Agri. & Technology, Meerut during 10–12 April, 2013 and 3-5 March, 2014. The CPRI stall was awarded second best in ICAR group in both the occasions.
- Arranged institute's stall in three days *Pusa Krishi Vigyan Mela* held at I.A.R.I., New Delhi during 6-8 March, 2014.

Extension activities at CPRS Ooty

Various technology transfer activities were organized at CPRS, Ooty (Tamil Nadu). Following table provides information on these extension activities.

Sr.No	Title	Date	Place	No. of beneficiaries
1.	Farmers' Day	10 July, 2013	CPRS, Ooty	25 farmers
2.	Farmers' Interactive Meeting	24 July,2013	Office of the Deputy Director of Horticulture, Hassan	30 farmers
3.	Farmers' Awareness Camp	26 July,2013	Horticultural Research Station and AICRP-Potato centre, Somanahallykaval, Hassan	35 farmers
4.	Exhibition	23 October, 2013	Central Soil and Water Conservation Research and Training Institute, Regional Station, Teetikal, Ooty	100 farmers
5.	Training	5 Feb. 2014 – 7 Feb., 2014	CPRS, Ooty	30 farmers
6.	Exhibition	28 Feb., 2014	Radio Astronomy Centre, Ooty	500 students

Extension activities at CPRS Patna

- Five days Farmers Training on "Quality Seed Potato Production" was organized during 9-13, December 2013. The programme was attended by 49 farmers.
- Five days farmers training of 27 farmers of Latehar (Jharkhand) on "Scientific Cultivation of Potato" was organized during 22-26 January, 2014 at CPRS, Patna. The training programme was sponsored by ATMA, Latehar (Jharkhand).
- One day training was organized at NAIP adopted village Chakramdas, Vaishali on 6th Feb., 2014 in which 57 farmers were trained.
- Training of NAIP farmers was organized at Pirapur, Jandaha, Vaishali on 30th Jan., 2014 in which 68 farmers were trained.
- Participated and put stall in *Kisan Mela* at ICAR, RCER, Patna during 06-07 December, 2013.
- Participated in exhibition in National Farmer Fair at IIVR, Varanasi on Feb. 1, 2014.
- Participated and put a stall in exhibition at CPRS, Patna on Feb 25, 2014 in which 118 farmers participated.

Extension activities at CPRS Jalandhar

- Stakeholders meeting on "Potato Research Development" held on 16th December, 2013.
- A *Kisan Mela* cum farmers' training programme on "Potato Seed Production" was organized at CPRS, Jalandhar on December 15, 2013.

Extension activities at CPRS Gwalior (MP)

- A *Kisan Mela*-cum-Farmer's Training programme was organized at Central Potato Research Station, Gwalior on January 22, 2014. The objective of this programme was to create awareness and enhance knowledge about improved potato production technologies. Nearly 400 farmers from different districts of Madhya Pradesh, Uttar Pradesh and Punjab attended this programme.

Extension activities at CPRS Shillong (Meghalaya)

- One-day training programme on "Improved Potato Production and Protection Technology" was organized for 47 farmers on November 22, 2013 at CPRS, Shillong.
- Another one-day training programme on "Disease and Pest Management in Potato" was organized for 45 farmers on December 5, 2013 at CPRS, Shillong.
- 5 demonstrations of TPS technology were conducted at the farmers' field in Thangsning Village in East Khasi Hills district of Meghalaya.
- Participated and displayed the technologies of the CPRI in the Agri Business Meet held at ICAR

Activities of Agriculture Technology Information Centre (ATIC)

Research Complex for NEH Region, Umiam, Barapani on 21st December 2013.

- Participated in the "1st Assam International Agri-Horticultural Show-2014" organised by CII, Kolkata at College of Veterinary Sciences, AAU, Guwahati, Assam during 8-11th January, 2014. One exhibition stall was installed for farmers and other visitors.

  Participated in Kisan Mela cum potato farmers training at KVK, East Khasi Hills district of Meghalaya during 27-29th January, 2014. One exhibition stall was installed for farmers and other visitors.

Sale and distribution of CPRI technical and extension bulletins: A total of 2490 technical bulletins were sold through ATIC. Moreover, a large number of extension bulletins, CPRI brochures, Crop Calendar and several leaflets related to modern potato technologies were distributed free of cost to the scientist, extension workers and farmers. Specially developed CDs of PPM (Potato Pest Manager) and CAASPS (Computer Aided Advisory System for Potato Crop Scheduling) were also sold through ATIC. Altogether this generated revenue of ₹ 1, 18,518/-.

Dissemination of knowledge to visitors: A museum has been set up in which the technology developed by CPRI has been displayed by means of display panels, live samples and models *etc.* The methodology and advantages of these technologies were explained by the ATIC staff to the visitors. The visitors were benefitted by strengthening their knowledge about potato cultivation. A total of 1771 stake holders visited in the institute during the period under report. The visitors included 1033 B.Sc./M.Sc. student of various universities of different states, 618 farmers from different states of the country and 120 scientist/extension worker/state level agriculture and horticulture officer.

Library and documentation services

Introduction: In accordance with 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 64 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 clearing house 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.

Resource Development

At the headquarter (Shimla), a total of 513 documents were purchased, procured and added to library resources. The total collection at Shimla stand at 38057 documents comprised of 15379 books, 15164 back volume of journals, 2576 serials, 2225 annual reports, 582 theses, 251 standards, 51 maps/atlases, 1663 reprints and 166 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 28,998 books; journals back volumes and other documents i.e. AR/ Reprints and Bulletins etc as per the details below (Table-1).

Periodicals and Serials Management

Twenty nine serials title i.e. advances, annual reviews, reference annuals, year books and statistical data publications etc. were purchased. A total of 179 current journals comprising of 30 foreign and 149 Indian have been subscribed at Shimla. Out of which 18 foreign and 138 Indian journals were subscribed on payment basis and rest on exchange or gratis. In all 1051 issues of such journals were received, marked and kept in library for use. Besides, 66 titles of different journals were subscribed at CPRS libraries. 11039 entries of library documents were made in Library Automation Software and 315 books were classified, catalogued, labeled, pasted and transcribed for use. The library has the complete series of CABCD and ISA databases for retrospective and current scientific literature search and use of scientists.

Computerized & Net Based Services

The institute scientists were facilitated with full text access to 5 online databases, 30 institutes subscribed foreign journals and more than 3000+ 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 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

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	4516	5716	2802	13034	23
2	CPRS, Jalandhar	3159	1401	1221	5781	18
3	CPRS, Patna	2036	1280	-	3316	11
4	CPRS, Gwalior*	957	4	59	1020	-
5	CPRS, Ooty	1606	1888	543	4037	10
6	CPRS, Shillong	1499	-	167	1666	4
7	CPRS, Kufri	144	-	-	144	
	TOTAL	13917	10289	4792	28998	66

Note: Figure shown for CPRS Gwalior is for the year 2012-13

web sites were visited and information and data were downloaded therefrom for scientists' use. Under the NAIP project "e-Granth" 39208 pages of 310 CPRI publications were got digitized and their metadata were checked, corrected and indexed to facilitate online digital access.

To promote the usage of online digital contents the CPRI library organized two workshops. The 1st one-a day-long "Workshop on e-Granth" on 8.10.2013 and the 2nd one-a two days workshop on "E-Resources in Agriculture" from 28.02.2014 to 01.03.2014 at CPRI, Shimla under e-Granth project of NAIP.

Readers and Reference Service

A total of 1955 documents were circulated (borrowed and returned) for home studies and 6832 readers consulted 9628 documents within the library. Besides,39 outside scientists and research scholars of various research organizations consulted the library resources. 6 new members were enrolled and 8 old members withdrew their library membership due to their transfer or retirement. At present 150 readers are active members of library including RAs/SRAs. Library received 10145 reference queries from the users of the library and responded to them satisfactorily. Besides, 669 job requests were received for 2,56,249 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

1051 issues of journals (766 issues of national and 285 issues of international journals) were scanned for potato literature and 90 potato articles were found and recorded. Approximately, 35,000 records of library resources have been successfully migrated from 'Liberty' to 'Koha' an open source library management software and integrated with World CAT of OCLC through AgriCat OPAC of NARS libraries. This has provided international visibility of CPRI library resources. Besides, the in-house documentation services in the form of Current Periodicals Received Last Week (Weekly) and List of New Additions (Monthly) were brought out regularly and updated for library users.

Resource Generation and utilization

The library has generated the revenue of Rs. 2,75,991.00 which includes the amount chargedon account of rendering CDROM searching & photocopying (Rs. 6,898.00), IGNOU computer practical (Rs. 29,850.00) and library discount (Rs.2,39,186.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 46,99,016.00 was spent (under Plan Rs. 44,99,824.00 and Non-Plan Rs. 1,99,192.00) on purchase of library resources like books (Rs.14,35,602.00), and subscription of journals (Rs.23,50,143.00) at HQ library Shimla and Rs 9,13,271.00 on CPRS libraries.

CDS/ISIS Practical Training

As per MOU between CPRI and IGNOU, New Delhi, a 17-days computer, IT, and database creation and operation practical session was organized during 9th Aug – 25th Aug 2013 for 13 MLIS and 19 BLIS students of IGNOU Study Center, Shimla.

Infrastructure Development

Under the e-Granth project of NAIP one computer server (Dell), two PCs (Dell), two printers (HP), two MS Office 2010 software, two UPS, and two computer tableswith computer chairs have been procured and installed to facilitate digital content storage, searching and downloading of scientific documents.

Institute Research Council Meeting, 2013

The Institute Research Council Meeting (IRC), 2013 was held at CPRI, Shimla during 22nd-24th August, 2013 which was attended by 55 scientists from the Headquarters and the regional stations. The basic objective of this meeting was to review the achievements of 2012-13 and finalize the work plan for 2013-14 of different research programmes. The major decisions taken during the Meeting are given below.

1. Every year about 25 accessions/cultivars should be made free from viruses through meristem tip culture and the virus freedom be ensured by electron microscopy.

2. Entire potato germplasm collection (*grp tuberosum*) should be conserved in the DNA form in phased manner *i.e*. about 500 accessions/year.

3. Passport data and virus testing results of the imported accessions will be recorded in detail in the quarantine register being maintained in the Division of Plant Protection and Division of Crop Improvement.

4. Early maturing processing lines being used as parents in the processing programme should also be evaluated at Jalandhar and Modipuram centres for foliage maturity**.**

5. Advance hybrids J/2-14, MS/7-645, MP/04-816 PS-05/75 and PS/06-24 have been recommended for introduction into AICRP (P) for multilocation testing.

6. Virus testing of advanced hybrids/lines may be carried out through ELISA at respective breeding Stations/Campus/HQ.

7. Evaluation of Glycemic index in selected potato cultivars (Kufri Bahar, Kufri Pukhraj, Kufri Chipsona-1 and Kufri Frysona) should be initiated at National Institute of Nutrition.

8. Possibility may be explored for exploitation of diploid wild species for development of early processing potatoes through protoplast fusion.

9. Isolation and cloning of gene (s) controlling nitrogen use efficiency should be done.

10. Data analysis of whole genome sequencing of *P. infestans* and *R. solanacearum* work should be completed.

11. The status of virus resistance in 25 germplasm accessions selected from inventory will be confirmed by challenge inoculation and visual observations/serological assay and molecular markers for using them as parental lines in the breeding programme.

12. Develop recommendation on weed management immediately after the experiment on bentazone is concluded.

13. Impact of climate change on performance of potato varieties may be studied for other states also, like it was done for Punjab state.

14. In Chlorophyll Concentration Index experiment, method and source of nutrients should also be tried.

15. Efforts should be made to get the J-93-58 germplasm registered with the authorities.

16. Prepare the design of potato combine harvester to commercialize it. Data on operation of new and improved potato combine harvester may be collected for comparison.

17. To explore the possibilities of seed production in Chikmangalur district of Karnataka, a few locations in the district may be selected and at least three observations may be taken at 15 days interval on wilt, late blight, leaf hopper burn *etc*. and develop a graph.

18. Breeder seed may be planted at one location in Chikmanglur following the seed plot technique and the observations should be recorded on level of infestation in first year, yield and rate of degeneration before giving recommendation for suitability of site for seed potato production.

19. All possible methods should be tried including outsourcing for production of antisera against ToLCNDV-potato. The various hosts may be used for multiplying viruses.

20. Study the survival *of Ralstonia solanacearum* in soil after harvest of potatoes in Malwa region of Madhya Pradesh.

21. All aphids spp. occurring on potato crop across India should be mapped and their transmission efficiency worked out in subsequent years.

22. The procurement of potato variety Papa Amrila (yellow- fleshed) from CIP, Lima Peru should be initiated for use in profiling of flavour compounds.

23. Residue levels of palacobutrazole (PBZ) should be estimated in tuber tissues when PBZ was applied on standing crop.

24. Storage studies involving volatile compounds may be carried out at CPRIC, Modipuram. Cold chambers for conducting storage studies with volatile compounds will be made available at Modipuram.

25. The variety Kufri Surya should not be used as control for processing traits. It should be preferred control in studies involving heat tolerance parameters only.

26. One year/season additional data should be generated for HT-hybrids (2 Nos.) proposed for inclusion in AICRP on Potato**.**

27. Extent of water stress imposed should be measured in terms of physiological parameters *viz.* leaf relative water content (RWC) / leaf water potential *etc.*

28. Data should be added for one more season with respect to hybrids (two numbers) suitable for low water regime for inclusion in AICRP(P).

29. The project "Integrated approach for maximization of breeder/quality seed potato production in India" should be merged with project on "Development, production and supply of disease free nucleus and breeder seed of potato".

30. All scientists involved in seed production programme will submit data on aphid occurrence in tabular form during crop season.

31. Impact assessment of new varieties and technologies developed by the Institute should be initiated.

32. Cost of cultivation of seed, ware and processing potato in different regions should be worked out.

Publications

A. Research Papers

1. Arora RK (2013) Comparative efficacy of boric acid and pencycuron for management of black scurf of potato. *Potato J* 40: 60-64.

2. Bhardwaj V, Luthra SK, Dalamu, Singh BP, Kumar V, Kumar D and Sharma S (2013) SS 1735-02 (IC0594469; INGR13048) a hexaploid wild potato clone (*solanum demissum*) with high resistance against late blight and low cold induced sweetening even after 6 months of cold storage (2-4ºC). *Indian J Plant Genet Resour* 26: 252-263.

3. Bhardwaj V, Srivastava AK, Sharma S, Kumar V, Kaushik SK and Singh BP (2013) Efficiency of different potato (*Solanum tuberosum* L.) cross combinations in late blight resistance breeding. *Inter J Innov Hort* 2: 63-69.

4. Bhatnagar A (2013) Management of sap sucking and soil insect pests of potato with insecticides. *Pesticide Res* J 30: 1-4.

5. Bhatnagar A and Singh BP (2013) Evaluation of IPM module for insect pest in potato (*Solanum tuberosum*) opportunities and challenges in India. *Curr Hort* 1: 22-28.

6. Chakrabarti SK, Singh BP, Thakur G, Tiwari JK, Kaushik SK, Sharma S and Bhardwaj V (2014) QTL mapping underlying resistance to late blight in a diploid potato population of *Solanum spegazzinii* × *S. chacoense*. *Potato Res* DOI 10.1007/s11540-014-9249-1.

7. Devendra K and Minhas JS (2013) Evaluation of indigenous potato varieties, advanced clones and exotic genotypes against water deficit stress under sub-tropical environment. *Indian J Plant Physiol* 18: 240-249.

8. Dua VK, Singh BP, Govindakrishnan PM, Kumar S and Lal SS (2013) Impact of climate change on potato productivity in Punjab- a simulation study. *Curr Sci* 105: 787-794.

9. Dua, VK, MK Jatav and SS Lal (2013) Effect of planting pattern and population in potato + maize intercropping system under north-western hills of India. *Indian J Hort* 70: 255-259.

10. Gopal J, Kumar V, Kumar R, Mathur P (2013) Comparison of different approaches to establish a core collection of Andigena (*Solanum tuberosum* Group Andigena) potatoes. *Potato Res* 56: 85-98.

11. Gurjar MS, Ali S, Akhtar M, Singh KS (2012) Efficacy of the plant extracts in plant disease management. *Agric Sci* 3: 425-433.

12. Gurjar MS, Sagar V, Bag TK, Singh KS, Sharma S and Singh BP (2013) Biovar distribution of *Ralstonia solanacearum* strains Causing Bacterial wilt/brown rot of Potato in Meghalaya hills. *J Mycopathol Res* 51: 267-272.

13. Jatav MK, Dua VK, Kumar M, Trehan SP and Kumar S (2013) Spatial distribution of soil available nutrients in the potato growing pockets of Hoshiarpur district of Punjab. *Potato J* 40: 128-134.

14. Jatav MK, Kumar M, Trehan SP, Dua VK and Kumar S (2013) Effect of nitrogen and varieties of potato on yield and agronomic N use efficiency in north-western plains of India. *Potato J* 40: 55-59.

15. Jeevalatha A, Kaundal P, Shandil RK, Sharma NN, Chakrabarti SK and Singh BP (2013) Complete genome sequence of *Potato leafroll virus* isolates infecting potato in the different geographical areas of India shows low level genetic diversity. *Indian J Viro.* DOI 10.1007/s13337-013-0138-z.

16. Jeevalatha A, Kaundal P, Sharma NN, Thakur P, Chakrabarti SK and Singh BP (2013) Expression of coat protein of an ordinary strain of *Potato virus Y* in *E. coli* and production of polyclonal antibodies for diagnosis. *J Phytopathol* 161: 671-674.

17. Jeevalatha A, Kaundal P, Venkatasalam EP, Chakrabarti SK and Singh BP (2013) Uniplex and duplex PCR detection of geminivirus associated with potato apical leaf curl disease in India. *J Virol Methods* 193: 62-67.

18. Kaushik SK, Sharma R, Garg ID, Singh BP, Chakrabarti SK, Bhardwaj V and Pandey SK (2013) Development of triplex (YYYy) potato

parental line having extreme resistance to PVY using Marker Assisted Selection (MAS). *J Hort Sci Biotech* 88: 580–584.

19. Khan MA, Upadhayay NC and Singh N (2013) System productivity and soil status with different nutrient management options in sesamum-potato-moong cropping system under long term experiment. *Prog Agric* 14: 67-71.

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25. Kumar S (2013) Screening of suitable potato lines for flowering and berry setting under low temperature (below 8°C) conditions. *Crop Res* 46: 182-184.

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33. Raigond B, Sharma M, Chauhan Y, Jeevalatha A, Singh BP and Sharma S (2013) Optimization of duplex RT-PCR for simultaneous detection of potato virus Y and S. *Potato J* 40: 22-28.

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35. Rana RK, Sharma N, Arya S, Kadian MS, Singh BP and Pandey SK (2013) Status of potato husbandry and farmers' socio-economic profile in moisture and heat prone Karnataka, India. *Pakistan J Agric Sci* 51: 7-16.

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51. Singh SP, A Bhatnagar and Singh N (2013). Effect of FYM and NPK levels on potato (*Solanum tuberosum*) –sesame (*Sesamum indicum*) crop sequence. *Ann Hort* 6: 60-64.

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53. Singh, SP and Lal SS (2013). Irrigation requirement of processing variety (Kufri Chipsona 1) under central plains of India. *Potato J* 40: 87-8.

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55. Sunndaresha S, Tiwari JK, Sindhu R, Sharma S, Bharwaj V, Chakrabarti SK and Singh BP (2014) *Phytophthora infestans* associated global gene expression profile in a late blight resistant Indian potato cv Kufri Girdhari. *Aust J Crop Sci* 8: 215-222.

56. Tiwari JK, Chandel P, Gupta S, Gopal J, Singh BP and Bhardwaj V (2013) Analysis of genetic stability of in vitro propagated potato microtubers using DNA markers. *Physiol Mol Biol Plants* 19: 587–595.

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B. Popular Articles

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Institute Activities

Important meetings and Visitors

Potato processing plant and sale counter named "Potato Park" opened at Kufri

'Potato Processing Facility' as well as 'Potato Park' was inaugurated by Hon'ble Deputy Director General (Horticulture) Dr. N. K. Krishna Kumar on April 8, 2013. This function was presided over by Director, CPRI, Dr B.P. Singh. A large no. of scientists and other staff were present on this occasion. Chips and par-fried French Fries will be prepared at potato processing facility at CPRS, Kufri. Freshly prepared French Fries and Chips with the name 'Golden Chips' will be sold at Potato Park. This is the first plant opened by CPRI with aim to popularise the name of CPRI and its product among Indian consumers. These Products will be prepared from the processing varieties developed by CPRI. Chips will be prepared from the potato varieties viz. Kufri Chipsona 1 and Kufri Chipsona 3 and French Fries will be prepared by variety Kufri Frysona.

Inauguration of processing plant by DDG (Horticultural Science), ICAR at CPRS, Kufri

Institute Management committee (IMC) meeting held at CPRS Shillong & Modipuram

Institute Management Committee (IMC) meeting was held at CPRS Shillong on 26th June 2013. Dr B. P. Singh, Director, CPRI Shimla, Dr. S. K. Kausik, Joint Director, CPRIC, Modipuram, Dr James George, project Coordinator (Tuber crop), CTCRI Trivandram, Sri Ved Prakash, Finance and account officer, CSSRI, Karnal, Dr R. C. Sharma , Director of Research, YSPUAF, Nauni, Dr T. K. Bag, Head CPRS Shillong , Dr A. K. Srivastava Scientist (Plant Breeding) CPRS Shillong, Sri A. K. Singh CAO, CPRI Shimla and Sri A. S. Negi, AO participated the meeting.

Another IMC meeting was conducted on 10th Feb., 2014 at CPRIC, Modipuram in the Chairmanship of Dr BP Singh, Director CPRI. The meeting was attended by other members of IMC and member secretary Sh. AK Singh. Important decisions were taken during this meet.

CPRI celebrated its Foundation Day

CPRI celebrated its 64th Foundation Day on 22nd August, 2013. Himachal Pradesh State Congress Committee President Thakur Sukhvinder Singh, graced the occasion as the Chief Guest of the function. Eminent Agriculture Scientist Dr PL Gautam presided over the function. Dr BP Singh, Director, CPRI welcomed all the dignitaries and briefed them about the function and achievements of CPRI in last 64 years. Dr PL Gautam delivered the Ramanujam Award lecture and praised CPRI for bringing potato revolution in the country through development of 50 potato varieties and production technologies. The function was also graced by Dr Manjit Singh, Director, Directorate of Mushroom Research, Chambaghat, Solan & Former Director of CPRI, Dr JS Grewal. Two publications were released on this occasion related to potato cultivation in plateau area and management of potato disease & pests. Retired persons of CPRI were also felicitated during the function. Many school children and farmers from Himachal Pradesh and Punjab also participated in this function. The Chief Guest and other dignitaries congratulated CPRI fraternity on its foundation day.

Business Planning and Development Unit launch Workshop at CPRI, Shimla

A Business Planning Development (BPD) Unit was also launched through a workshop on August 22, 2013. The main purpose of the workshop was to commercialize the technologies developed at CPRI. The BPD unit is now fully functional and is working from Central Potato Research Station, Jalandhar. The Head, CPRS, Jalandhar Dr JS Minhas presented important CPRI technologies to farmers and entrepreneurs from Punjab and Himachal Pradesh. A CPRI Tehnology Kit was released during this function. Dr PL Gautam, Former Chairman, PPVFRA was chairman of the function. The function concluded with best wishes from all dignitaries to BPD Unit.

IRC Meeting

The Institute Research Committee meeting was held on August 22-24, 2013 at CPRI, Shimla. The meeting was attended by 55 scientists from Shimla and Regional Station of the Institute. The main objective of the meeting was to review the progress made in different research programmes of the Institute. The programme leaders presented the achievements made during 2012-13 under various research programmes of the Institute.

Hindi Chetna Maas

The institute celebrated the Hindi Chetna Maas from 14 September to 13 October, 2013. Many competitions were held in which all the staff of CPRI participated were covered. Hindi Divas was also celebrated at CPRI Stations viz. Modipuram, Jalandhar, Patna, Gwalior, Ooty and Shillong. The winner of these competitions were honoured with prizes by Dr BP Singh, Director, CPRI. He emphasized on the maximum use of Hindi in the day today work of the Institute.

Group meeting of AICRP (Potato)

The 31st Group Meeting of AICRP (Potato) was organized at CPRS, Patna (Bihar) during September 20-22, 2013. The meeting was attended by delegates from Indian Council of Agricultural Research, Central Potato Research Institute, State Agriculture Universities and representatives from Industries. During the workshop the action taken on the recommendations of 30th Group Meeting were reviewed in the presence of Dr. NK Krishan Kumar, DDG (Hort.), ICAR, New Delhi. The highlights of Group Meeting were as under:

1. The red hybrid 2001-P-55 was recommended for release by the name of Kufri Lalit by Hon'ble DDG (Horticulture) Dr. NK Krishna Kumar and Dr. Mittal, Vice Chancellor, RAU Pusa, Samastipur (Bihar) for cultivation in Eastern Indo-gangtic plains which covers Bihar, West Bengal, Assam, Orissa, Jharkhand etc. On this occasion Dr. Bir Pal Singh, Director, CPRI Shimla and Dr. PM Govindakrishnan, Project Coordinator, AICRP (Potato), Shimla were also present.

2. Release of late blight forecasting model INDO BLIGHTCAST for pan India forecast of late blight appearance.

3. Apart form the above, four recommendations in Crop Production and four in Crop Protection were recommended during the group meeting.

4. Two publications viz "AICRP (Potato) A Profile" and "Possibilities of Potato Seed Production in Hooghly District (New Alluvial Zone) of West Bengal" were also released during the group meeting.

RAC Meeting

The Institute Research Advisory Committee meeting was held at CPRI, Shimla on 27-28 September, 2013 under the chairmanship of Dr GL Kaul, Ex Vice Chancellor, Assam Agricultural University, Jorhat.

Important decisions were taken to guide the research agenda of CPRI during the meet.

Additional Secretary, DARE and Secretary, ICAR Visited CPRI

Shri Arvind Kaushal, Additional Secretary, DARE and Secretary, ICAR inaugurated the Aeroponic facility-II for disease free seed production at CPRI, Shimla on 16th November, 2013. Officiating director, CPRI, Dr NK Pandey told that this new technology will help farmers in future by increasing the availability of disease free potato seed in the country. Sh Kaushal was accompanied by Dr. KD Kokate, DDG (Agricultural Extension) and Dr AM Narula, Zonal Project Director, Zone-I, Ludhiana. Dr PM Govindakrishanan, Project Coordinator, AICRP (Potato) briefed the team about the institute activities and its achievement. Later on, the team visited different laboratories and reviewed the work done by CPRI in the field of potato research and development. Addressing the scientific and other staffs of the institute, Sh. Kaushal and Dr KD Kokate lauded the efforts of CPRI in increasing potato production and productivity in the country. They also praised the institute specially for establishing a seed potato production system in the country.

Stakeholders meet held at CPRS, Jalandhar

Third Potato Stakeholders meeting was held on 16th December 2013 at Central Potato Research Station, Jalandhar under the chairmanship of Dr B.P. Singh, Director, CPRI, Shimla. Representatives from major companies such as Syngnenta, Technico Agribusiness, United Phosphorus Limited, Pepsico, Jain Irrigation etc participated in the meet and raised their concern on potato research and development in the country. Important issues like inadequate supply of potato seed to eastern UP and low potato productivity in many areas were discussed in detail. It was suggested that CPRI should provide facility for

testing G1 and G2 stages during seed production as unknown virus introduction is emerging as a big challenge in Potato seed industry. It was felt that economizing seed production through technological advancement is the need of the hour. In order to enhance the yield potential of varieties, Syngenta suggested to work with CPRI in collaborative way. Moreover, during the meet, It was also felt that potato processing industry is still lagging behind and therefore a lot needs to be done to develop processing technologies and promotional approaches. During this meet, Dr JS Minhas, Head CPRS, Jalandhar and many scientists from CPRI, Shimla and Jalandhar were also present.

National Science Day Celebrated at CPRI, Shimla

The National Science Day was celebrated at Central Potato Research Institute, Shimla on February 28, 2014. Nearly 100 students from different schools of Shimla participated in this function along with scientists and technical staff of the institute. The programme started with welcome address by Director, Central Potato Research Institute, Shimla (HP), Dr. BP Singh. He addressed the gathering and talked about importance of science in day to day life. He also ignited the young students about choosing science and developing scientific temper. Dr. P.M. Govindakrishnan, Project Coordinator (Potato) in his address, talked about the science behind agriculture. A visit to institute museum and laboratories was also organized for young students. They were briefed about latest technologies in potato production like tissue culture and aeroponic technology.

Diwali Mela celebrated at CPRI, Shimla

On the occassion of Deepawali families of CPRI employees celebrated Diwali Mela on October 29, 2013 at Institute campus. Various types of games were organized during the function and awards were given to the winners by the Chief Guest Smt. Madhu Singh. An exhibition was also organised for farmers on this occassion.

Foreign visit by CPRI Scientists

Sl. No.	Name of the scientist place & duration
1.	Dr. Bir Pal, Singh, Director, CPRI, Shimla participated in the meeting on "Late Blight Potato Development Project" under ABSP-II/USAID project held at Bandung, Indonesia during 29th April to 1st May, 2013
2.	Dr. Vinay Bhardwaj, Sr. Scientist, CPRI, Shimla participated in the meeting on "Late Blight Potato Development Project" under ABSP-II/USAID project held at Bandung, Indonesia during 29th April to 1st May, 2013
3.	Dr. Sanjeev Sharma, Sr. Scientist, CPRI, Shimla participated in the meeting on "Late Blight Potato Development Project" under ABSP-II/USAID project held at Bandung, Indonesia during 29th April to 1st May, 2013
4.	Dr. S. Sundaresha, Scientist, CPRI, Shimla participated in the meeting on "Late Blight Potato Development Project" under ABSP-II/USAID project held at Bandung, Indonesia during 29th April to 1st May, 2013
5.	Dr. Bir Pal, Singh, Director, CPRI, Shimla participated in the "Orientation training programme of CIP Board Member" held at France during 10-12 June, 2013
6.	Dr. Rajesh Kumar Rana, Principal Scientist, CPRI, Shimla participated in the training in the area of "Potato Value Chain Analysis & Management" at the International Potato Centre (HQ), Lima-Peru from June 24, 2013 to July 05, 2013
7.	Dr. Baswaraj Raigond, Scientist, CPRI, Shimla participated in training course on "Small RNA library preparation and sequence assembly for virus identification" at CIP, Lima Peru during 1-9 July, 2013
8.	Dr. S. Sundaresha, Scientist, CPRI, Shimla participated in the training programme on "Potato Crop Improvement Techniques" at Cornell University, Ithaca, New York w.e.f. August 15, 2013 to October 25, 2013
9.	Dr. P.M. Govindakrishnan, Project Coordinator, CPRI, Shimla participated in "Potato Europe 2013" during 9-13 September, 2013, Emmeloord, Netherland
10.	Dr. Bir Pal Singh, Director, CPRI, Shimla participated in the meeting of Board of Trustees of CIP held at Lima-Peru w.e.f. 18-29 Novemebr, 2013
11.	Dr. VU Patil, Scientist, CPRI, Shimla participated in the training in the area of Allele Mining at College of Agriculture and Life Sciences, Cornell University, Ithaca, NY, USA from January 06, 2014 to March 14, 2014
12.	Dr. R.K. Rana, Principal Scientist, CPRI, Shimla Participated in the Inception Meeting for CGIAR sponsored meeting on "Strengthening Impact Assessment" project during 15-16 January, 2014 at Bangkok, Thailand
13.	Dr. R. Muthuraj, Sr. Scientist, CPRI, Shimla visited Tuber Crop Research Centre, BARI, Bangladesh from February 02-07, 2014
14.	Dr. Brajesh Singh, Principal Scientist, CPRI, Shimla participated in the training programme at "Quality and Nutrition Laboratory" at Lima Peru during 03-14, February, 2014

Education, Trainings, Awards and Honours

Conference/Seminar/Symposium etc.

Sl.No.	Name & Designation	Title	Date & Venue
1.	Dr. Vinay Bhardwaj, Act. Head, Crop Improvement. Dr. Sundresha S., Scientist, Dr. VU Patil, Scientist, CPRI, Shimla.	NationalSeminar on "Horticultural Biotechnology NSHB-2013"	May 14th, 2013 at IIHR, Bangalore
2.	Dr. SS Lal, Head, Crop Production, Dr. S.K. Yadav, Scientist, Dr. Manoj Kumar, Head, CPRS, Patna, Dr. RK Singh, Scientist, Patna, Dr. Vinay Singh, PS, CPRIC, Modipuram	International Conference on "Water Quality and Management for Climate Resilient Agriculture"	May 26th to 31st, 2013 at Jalgaon.
3.	Dr. S. Roy, Head, CPRS, Gwalior, Dr. SP Singh, Sr. Scientist. Dr. Murlidhar J. Sadawarti, Scientist, CPRS, Gwalior.	National Conference on "Making Agriculture Profitable"	August, 26th to 27th, 2013 at Rajmata Vijayaraje Scindia Krishivishwa Vidyalaya, Gwalior.
4.	Dr BP Singh, Dr PM Govindakrishnan Dr NK Pandey, Dr SS Lal, Dr Brajesh Singh, Dr KK Pandey, Dr Sanjeev Sharma, Dr Vinay Bhardwaj, Dr Shashi Rawat	31st AICRP (Potato) Group Meeting and Workshop on "Problems and Prospects of seed potato Production Systems in India" organized by CPRI, Shimla And Indian Potato Association, Shimla.	21-22 September, 2013, CPRS, Patna 20th September, 2013 CPRS, Patna
5.	Dr. Jagesh Kumar Tiwari, Scientist, CPRI, Shimla.	Interactive meeting on "Doubled haploids: Scope and future in horticulture crops"	October 04th, 2013 at IIHR, Bangalore.
6.	Dr. SP Trehan, PS, CPRS, Jalandhar.	National Seminar on "Developments in Soil Science – 2013"	October 23rd to 26th, 2013 at CAZRI, Jodhpur.
7.	Dr. (Ms.) Aarti Bairwa, Scientist, CPRS, Muthorai.	National Symposium on "A Frield and Foe of Agri-Horticultural Crops"	November 21st to 23rd, 2013 at Dr. YS Parmar University, Nauni, Solan.
8.	Dr. Dhiraj Kumar, Scientist, CPRI, Shimla.	International Conference on "Extension Educational Strategies for Sustainable Agricultural Development"	December 05th to 08th, 2013 at GKVK Campus of UAS, Bangalore.
9.	Dr. Devendra Kumar, PS, CPRIC, Modipuram.	National Conference of Plant Physiology – 2013 on "Current Trends in Plant Biology Research"	December 13th to 16th, 2013 at Directorate of Groundnut Research, Junagarh.
10.	Dr. (Ms.) Jeevalatha, Scientist, CPRI, Shimla.	Asia Pacific Congress of Virology "VIROCON 2013"	December 17th to 20th, 2013 at Amity University, Noida.
11.	Dr. (Mrs.) Kamlesh Malik, PS, CPRIC, Modipuram Dr. R. Umameshwari, Scientist, Dr. (Ms.) R. Sudha, Scientist, CPRS, Muthorai.	International Conference on "Biodiversity, Bioresources and Biotechnology"	January 30th to 31st, 2014 at Mysore, Karnataka.

Sl.No.	Name & Designation	Title	Date & Venue
12.	Dr. Rakesh Mani Sharma, Sr. Librarian, CPRI, Shimla.	National Conference on "Agricultural Librarians and User community (NCALUC)".	February 04th to 05th, 2013 at IGKV, Raipur, Chattisgarh.
13.	Dr. Shashi Rawat, Sr. Scientist, CPRI, Shimla.	Symposium on "Accelerating Biology – 2014: Computing life".	February 18th to 20th, 2014 at C-DAC, Pune.
14.	Dr. (Ms.) Jeevalatha, Scientist, CPRI, Shimla.Dr. (Ms.) Aarti Bairwa, Scientist, CPRS, Muthorai.	National Conference on "Science of omics for agricultural productivity: future perspectives"	March 04th to 06th, 2014 at GBPUA&T, Pantnagar, Uttrakhand.
15.	Dr. Sundaresha S. Scientist, CPRI, Shimla.	National Symposium on "Advances in Plant Molecular Biology and Biotechnology"	March 10th to 12th, 2014 at IISER, Pune.
16.	Dr Dhiraj Kumar Singh, Scientist CPRI, Shimla	Brain Storming Session on Research in Agricultural Extension	April 24, 2013 at PAU Campus, Ludhiana

National Trainings attended

Sl.No.	Name & Designation	Training Programme	Date & Venue
1.	Smt. Tarvinder Kochhar, TO, CPRI, Shimla.	Training programme on "Electron Microscopy at AIIMS"	May 16th to July 26th, 2013 at New Delhi.
2.	Dr. Rakesh Mani Sharma, Sr. Librarian, CPRI, Shimla.	One day workshop on "DELNET: Resources, Services and Facilities & Koha: An Open source Integated Library Management software"	June 15, 2013 at Central University of Himachal Pradesh, Shahpur, Kangra.
3.	Er. Sunil Gulati, CPRS, Jalandhar.	Training programme on "Managing Innovation and technology of compictatieness".	January 27th to February 02nd, 2014 at ASCI, Hyderabad.
4.	Er. Manjit Singh, PS, CPRS, Jalandhar.	National workshop on "खाद्य प्रसंस्करण एवं प्रबंन्धनः उद्यमियों के लिए स्वरोजगार की संभावनाए".	January 28th to 29th, 2014 at CIPHET, Ludhiana.
5.	Sh. Raj deep Bux, CPRI, Shimla.	KOHA professional training.	February 11th to 12th, 2014 at IASRI, New Delhi.
6.	Sh. Islam Ahmad, CPRIC, Modipuram.	Training programme on "Data Analysis Using SAS"	February 17th to 22nd, 2014 at NDRI, Karnal.
7.	Dr. Baswaraj, Scientist, CPRI, Shimla.	Training course on "Application of nanotechnology in Agriculture"	March 10th to 19th, 2014 at CAZRI, Jodhpur.

Awards and Honours

Sl.No.	Name of the Person	Award	Year
1.	CPRI, Shimla	Best Annual Report Award	2013
2.	Dr. Jagesh Kumar Tiwari, Scientist, CPRI Shimla.	Chandra Prabha Young Scientist Award of IPA	(2011-12)
3.	Dr. SK Chakrabarti, Director, CTCRI Thiruvananthapuram, Kerala, based on his work done at CPRI, Shimla.	Dr. S. Ramanujam Award IPA	(2008-11)

Classified Absract of Expenditure of Non-plan, plan and Reciept

Details of Institute Non Plan Expenditure for the year **(Amount in Rupees)**

Sl. No.	Head	Allocation Govt. Grant	Allocation Iinternal resource+ Additional amount provided by HQ out of Council's share	Total Allocaation	Expenditure (Govt. Grant)	Expenditure (Revenue Generation)	Total Expenditure
1	2	3	4	5 (3+4)	6	7	8 (6+7)
Grants in Aid - Capital Works							
A.1 Land		0.00	0.00	0.00	0.00	0.00	0.00
B.1 Office Buildings		0.00	0.00	0.00	0.00	0.00	0.00
B.2 Residential Buildings		0.00	0.00	0.00	0.00	0.00	0.00
B.3 Other works		0.00	0.00	0.00	0.00	0.00	0.00
	Total: Works	0.00	0.00	0.00	0.00	0.00	0.00
	Other Capital Expenditure						
C. Equipments		0.00	900000.00	900000.00	0.00	629132.00	629132.00
D, Information Technology		0.00	0.00	0.00	0.00	270868.00	270868.00
E. Library Books and Journals		200000.00	0.00	200000.00	199192.00	0.00	199192.00
F. Vehicles and Vessels		0.00	1550000.00	1550000.00	0.00	1516744.00	1516744.00
G. Livestock		0.00	0.00	0.00	0.00	0.00	0.00
H. Furniture & fixtures		0.00	300000.00	300000.00	0.00	300000.00	300000.00
I. Others		0.00	0.00	0.00	0.00	0.00	0.00
	Total: Other Capital Expenditure	200000.00	2750000.00	2950000.00	199192.00	2716744.00	2915936.00
	Total Grants in Aid - Capital	**200000.00**	**2750000.00**	**2950000.00**	**199192.00**	**2716744.00**	**2915936.00**

Sl. No.	Head	Allocation Govt. Grant	Allocation linternal resource+ Additional amount provided by HQ out of Council's share	Total Allocaation	Expenditure (Govt. Grant)	Expenditure (Revenue Generation)	Total Expenditure
	Grants in Aid - Salaries						
	Establishment Expenses						
A.1 Establishment Charges		260000000.00	5000000.00	265000000.00	252428046.00	5000000.00	257428046.00
A.2 Wages		6500000.00	0.00	6500000.00	5723865.00	0.00	5723865.00
A.3 Overtime Allowance		0.00	0.00	0.00	0.00	0.00	0.00
	Total: Establishment Expenses	266500000.00	5000000.00	271500000.00	258151911.00	5000000.00	263151911.00
	Total Grants in Aid - Salaries	**266500000.00**	**5000000.00**	**271500000.00**	**258151911.00**	**5000000.00**	**263151911.00**
	Grants in Aid - General						
	Pension and Retirement Benefits						
A. Pension & Other Retirement Benefits		91200000.00	5000000.00	96200000.00	91200000.00	5000000.00	96200000.00
Total:	**Pension and Retirement Benefits**	91200000.00	5000000.00	96200000.00	91200000.00	5000000.00	96200000.00
	Travelling Allowances						
A. Domestic TA / Transfer TA		1050000.00	0.00	1050000.00	1049972.00	0.00	1049972.00
B. Foreign TA		0.00	0.00	0.00	0.00	0.00	0.00
	Total: Travelling Allowances	1050000.00	0.00	1050000.00	1049972.00	0.00	1049972.00
	Research and Operational Expenses						
A. Research Expenses		3531000.00	3000000.00	6531000.00	3512088.00	3454404.00	6966492.00
B. Operational Expenses		4742000.00	1000000.00	5742000.00	4760731.00	981449.00	5742180.00
	Total: Research and Operational Expenses	8273000.00	4000000.00	12273000.00	8272819.00	4435853.00	12708672.00

Sl. No.	Head	Allocation Govt. Grant	Allocation linternal resource+ Additional amount provided by HQ out of Council's share	Total Allocaation	Expenditure (Govt. Grant)	Expenditure (Revenue Generation)	Total Expenditure
	Administrative Expenses						
A. Infrastructure		5965000.00	4560000.00	10525000.00	5965000.00	4121152.00	10086152.00
B. Communication		573000.00	0.00	573000.00	573053.00	0.00	573053.00
C.1 Repairs/Maintenance - Equipments,Vehicles & Others		2587000.00	1000000.00	3587000.00	2589753.00	996910.00	3586663.00
C.2 Repairs/Maintenance - Office building		2073000.00	1000000.00	3073000.00	2070418.00	990029.00	3060447.00
C.3 Repairs/Maintenance - Residential building		-59000.00	0.00	-59000.00	-59757.00	0.00	-59757.00
C.4 Repairs/Maintenance - Minor Works		558000.00	0.00	558000.00	558339.00	0.00	558339.00
D. Others (excluding TA)		6228000.00	1500000.00	7728000.00	6073342.00	1655312.00	7728654.00
	Total: Administrative Expenses	17925000.00	8060000.00	25985000.00	17770148.00	7763403.00	25533551.00
Miscellaneous Expenses							
A. HRD		200000.00	0.00	200000.00	200000.00	0.00	200000.00
B. Other Items (Fellowships, Scholarships etc.)		0.00	0.00	0.00	0.00	0.00	0.00
C. Publicity & Exhibitions		0.00	0.00	0.00	0.00	0.00	0.00
D. Guest House – Maintenance		0.00	0.00	0.00	0.00	0.00	0.00
E. Other Miscellaneous		0.00	0.00	0.00	0.00	0.00	0.00
	Total: Miscellaneous Expenses	200000.00	0.00	200000.00	200000.00	0.00	200000.00
	Tota Grants in Aid - General	**118648000.00**	**17060000.00**	**135708000.00**	**118492939.00**	**17199256.00**	**135692195.00**
	Grand Total : Capital + Revenue	**385348000.00**	**24810000.00**	**410158000.00**	**376844042.00**	**24916000.00**	**401760042.00**
	(Salaries)+						
	Loan and Advances	1300000.00	1300000.00	1194000.00	1194000.00		

Annexure - B-1

Details of Institute Plan Expenditure for the year **(Amount in Rupees)**

Head	RE Allocation	Expenditure
Grants in Aid - Capital Works		
A.1 Land	0.00	0.00
B.1 Office Buildings	0.00	0.00
B.2 Residential Buildings	0.00	0.00
B.3 Other works	0.00	0.00
Total: Works	0.00	0.00
Other Capital Expenditure		
C. Equipments	11075000.00	10683668.00
D, Information Technology	0.00	368105.00
E. Library Books and Journals	4500000.00	4499824.50
F. Vehicles and Vessels	0.00	0.00
G. Livestock	0.00	0.00
H. Furniture & fixtures	91000.00	91251.00
I. Others	0.00	0.00
Total: Other Capital Expenditure	15666000.00	15642848.50
Total Grants in Aid - Capital	15666000.00	15642848.50
Grants in Aid - Salaries		
Establishment Expenses		
A.1 Establishment Charges	0.00	0.00
A.2 Wages	0.00	0.00
A.3 Overtime Allowance	0.00	0.00
Total: Establishment Expenses	0.00	0.00
Total Grants in Aid - Salaries	0.00	0.00
Grants in Aid - General		
Pension and Retirement Benefits		
A. Pension & Other Retirement Benefits	0.00	0.00
Total: Pension and Retirement Benefits	0.00	0.00
Travelling Allowances		
A. Domestic TA / Transfer TA	3731000.00	3729989.00
B. Foreign TA	0.00	0.00
Total: Travelling Allowances	3731000.00	3729989.00
Research and Operational Expenses		
A. Research Expenses	47005000.00	47024043.00
B. Operational Expenses	8183000.00	7093127.00
Total: Research and Operational Expenses	55188000.00	54117170.00

Head	RE Allocation	Expenditure
Administrative Expenses		
A. Infrastructure	2007000.00	2006652.00
B. Communication	244000.00	244376.00
C.1 Repairs/Maintenance - Equipments,Vehicles & Others	2175000.00	2174894.00
C.2 Repairs/Maintenance - Office building	3031000.00	3030607.00
C.3 Repairs/Maintenance - Residential building	3075000.00	3074936.00
C.4 Repairs/Maintenance - Minor Works	219000.00	219402.00
D. Others (excluding TA)	1486000.00	2576126.00
Total:Administrative Expenses	12237000.00	13326993.00
Miscellaneous Expenses		
A. HRD	6353000.00	6351390.00
B. Other Items (Fellowships, Scholarships etc.)	0.00	0.00
C. Publicity & Exhibitions	0.00	0.00
D. Guest House – Maintenance	0.00	0.00
E. Other Miscellaneous	0.00	0.00
Total: Miscellaneous Expenses	6353000.00	6351390.00
Total: Grants in Aid - General	77509000.00	77525542.00
Grand Total : Capital + Revenue (Salaries)	**93175000.00**	**93168390.50**

REVENUE RECEIPTS **Annexure - A**

Sl. No.	Particulars	Amount
1.	Sale of Farms Produce	16387.00
2.	Sale of Fish & Poultry	0.00
3.	Sale of Land	0.00
4.	Sale of Building	0.00
5.	Sale of Vehicle, other Machine Tools	277991.00
6.	Sale of Livestocks	0.00
7.	Income from Royalty, Sale of Publications and Advertisement	93160.00
8.	Licence Fee	1343287.00
9.	Interest earned on Loans and Advances	935735.00
10.	Leave Salary and Pension Contribution	0.00
11.	Receipts from Schemes	0.00
12.	Analytical and Testing Fee	0.00
13.	Pre-shipment Fee	0.00
14.	Application fee from candidates	217820.00
15.	Diploma Charges	0.00
16.	Receipts from Services Rendered	0.00
17.	Unspent Balance of Grants	0.00
18.	Interest earned on short term deposits	3485151.00
19.	Income generated from Internal Resource Generation	0.00
20.	Net profit in Revolving Funds	2986156.00
21.	Recoveries of Loans and Advances	1505933.00
22.	Miscellenous Receipts	13142311.00
	Break up : Grand Total	**24003931.00**

Revenue Receipts : 22220007.00

Loan recovereis : 1505933.00

Sale of Assets : 277991.00

24003931.00

Promotions / Transfers / MACP / Probation / Retirments / Deaths as on 31.3.2014

Scientific Staff

Transfers / Relieving /Promotion

1. Dr. (Mrs.) K Manorama, Sr. Scientist, CPRS, Ooty relieved from 20.4.2013 to join at Directorate of Oil Palm Research, Pedavegi.

2. Dr. G. Ravichandran, Sr. Scientist, Seed Technology relieved from 31.5.2013 to join at Directorate of Oil Palm Research, Pedavegi, West Godavari.

3. Dr. R. Ezekiel, Head, Division of CPB&PHT relieved from 22.6.2013 to join as National Coordinator, NAIP, ICAR, New Delhi.

4. Dr. MK Jatav, Sci.(SS),CPRI, Shimla relieved from 30.7.2013 to join as Sr. Scientist at CIAH, Bikaner.

Appointments / Joining

1. Dr. (Mrs.) G. Vanishree, Scientist (Plant Breeding) has joined at CPRI, Shimla with effect from 15.4.2013 (FN) after having been relieved from Directorate of Sorghum Research, Regional Centre, Solapur.

2. Dr. (Ms.) Aarti Bairwa, Scientist(Plant Nematology) has joined at CPRI, Shimla with effect from 11.4.2013 (FN) after completing FOCARS training.

3. Dr. Rajender Prasad Pant, Sr. Scientist(Plant Pathology) has joined at CPRIC, Modipuram in the forenoon of 20th May, 2013 after having been relieved from NRC for Orchids, Pakyong, Sikkim.

4. Dr. Satyajit Roy, PS & Head, CTRI Research Station, Dinhata (WB) joined to the post of Head, CPRS, Gwalior on 26.7.2013 (FN).

5. Dr.(Ms). R. Sudha, Scientist(Hort.) joined at CPRS, Ooty on transfer from Central Agril. Research Institute, Port Blair (A&N Islands) on 19.8.2013.

6. Dr. EP Venkatasalam, Scientist (SS) after having been relieved from IARI Regional Centre, Wellington (Nilgiris) has joined at CPRS, Ooty on 30.8.2013

Technical Staff

i) Promotion through assessment

1. Shri S.B.S. Parihar, T.O. (T-6) Central Potato Research Institute Campus, Modipuram, promoted through assessment as T-4 (Field Farm Technician) w.e.f. 1.1.1995, subject to the outcome of the S.L.P. titled D.G. ICAR Vs. V. Ravindran S.L.P. (CC) 2773/2009-3393/09-3411/ 2009 i.e. Civil Appeals No. 415-4161/2009. Retired on 30.06.2013.

2. Shri Raj Kumar, Sr. TO (T-6), CPRS, Jalandhar (*Retired on 31.3.2012*), promoted as T 7-8, w.e.f. 24.02.2011, in PB 15600-39100 + GP 6600

3. Sh. Balak Ram Singh, Sr. Tech. Officer, CPRIC, Modipuram, promoted to Asstt. Chief Tech. Officer in the Pay Band Rs. 15600-39100+ Rs.6600(GP) w.e.f 03.02.2009

4. Sh. Ramesh Chand, Sr. Tech. Officer, CPRIC, Modipuram, promoted to Asstt. Chief Tech. Officer in the Pay Band Rs. 15600-39100+ Rs.6600(GP) w.e.f 11.01.2012

5. Sh. Krishan Pal Singh, Sr. Tech. Officer, CPRIC, Modipuram, promoted to Asstt. Chief Tech. Officer in the Pay Band Rs. 15600-39100+ Rs.6600(GP) w.e.f 12.03.2012

6. Sh. AK Atrey, Tech. Officer, CPRI, Shimla, promoted to Sr. Technical Officer in the Pay Band Rs. 15600-39100+ Rs.5400(GP) w.e.f 30.01.2013

7. Sh. Jasvir Singh, Tech. Officer, CPRIC, Modipuram, promoted to Sr. Technical Officer in the Pay Band Rs. 15600-39100+ Rs.5400(GP) w.e.f 16.02.2013

8. Sh. Subhash Chand, Tech. Officer, CPRIC, Modipuram, promoted to Sr. Technical Officer in the Pay Band Rs. 15600-39100+ Rs.5400(GP) w.e.f 16.09.2013

9. Sh. Tilak Raj, Sr. Tech. Asstt., CPRI, Shimla, promoted to Technical Officer in the Pay Band Rs. 9300-34800+ Rs.4600(GP)w.e.f 24.09.2012

10. Sh. Udaivir Singh, Sr. Tech. Asstt., CPRIC, Modipuram, promoted to Technical Officer in the Pay Band Rs. 9300-34800+ Rs.4600(GP)w.e.f 16.02.2012

11. Sh. Vijay Kumar, Sr. Technician, CPRI, Shimla, promoted to Technical Assistant in the Pay Band Rs. 5200-20200+ Rs.2800(GP)w.e.f 17.11.2012

12. Sh. R. Lakshamanan, Sr. Technician, CPRS, Muthorai, promoted to Technical Assistant in the Pay Band Rs. 5200-20200+ Rs.2800(GP)w.e.f 13.04.2013

13. Sh. S. Nongrum, Sr. Technician, CPRS, Shillong, promoted to Sr. Technician in the Pay Band Rs. 5200-20200+ Rs.2800(GP)w.e.f 21.08.2012

Transfer within Institute

1. Shri Munna Lal, Technical Officer (T-6), from CPRS Gwalior to CPRS Jalandhar, on 6.5.2013

2. Shri Ajit Singh, T-2 (FFT), CPRS, Jalandhar to CPRI Shimla/CPRS, Kufri, on 8.5.2013

3. Dr. TK Sinha, ACTO, CPRS Patna to CPRI, Shimla on 04.03.2014

4. Sh. Rajdeep Bux, TO, CPRIC, Modipuram to CPRI, Shimla 15.02.2014

Administrative Staff

Promotion

1. Sh.SS Thakur, Asstt., CPRI, Shimla promoted as AAO at CPRI, Shimla w.e.f 19.4.2013.

2. Sh. Sikandra Ishwari, Asstt.,CPRS, Shillong promoted as AAO at CPRS, Shillong w.e.f. 4.7.2013

3. Sh.S. Athimoolam, AAO, CPRS, Gwalior promoted as Admn.Officer at NIANP, Bengaluru and relieved from CPRS, Gwalior on 5.8.2013.

4. Sh. Joginder Singh Thakur, Asstt., CPRI, Shimla promoted as AAO (through LDCE), at CPRI, Shimla w.e.f. 27.9.2013.

5. Sh.Krishan Lal, Asstt., CPRI, Shimla promoted as AAO at CPRS, Gwalior w.e.f. 24.2.2014

6. Sh.Mahendra Singh, UDC, CPRIC, Modipuram promoted as Assistant at CPRIC, Modipuram w.e.f. 23.5.2013.

7. Sh.Jagdish Chand, UDC, CPRI, Shimla promoted as Assistant at CPRI, Shimla w.e.f. 23.5.2013.

8. Sh.Sukhpal Sharma, UDC, CPRS, Jalandhar promoted as Assistant at CPRS, Jalandhar w.e.f. 28.10.2013.

9. Ms Rita Walia,UDC, CPRI, Shimla promoted as Assistant at CPRI, Shimla w.e.f. 21.12.2013.

10. Sh.Amar Chand, UDC, CPRI, Shimla promoted as Assistant at CPRI, Shimla w.e.f. 31.12.2013.

11. Smt.Kanta Rani, UDC, CPRI, Shimla promoted as Assistant at CPRI, Shimla w.e.f. 31.12.2013.

12. Sh.Ramesh Kumar Gupta,LDC, CPRS, Patna promoted as UDC at CPRS, Patna w.e.f. 31.12.2013

13. Sh.Pawan Kumar,LDC, CPRI,Shimla promoted as UDC at CPRI, Shimla w.e.f. 31.12.2013

Transfer

1. Sh.Girish Thakur, Steno. Gr.III, CPRS, Gwalior to CPRI, Shimla on 29.4.2013.

Skilled Support Staff

Promotion

Temporary Status

1. Sh. Sohan Pal,SSS, has joined CPRIC, Modipuram on dated 04.01.2014

2. Sh. Ramphal,SSS, has joined CPRIC, Modipuram on dated 04.01.2014

3. Sh. Mukesh, SSS, has joined CPRIC, Modipuram on dated 04.01.2014

4. Sh. Murari, SSS, has joined CPRIC, Modipuram on dated 04.01.2014

5. Sh. Rajpal Singh SSS, has joined CPRIC, Modipuram on dated 04.01.2014

Financial Upgradaton Granted Under MACP Scheme

Sl. No.	Name & Designation of the Officials	Granted financial up gradation under MACP Scheme
1.	Sh.Devendra Kumar, Asstt., CPRI, Shimla	Granted 3rd MACP w.e.f. 11.10.2012 in the PB Rs. 9300-34800+4600 GP
1.	Smt. Teirina Nongkhlaw, CPRS, Shillong	Granted 3rd MACP w.e.f. 17.3.2013 in the PB Rs. 9300-34800+4600 GP
2.	Smt. Sandhya Kapila, CPRS, Jalandhar	Granted 2nd MACP w.e.f. 2.10.2012 in the PB Rs.5200-20200 +2800GP Rs. GP
3.	Smt. Shyam Lata Beakta, CPRI, Shimla.	Granted 2nd MACP w.e.f. 30.1.2013 in the PB Rs.5200-20200 +2800GP Rs. GP
4.	Sh.Jagdish Chand, UDC, CPRI, Shimla	Granted 2nd MACP w.e.f. 2.10.2012 in the PB Rs.5200-20200 +2800GP Rs. GP
5.	Sh.Miraj Ul Haq, AAO, CPRIC, Modipuram	Granted 3rd MACP w.e.f. 24.12.2012 in the PB Rs. 9300-34800+4800 GP
6.	Smt. Pomilian W.Syiem,Asstt., CPRS, Shillong	Granted 3rd MACP w.e.f. 19.3.2013 in the PB Rs. 9300-34800+4600 GP
7.	Sh.Jai Ram Thakur,Asst., CPRI, Shimla	Granted 3rd MACP w.e.f. 7.1.2014 in the PB Rs. 9300-34800+4600 GP
8.	Sh.Suresh Kumar, Steno Gr.III, CPRS, Jalandhar	Granted 2nd MACP w.e.f. 12.8.2013 in the PB Rs. 9300-34800+4600 GP
9.	Smt.Daishey Tuli, LDC, CPRS, Jalandhar	Granted 1st MACP w.e.f. 5.9.2013 in the PB Rs. 5200-20200 +2000GP
10.	Sh.Daljeet Singh, LDC, CPRS, Jalandhar	Granted 1st MACP w.e.f. 5.5.2013 in the PB of Rs. 5200-20200 +2000GP
11.	Sh.Gokal Ram, LDC, CPRI, Shimla	Granted 1st MACP w.e.f. 16.6.2013 in the PB of Rs. 5200-20200 +2000GP

Probations Clearance

Sl.No.	Name & Designation	Date from which probation cleared
1.	Smt. Pomilian W. Syiem, Asstt.,CPRS, Shillong	25.11.2012
2.	Sh.Jai Ram Thakur, Asstt.,Audit Section, CPRI, Shimla	26.4.2013
3.	Smt. Meena Verma,Asstt., Estt. Section,CPRI, Shimla.	28.6.2013
4.	Sh.Jagbir Singh, Asstt.,CPRIC, Modipuram	28.6.2013
5.	Smt. Babli Bhawani, Asstt.,Estt. Section,CPRI, Shimla	28.6.2013
6.	Sh. Rajesh Kumar, Personal Asstt.,CPRIC, Modipuram	20.3.2013
7.	Sh. Suresh Kumar, Personal Asstt., Hindi Cell, CPRI,Shimla	19.3.2013

Skilled Support Staff Promoted to under 33.33% Departmental Promotion Quota

1. Shri B Suresh, Skilled Support Staff, CPRS, Muthorai, promoted as T-1 (Field Farm Technician) at CPRS, Muthorai, w.e.f. 21.06.2013 (FN)

2. Shri Chet Ram, Skilled Support Staff, CPRS, Gwalior, promoted as T-1 (Field Farm Technician) at CPRS,Gwalior, w.e.f. 13.09.2013 (FN)

Joined on Transfer from outside Institute

1. Sh. Arjun Dass, Skilled Support Staff, DMR, Solan joined at CPRI, Shimla on 02.09.2013.

Scientific Staff

Retirements

1. Dr. NC Upadhayay, PS, CPRIC, Modipuram retired on 30.11.2013

2. Dr. RK Verma, Sr. Scientist retired on 31.12.2013

3. Dr. SP Trehan, PS, CPRS, Jalandhar retired w.e.f. 31.3.2014

Technical Staff

Retirements

1. Sh. Sita Ram Sahu, Tech. Asstt retired on 30.04.2013

2. Sh. Sudarshan Singh, Sr. Tech Asstt. retired on 30.06.2013

3. Dr. SBS Parihar, Sr. Tech. Officer retired on 30.06.2013

4. Sh. Munna Lal Bharti, Sr. Tech. Asstt. retired on 31.07.2013

5. Sh. Ram Charan Dass, Tech. Officer retired on 31.08.2013

6. Sh. Gatum Prasad Singh, Tech. Officer retired on 30.09.2013

Financial Upgradaton Granted Under MACP Scheme

Sl. No.	Name of the Officials	Present Pay Band + Grade Pay	Date of grant of *I/II/III MACPS	Pay Band and Grade Pay granted after MACPS
1.	Sh. Ramji Lal, SSS, CPRS, Gwalior	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 20.07.2013	Rs.5200-20200+Rs.2000
2.	Sh.Amiruddin, SSS, CPRIC, Modipuram	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 11.02.2013	Rs.5200-20200+Rs.2000
3.	Sh.Raj Kumar, SSS, CPRS, Jalandhar	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 25.03.2013	Rs.5200-20200+Rs.2000
4.	Sh. Gian Singh, SSS, CPRS, Jalandhar	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 25.03.2013	Rs.5200-20200+Rs.2000
5.	Sh. Karnail Singh,SSS, CPRS, Jalandhar	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 25.03.2013	Rs.5200-20200+Rs.2000
6.	Sh. Satnam Singh,SSS, Jalandhar	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 25.03.2013	Rs.5200-20200+Rs.2000
7.	Sh.Passo, SSS, CPRS, Jalandhar	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 01.10.2013	Rs.5200-20200+Rs.2000
8.	Sh. Teka Rai, SSS, CPRS, Patna	Rs.5200-20200+ 1900	2nd MACPS w.e.f. 07.10.2013	Rs.5200-20200+Rs.2000
9.	Sh. Ram Kishun Ram,	Rs.5200-20200+ SSS, CPRS, Patna	2nd MACPS w.e.f. 1900	Rs.5200-20200+Rs.2000 07.10.2013

Administrative Staff

Retirements

1. Sh.Inder Singh Negi, AAO, CPRI, Shimla 30.4.2013
2. Sh.Sher Singh Thakur, Asstt.Admn. Officer,CPRI, Shimla 31.5.2013
3. Sh. KK Sood, AO, CPRI, Shimla 31.7.2013
4. Smt. Neelam Grover, PA, CPRI, Shimla 30.9.2013
5. Mrs. Bindra Gupta, Asstt., CPRI, Shimla 31.1.2014

Skilled Supprot Staff

Retirements

1. Smt. Klossidian Kharsyntielo, SSS, CPRS, Shillong retired on 31.08.2013.
2. Smt. Kunda S Walse, SSS, CPRS, Gwalior retired on 30.11.2013

Technical Staff

Untimely Demise

1. Sh. Baljinder Singh, Sr. Tech. Asstt. expired on 07.04.2013
2. Sh. NK Budhanah, Tech. Asstt. expired on 23.06.2013

Skilled Support Staff

Untimely Demise

1. Sh. Ram Lagan, SSS, CPRS, Jalandhar, died on 21.8.2013
2. Sh. Hari Singh, SSS, CPRS, Gwalior died on 03.11.2013
3. Sh. Pal Bahadur, SSS,CPRS, Kufri, died on 06.11.2013
4. Sh. Kedar Singh, SSS, CPRS, Gwalior died on 24.12.2013
5. Smt. Sodha Devi, Temporary Status, CPRS, Kufri died on 01.02.2014.

Station-wise staff sanctioned

List of Scientific staff at CPRI, Shimla & its Regional Stations as on 31.03.2014

Dr. BP Singh : Director

AICPIP Unit

1. Dr. PM Govindakrishnan, Project Coordinator

Division of Crop Improvement

2. Dr. Vinay Bhardwaj, Sr. Scientist
3. Sh. Virupakshagauda U Patil, Scientist
4. Dr. Jagesh Kumar Tiwari, Scientist
5. Dr.(Ms) Dalamu, Scientist
6. Dr.(Mrs.) G Vanishree, Scientist

Division of Seed Technology

7. Dr. KK Pandey, PS & Head
8. Dr. R. Muthu Raj, Sr. Scientist

Division of Crop Production

9. Dr. S.S. Lal, PS & Head
10. Dr. M.C. Sood, Principal Scientist
11. Dr. VK Dua, Principal Scientist

Division of Social Sciences

12. Dr. NK Pandey,PS& Head
13. Dr. Rajesh Kumar Rana, Principal Scientist
14. Dr. Dhiraj Kumar Singh, Scientist

Division of Plant Protection

15. Dr. Sanjeev Sharma, Sr. Scientist
16. Dr. Vinay Sagar, Sr. Scientist
17. Dr.(Ms) Jeevalatha A, Scientist
18. Dr. Baswaraj R., Scientist
19. Dr. Sundersha S, Scientist
20. Dr. Ravinder Kumar, Scientist
21. Dr. VallepuVenkateswarlu, Scientist
22. Sh. ShridharJandrajupalli, Scientist
23. Dr.(Mrs.) TC KumariSugitha, Scientist

Division of Crop Phy.& PHT

24. Dr. Brajesh Singh, Principal Scientist
25. Dr. (Mrs.) Pinky Raigond, Scientist

ARIS Cell

26. Dr. ShashiRawat, Sr. Scientist

CPRI Campus, Modipuram

27. Dr. SK Kaushik, Joint Director
28. Dr. Devendra Kumar, PS
29. Dr. (Mrs.) Kamlesh Malik, PS
30. Dr. SK Luthra, Principal Scientist
31. Dr. Name Singh, Principal Scientist
32. Dr. Vinay Singh, Principal Scientist
33. Dr. Anuj Bhatnagar, Principal Scientist
34. Dr. MA Khan, Principal Scientist
35. Dr. Rajender Prasad Pant, Sr. Scientist
36. Dr. Sanjay Rawal, Principal Scientist
37. Dr. Dhruv Kumar, Sr. Scientist
38. Dr. Vijay Kishore Gupta, Sr.Scientist
39. Dr. MehiLal, Scientist
40. Dr.(Ms) Bandna, Scientist

CPRS, Jalandhar

41. Dr. JS Minhas, Head
42. Dr. RK Arora, PS

43. Dr. (Mrs.) Ashiv Mehta, PS

44. Er. Manjit Singh, PS

45. Dr. Raj Kumar, Principal . Scientist

46. Er. Sukhwinder Singh, Scientist SG

47. Er. Sunil Gulati, Scientist (SG)

48. Dr.(Ms) RatnaPreeti Kaur, Scientist

CPRS, Gwalior

49. Dr. S Roy, Head

50. Dr. Shiv Pratap Singh, Principal Scientist

51. Dr. Murlidhar .J.Sadawarti, Scientist

CPRS, Shillong

52. Dr. TK Bag, Head

53. Dr. AK Srivastava, Scientist

54. Dr. Sanjay Kumar Yadav, Scientist

55. Dr. Malkhan Singh Gurjar, Scientist

CPRS, Muthorai

56. Dr. EP Venkatsalam, Sr. Scientist

57. Dr. Uma Maheshwari, Scientist

58. Dr. (Ms.) R. Sudha, Scientist(SS)

59. Dr. (Ms.) Aarti Bairwa, Scientist

CPRS, Kufri

60. Dr. Ashwani Kumar Sharma, Sr. Scientist

61. Dr. Vinod Kumar, Sr. Scientist

CPRS, Patna

62. Dr. Manoj Kumar, Head, CPRS, Patna

63. Dr. Shambhu Kumar, Sr. Scientist

64. Dr. SK Singh, Principal Scientist

65. Dr. Raj Kumar, Sr. Scientist

66. Sh. Rahul R Bakade, Scientist

Technical Staff at CPRI Shimla as on 31.03.2014

Sl. No.	Name	Post
1.	Sh. R.K Chauhan	Chief Technical Officer
2.	Sh. BS Latwal	Asstt. Chief Technical Officer
3.	Dr. Rakesh Mani Sharma	Asstt. Chief Technical Officer
4.	Dr. TK Sinha	Asstt. Chief Technical Officer
5.	Sh. Kameshwar Sen	Sr. Technical Officer
6.	Dr. Sushil Kumar	Sr. Technical Officer
7.	Smt. Shelly Chopra	Sr. Technical Officer
8.	Sh. PraveshJassal	Sr. Technical Officer
9.	Sh. Yogesh	Sr. Technical Officer
10.	Smt. TarvinderKochhar	Sr. Technical Officer
11.	Sh. DharminderVerma	Sr. Technical Officer
12.	Sh. Avnish Kumar Atrey	Sr. Technical Officer
13.	Sh. Krishan Singh Negi	Technical Officer
14.	Sh. Surinder Paul	Technical Officer
15.	Sh. Kana Singh Chauhan	Technical Officer
16.	Sh. Harvinder Singh	Technical Officer
17.	Smt. Shruti Gupta	Technical Officer
18.	Dr. (Smt.) Sumita Sharma	Technical Officer
19.	Smt. Ruma Chakraborty	Technical Officer
20.	Sh. Vinod Kumar	Technical Officer
21.	Sh. Rajdeep Bux	Technical Officer
22.	Sh. CM Bist	Technical Officer
23.	Sh. Tilak Raj	Technical Officer
24.	Sh. Khairati Lal	Sr. Technical Assistant
25.	Sh. Sheesh Ram	Sr. Technical Assistant
26.	Sh. Yash Pal Sharma	Sr. Technical Assistant
27.	Sh. Naresh Kumar Sharma	Sr. Technical Assistant
28.	Sh. DP Gautam	Sr. Technical Assistant

29.	Sh. Rakesh Kumar Patyal	Technical Assistant
30.	Sh. Rajinder Kumar	Technical Assistant
31.	Sh. Prakash Chand	Technical Assistant
32.	Smt. ManjitSyal	Technical Assistant
33.	Sh. Hari Kishore	Technical Assistant
34.	Smt. Asha Thakur	Technical Assistant
35.	Sh. Ranjesh Bhardwaj	Technical Assistant
36.	Sh. Naresh Chand Sharma	Technical Assistant
37.	Smt. MadhuBala	Technical Assistant
38.	Sh. Dharminder Kr. Gupta	Technical Assistant
39.	Sh. Naresh Kumar Thakur	Technical Assistant
40.	Sh. Onkar Singh	Technical Assistant
41.	Sh. Sushil Singh	Technical Assistant
42.	Sh. Ram Singh	Technical Assistant
43.	Sh. Vijay Kumar	Technical Assistant
44.	Sh. Prithi Raj	Sr. Technician
45.	Sh. Rakesh Kumar	Sr. Technician
46.	Sh. Deep Ram	Sr. Technician
47.	SmtJitender Kaur Arora	Sr. Technician
48.	Sh. Jagdish Chand	Sr. Technician
49.	Sh. Ravinder Kumar	Sr. Technician
50.	Sh. Jagdish Chand	Sr. Technician
51.	Sh. Ashok Kumar	Sr. Technician
52.	Sh. RoopLal	Sr. Technician
53.	Sh. Ram Dayal	Sr. Technician
54.	Sh. Anil Kumar Dubey	Sr. Technician
55.	Sh. Dev Raj	Sr. Technician
56.	Sh. Neem Chand	Technician
57.	Sh. PermeshDutt	Technician
58.	Sh. Sita Ram	Technician
59.	Sh. Laiq Ram	Technician
60.	Sh. Surinder Pal	Technician

Technical Staff at CPRS, Jalandhar

Sl. No.	Name	Post
1.	Sh. Ashwani Kumar Sharma	Asstt. Chief Technical Officer
2.	Dr. Sanat Kumar	Sr. Technical Officer
3.	Sh. Jaswinder Singh	Sr. Technical Officer
4.	Sh. Yogesh Kumar Gupta	Sr. Technical Officer
5.	Sh. Kapil Kumar Sharma	Sr. Technical Officer
6.	Sh. MunnaLal	Sr. Technical Officer
7.	Sh. Akhilesh Kumar Singh	Technical Officer
8.	Sh. Gurudev Singh	Technical Officer
9.	Sh. Jagdish Chand	Technical Officer
10.	Sh. SomDutt	Sr. Technical Assistant
11.	Sh. HarbansLal	Sr. Technical Assistant
12.	Sh. Narinder Mayer	Technical Assistant
13.	Sh. Nirmal Singh	Technical Assistant
14.	Sh. Bhag Singh	Technical Assistant
15.	Sh. Kulwinder Singh	Sr. Technician
16.	Sh. Anil Kumar Chandel	Sr. Technician
17.	Sh. Vijay Kumar Rai	Sr. Technician
18.	Sh. Pradeep Kumar Upadhya	Sr. Technician
19.	Sh. Pawan Kumar	Technician

Technical Staff at CPRIC, Modipuram

Sl. No.	Name	Post
1.	Sh. Islam Ahmad	Chief Technical Officer
2.	Sh. Ram Kumar Verma	Asstt. Chief Technical Officer
3.	Sh. Balak Ram Singh	Asstt. Chief Technical Officer
4.	Sh. Mahipal Singh	Asstt. Chief Technical Officer
5.	Sh. Ramesh Chand	Asstt. Chief Technical Officer

6.	Sh. Harvir Singh	Asstt. Chief Technical Officer
7.	Sh. Ashok Kumar	Asstt. Chief Technical Officer
8.	Sh. Krishan Pal Singh	Asstt. Chief Technical Officer
9.	Sh. Mahesh Kumar	Sr. Technical Officer
10.	Sh. Satendra Kumar	Sr. Technical Officer
11.	Sh. MuraiLal	Sr. Technical Officer
12.	Sh. Ompal Singh	Sr. Technical Officer
13.	Smt. Kusum Singh	Sr. Technical Officer
14.	Sh. Subhash Chand	Sr. Technical Officer
15.	Sh. Jasvir Singh	Sr. Technical Officer
16.	Sh. Mool Chand	Technical Officer
17.	Sh. RK Sharma	Technical Officer
18.	Sh. Harvir Singh	Technical Officer
19.	Sh. Santosh Kumar	Technical Officer
20.	Sh. Ombir Singh	Technical Officer
21.	Sh. Udaivir Singh	Technical Officer
22.	Sh. Vijay Kumar Yadav	Technical Officer
23.	Sh. NK Sood	Technical Officer
24.	Dr.(Smt.) VineetShamra	Technical Officer
25.	Sh. Avinash Chaudhary	Technical Officer
26.	Sh. Dinesh Singh	Technical Officer
27.	Sh. Ved Singh	Technical Officer
28.	Sh. Pushpender Singh	Technical Officer
29.	Sh. Kundan Singh	Technical Officer
30.	Sh. Krishanpal Singh	Technical Assistant
31.	Sh.Narayan Singh	Technical Assistant
32.	Sh. Kehar Singh	Technical Assistant
33.	Sh. Pawan Kumar Malik	Technical Assistant
34.	Sh. Ajay Vir Singh	Technical Assistant
35.	Sh. Mahesh Pal Singh	Technical Assistant
36.	Sh. Satpal Singh	Technician
37.	Sh. Rambir Singh	Technician
38.	Sh. Vipin Kumar	Technician
39.	Sh. Madan Pal	Technician
40.	Sh. Kamal Singh	Technician

Technical Staff at CPRS, Kufri

Sl. No.	Name	Post
1.	Sh. Brij Mohan Lal	Technical Officer
2.	Sh. Devi Chand Sharma	Technical Officer
3.	Sh. Kedar Singh	Technical Assistant
4.	Sh. Mohan Lal	Sr. Technician
5.	Sh. Ram Jivan Singh	Sr. Technician
6.	Sh. Ajit Singh	Sr. Technician

Technical Staff at CPRS, Gwalior

Sl. No.	Name	Post
1.	Sh. RK Samadhiya	Technical Officer
2.	Dr. Yogender Pal	Technical Officer
3.	Sh. Sanjay Kumar Sharma	Technical Officer
4.	Sh. Shyam Kumar Gupta	Technical Officer
5.	Sh. Surinder Singh	Sr. Technical Assistant
6.	Sh. Praveen Kumar	Technical Assistant
7.	Sh. Rakesh Singh Hada	Sr. Technician
8.	Sh. RadhaKrishan	Sr. Technician
9.	Sh. Nihal Singh	Sr. Technician
10.	Sh. Ram Het Singh	Technician
11.	Sh. Prakash Ram	Technician
12.	Sh. Bijendra Singh	Technician
13.	Sh. Tara Chand	Technician
14.	Sh. Chet Ram	Technician

Technical Staff at CPRS, Shillong

Sl. No.	Name	Post
1.	Sh. Emeralstone Syiemlieh	Technical Officer
2.	Sh. Bosterwell Langestieh	Sr. Technical Assistant
3.	Sh. Hesting Jyrwa	Sr. Technical Assistant
4.	Sh. P. Roy Khanghuh	Technical Assistant
5.	Sh. U. P. Paudel	Technical Assistant

6.	Sh. Ram Dass Rai	Sr. Technician
7.	Sh. S. Nongrum	Sr. Technician

Technical Staff at CPRS, Muthorai

Sl. No.	Name	Post
1.	Sh. B. Chandran	Technical Officer
2.	Sh. V. Rajendran	Technical Officer
3.	Sh. R. Lakashaman	Technical Assistant
4.	Sh. B. Suresh	Technician

Technical Staff at CPRS, Patna

Sl. No.	Name	Post
1.	Sh. Arun Kumar Singh	Asstt. Chief Technical Officer
2.	Sh. Ravinder Sharma	Technical Officer
3.	Sh. Arjun Kumar Singh	Technical Officer
4.	Sh. Rakesh Srivastva	Sr. Technical Assistant
5.	Sh. Anil Kumar	Sr. Technical Assistant
6.	Sh. AgreNand Singh	Sr. Technical Assistant
7.	Sh. AlekhNarain	Technical Assistant
8.	Sh. Bhuneshwar Prasad	Technical Assistant
9.	Sh. LalBabuDass	Technical Assistant
10.	Sh. SDA Rizvi	Sr. Technician
11.	Sh. Narinder Kumar	Sr. Technician
12.	Sh. Sunil Kumar Singh	Technician
13.	Sh. Pravesh Kumar	Technician

Station wise staff List of Administrative category as on 31.3.2014

CPRI, Shimla

1. Sh. AK Singh, Chief Admn. Officer
2. Sh.PraveenChandla,AD(OL)

Fin.& Accounts Officer(in lieu of SFAO)

3. Sh.Tej Singh Bhati

Admn.Officer

4. Sh. AS Negi

Asstt.Admn.Officer

5. Sh.AD Sharma
6. Sh.HiraNand Sharma
7. Smt. Roseline
8. Sh.Jeet Ram
9. Sh. Joginder Singh Thakur

Asstt.Fin.& Accounts Officer

10. Sh.Chander Prakash
11. Dr.AshishDhangar

Private Secretary

12. Sh. Chet Ram Nahata
13. Sh. HariKrishanVerma
14. Sh. RoshanLalVerma

Personal Asstt.

15. Sh. Gurjeet Singh
16. Sh. Ram Chand
17. Smt. ShashiBala Thakur
18. Sh.Suresh Kumar

Steno.Gr.III

19. Sh.Girish Thakur

Assistant

20. Sh. KC Chopra
21. Sh. Prem Chand Sharma
22. Sh. Dhani Ram
23. Sh. RoshanLal
24. Sh. Amar Singh
25. Sh. Laiq Ram
26. Smt. PoonamSood

27. Sh. Chanda Ram
28. Sh. DD Kashyap
29. Sh. Jai Ram Thakur
30. Smt. MeenaVerma
31. Mrs. BabliBhawani
32. Sh.Narinder Kumar
33. Ms. Prawartika Das
34. Sh.Jagdish Chand
35. Ms. Rita Walia
36. Sh. Amar Chand
37. Mrs. Kanta Rani

UDC

38. Mrs. Urmila Verma
39. Mrs. Sunita Thakur
40. Sh. Om Parkash
41. Mrs. ShyamLataBeakta
42. Sh. Jagdish Chand
43. Sh. Deep Ram
44. Sh.KrishanLal
45. Sh. Pawan Kumar

LDC

46. Sh. Hans Raj
47. Sh. Ashwani Gupta
48. Sh. Tej Singh
49. Mrs.Geeta Devi
50. Mrs. PunamJyoti
51. Sh. Mohinder Singh
52. Sh. SachinKanwar
53. Mrs. Nirmala Chauhan
54. Mrs. Sonia Chauhan
55. Sh. Narender Paul
56. Sh. Gokal Ram
57. Sh. Rakesh Negi
58. Sh. Raghubir Singh
59. Sh. KundanLal
60. Padam Chand

CPRS, Kufri

61. Sh. Devendra Kumar, Asstt.
62. Smt. ChandniBhagta, UDC

CPRIC, Modipuram

Asstt. Admn. Officer

63. Sh. Miraj-Ul-Haq
64. Sh.Baldev Raj

Asstt.

65. Sh. Jagbir Singh
66. Sh. Surender Singh
67. Sh. Mahendra Singh

UDC

68. Sh. Sandeep Verma
69. Sh. Santosh Kumar

LDC

70. Smt. SnehLata
71. Smt. SeemaVerma
72. Sh. Atar Singh,
73. Sh. Ashok Kumar

PA

74. Sh. Rajesh Kumar

CPRS, Jalandhar

Asstt.Admn.Officer

75. Sh. Jeevan Kumar

Asstt.

76. Sh. NK Sharma

77. Sh. Sukhpal Sharma

Steno.

78. Sh. Suresh Kumar Verma

UDC

79. Smt. SandhyaKapila

80. Sh. Rakesh

LDC

81. Smt. BimlaSalhotra

82. Smt. DaisheyTuli

83. Sh. Naresh Kumar

84. Sh. Daljeet Singh

CPRS, Gwalior

Asstt.Admn.Officer

85. Sh. KrishanLal

LDC

86. Sh. Kamal Chand Verma,

87. Sh. Ashish Kalyan

88. Sh. Shri Krishan

89. Sh. Pradhuman Kumar Sarswat

CPRS, Muthorai

Asstt.

90. Smt. IC Dharmapaul

UDC

91. Smt. M. Rani

PA

92. Smt. M. Lathika

CPRS, Patna

Private Secretary

93. Sh. HK Sen

Asstt.

94. Sh.Sandeep

UDC

95. Sh. Ramesh Kumar Gupta

LDC

96. Sh. Shatrughan Prasad

97. Sh. Akhilesh Singh

CPRS, Shillong

Assistant Admn.Officer

98. Sh. SikandraIshwari

Assistant

99. Smt. TeirinaNungkhla

100. Smt. Pomilian W. Syiem

List of Skilled Support Staff, CPRI, SHIMLA and its Regional Stations as on 31.03.2014

CPRI, SHIMLA

Name of the official & place of posting

SS Grade-IV

1. Sh. NarainDass

SS Grade-III

2. Sh. Maharaj Singh

3. Sh. Khem Chand

4. Sh. CharanDass

5. Sh. Roshan La

6. Sh. Kanhiya Prasad

7. Sh. BirBhadur
8. Sh. Piar Chand
9. Sh. Subhash Chand
10. Sh. Mansa Ram
11. Sh. Babu Ram
12. Sh. Ramesh Kumar

SS Grade-II

13. Sh. Rajinder Kumar
14. Sh. Kulwant Singh
15. Sh. Mansa Ram
16. Sh. Sanjeevan Kumar
17. Smt. Kamla Devi
18. Sh. Vinod Gir

SS Grade-I

19. Sh. Ashok Kumar
20. Sh. Narender Kumar
21. Smt. Kajal
22. Sh. Padam Dev
23. Sh. RoshanLal
24. Smt. Manjit
25. Sh. Amar Nath
26. Sh. Hira Singh
27. Sh.ArjunDass

CPRS, Kufri

Name of the official & place of posting

SS Grade-III

1. Sh. Hira Singh
2. Sh. Saran

SS Grade-II

3. Smt. Muni Devi
4. Smt. Indira Devi

SS Grade-I

5. Sh. Madan Lal
6. Sh. Sita Ram
7. Sh. Roop Singh
8. Sh. JiaLal

CPRIC, Modipuram

Name of the official & place of posting

SS Grade-III

1. Sh. Suraj Singh
2. Sh. Mangtey

SS Grade-II

3. Sh. Satyapal Singh
4. Sh. Amiruddin
5. Sh. Jagtey
6. Sh. Som Pal

SS Grade-I

7. Sh. Krishan Pal
8. Sh. Mani Ram
9. Sh. Rajpal
10. Sh. Rajvir Singh
11. Sh.Rajmkumar
12. Sh. Sudesh Pal
13. Sh. TejBir Singh
14. Sh. Gyanendra Kumar
15. Sh. Rishi Pal

CPRS, Patna

Name of the official & place of posting

SS Grade-IV

1. Sh. Kashi Chaudhary

SS Grade-III

2. Sh. SheoNath Singh
3. Sh. TapanBurman

SS Grade-II

4. Sh. Ram BabuRai
5. Smt. Tara Devi
6. Sh. Ram Kisun Ram
7. Sh. TekaRai
8. Sh. Jagat Kumar
9. Sh. Ram BalakRai

SS Grade-I

10. Sh. BishunRai

CPRS, JALANDHAR

Name of the official & place of posting

SS Grade-III

1. Sh. Komal

SS Grade-II

2. Ms. Niranjan Kaur
3. Sh. Gian Singh
4. Sh. Karnail Singh
5. Sh. Raj Kumar
6. Sh. Satnam Singh
7. Mrs. Passo
8. Smt. Rashpal Devi
9. Sh. Ram Lubhaya
10. Sh. Sukhwinder
11. Sh. Ram Prakash
12. Sh. Hans Raj
13. Sh. Subhash
14. Sh. Jagai Ram
15. Sh. Paramjit Singh

SS Grade-I

16. Sh. Manjinder Singh
17. Sh. Ram Sarup
18. Sh. Joginder Pal
19. Sh. Ram Nath
20. Sh. Rattan Chand
21. Sh. Niril
22. Sh. Jagan Nath

CPRS, GWALIOR

Name of the official & place of posting

SS Grade-II

1. Sh. Ram Babu
2. Sh. Mohan Lal
3. Sh. RamjiLal
4. Sh. Ajmer Singh
5. Sh. Ram Singh
6. Sh. Kailash
7. Sh. Shiv Singh
8. Sh. Niranjan Singh
9. Sh. Jagdish
10. Sh. Ram Rattan
11. Sh. Shyam Singh
12. Sh. ParkashTomar
13. Sh. Ranbir Singh
14. Sh. Virendra Singh
15. Sh. Kallu
16. Sh. Ashok Kumar

SS Grade-I

17. Smt. Vimla Devi

18. Sh. Kedar
19. Sh. Jaswant Singh
20. Sh. Sonpal
21. Sh. Parasu Ram
22. Sh. Punjab Singh
23. Sh. Ram Parkash
24. Sh. Bharat Singh
25. Sh. Munnu Singh
26. Sh. Sohan Pal
27. Sh. Ramphal
28. Sh. Mukesh
29. Sh. Murari
30. Sh. Rajpal Singh

CPRS, SHILLONG

Name of the official of posting

SS Grade-IV

1. Sh. Bat Bok Kharir
2. Sh. DhominikMawkhlieng

SS Grade-III

3. Sh. Ashok Kumar Dev
4. Sh. Ram EkbalRai
5. Smt.TheibetThawmuit
6. Mrs. Tellinora
7. Km. Thapa

CPRS, Muthorai

Name of the official & place of posting

SS Grade-I

1. Smt. Rajamma
2. Sh. K. Ramasamy
3. Sh. J. Bhojan
4. Smt. Pankajam

Canteen Staff

Name of the official & Place of posting

1. Sh. NarinderSood, Cook
2. Sh. NandLal, Wash Boy
3. Sh. Anant Ram, Tea Maker

Scientific Strength, Stationwise, Sanctioned / Filled / Vacant Position as on 31.03.2014

Sl. No.	Name of the station	Principal Scientist			Sr. Scientist			Scientist			Total		
		S	F	V	S	F	V	S	F	V	S	F	V
1.	Shimla	5	4	1	10	3	7	29	19	10	44	26*	18
	including AICPIP												
2.	Kufri	-	-	-	1	-	1	2	2	-	3	2	1
3.	Jalandhar	1	1	-	2	-	2	10	7	3	13	8	5
	Modipuram	1	1	-	4	3	1	16	10	6	21	14	7
5.	Gwalior	1	1	-	1	-	1	3	2	1	5	3	2
6.	Patna	1	1	-	1	1	-	9	3	6	11	5	6
7.	Ooty	1	-	1	-	-	-	3	4	(-)1	4	4	-
8.	Shillong	1	1	-	-	-	-	5	3	2	6	4	2
	Total	11	9	2	19	7	12	77	50	27	107	66	41

*Excluding RMP

Administrative Staff in Position as on 31.03.2014

Cadre	Shimla		Jalandhar		Mod.		Gwlr.		Shillong		Kufri		Patna		Ooty		Total	
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Chief Admn. Officer	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
FAO (in lieu of Sr. Fin. & A/Cs Officer)	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Admn. Officer	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Asstt. Admn. Officer	5	5	1	1	2	2	1	1	-	1	-	-	1	-	-	-	10	10
Asstt. Fin. & A/Cs Officer	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Asstt. Director(OL)	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Private Secretary	3	3	-	-	1	-	-	-	-	-	-	-	-	1	-	-	4	4
Personal Assistant	7	4	1	-	-	1	1	-	-	-	-	-	1	-	-	1	10	6
Stenographer Grade-III	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Assistant	20	18	1	2	3	3	1	-	2	2	1	1	1	1	1	1	30	28
UDC	5	08	3	2	3	2	1	-	1	-	1	1	2	1	1	1	17	15
LDC	14	15	2	4	3	4	1	4	1	-	-	-	2	2	1	-	24	29
Total	61	60	8	10	12	12	5	5	4	3	2	2	7	5	3	3	102	100

Technical Staff in Position as on 31.03.2014

Grade	Shimla	Modipuram	Jalandhar	Patna	Gwalior	Shillong	Ooty	Kufri	Total
CTO	1	1	-	-	-	-	-	-	2
ACTO	3	7	1	1	-	-	-	-	12
Sr. TO	8	7	5	-	-	-	-	-	20
TO	11	14	3	2	4	1	2	2	39
Sr. Tech Asstt.	5	-	2	3	1	2	-	-	13
Tech. Asstt.	15	6	3	3	1	2	1	1	32
Sr. Technician	12	-	4	2	3	2	-	3	26
Technician	5	5	1	2	5	-	1	-	19
Total	60	40	19	13	14	7	4	6	163

Sanctioned Strength of Skilled Supporting Staff 31.03.2014

Grade	Sanctioned	Filled	Vacant
SS Grade-I	82*	48	34
S Grade-II	65	48	17
SS Grade-III	39	23	16
SS Grade-IV	18	04	14
Sub Total	204	123	81
Canteen Staff			
Cook	1	1	0
Tea Maker	1	1	0
Wash Boy	1	1	0
Grand Total	207	126	81

Station-wise/Grade-wise list of the Skilled Supporting Staff 31.03.2014

Station	Sanctioned Strength	Grade-IV	Grade-III	Grade-II	Grade-I	Total
Shimla	75	01	11	06	09	27+3* canteen staff
Kufri	12	—	02	02	04	08
Patna	20	01	02	06	01	10
Jalandhar	26	—	01	14	07	22
Modipuram	42	—	02	04	09	15
Shillong	12	02	05	-	-	07
Muthorai	08	-	-	-	04	04
Gwalior	12	-	-	16	14	30
Total	207	04	23	48	48	123+3=125

*3 Posts of Canteen Staff

* 3 posts of Skilled Support Staff redeployed to Ranchi Regional Centre of the ICAR research Complex for Eastern Region vide Council letter No.33-12/2007-Estt.I(Pt.) dated 23rd September, 2010 and reverted back to CPRI, Shimla as and when these posts will be vacated on account of superannuation etc. of the incumbent against these posts.

Staff in position as on 31.03.2014 of CPRI showing number of SCs, STs, OBCs & Women

Category	Sanctioned	Filled	SC	ST	OBC	Women
Scientific	108*	67	08	08	03	12
Technical	178	163	31	7	8	11
Administrative	102	100	26	05	06	27
Skilled Support Staff	207	125	39	06	13	12

*Including RMP