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Preface

It is indeed my pleasure to present the Annual Report 2015-16 of ICAR-Central Potato Research Institute (ICAR-CPRI). This institute was established by the Government of India in the year 1949 to harness the potential of this promising crop for food security. Since its establishment, the institute developed suitable varieties and technologies that virtually transformed the temperate potato crop to sub-tropical one enabling its spread from cooler hill regions to the vast Indo-Gangetic plains as a rabi crop. As a consequence, ICAR-CPRI emerged as a premier research institution in the world for research and development on potato. The institute developed 52high yielding varieties and effective production and protection technologies for different agro-climatic regions of the country. Today, India is the second largest potato producer in the world, only after China. During the year 2014-15, India produced 44.9 million tonnes of potato from 2.10 million ha area with an average productivity of 21.4 t/ha. In order to provide food and nutritional security to the burgeoning population in the country, potato production still needs to grow at a brisk pace which will require continuous development of superior varieties and technologies.

The year 2015-16 brought in several noteworthy achievements in the field of potato research and development. A total of 30 accessions from 7 countries were added to the cultivated germplasm collection. Thus, present potato germplasm collection at this institute consists of more than 4,300 accessions of cultivated and wild species from 30 countries. A new table potato variety, Kufri Mohan suitable for northern and eastern plains of the country, was recommended for release during 33rd AICRP (Potato) group meeting. Besides, seven advanced hybrids namely J/8-85, J/8-91, J/8-119, PS/09-16, PS/09-9 (table purposes); MP/9-28 (chips) and HT/07-1329 (heat stress) were identified for introduction in AICRP (Potato) for multi-location trials. Whole genome sequencing of *Rhizactoniasolani* (Anastomosis Groups (AGs)) strain RS-20 has been completed that will provide a handle for better management of this chronic disease. Several diagnostic tools for potato pathogens viz. RT-PCR protocol for detection of quarantine pathogens, duplex RT-qPCR assay for detection of ToLCNDV-potato along with PVX and PLRV, Loop mediated isothermal amplification (LAMP) assay for detection of ToLCNDV-potato, multiplex RT-PCR protocol for the simultaneous detection of PVV, PMTV, TMV and TRV and quantum dots for detection and localization of PVX & PVY were developed during this year.Indo-Blightcast model was validated across the agro-ecologies through AICRP (Potato) centres and IMD which forecasted late blight appearance accurately. The impact of climate change on potato productivity in West Bengal was assessed using WOFOST crop growth model. The Model predicted that under the combined effect of CO2 and temperature, the highest decline of 6.1% in productivity of Kufri Pukhraj is expected followed by 5.9% in Kufri Jyoti and 5.1% in Kufri Badshah in 2020, with corresponding figures of 12.0, 10.5 and 8.8% in 2055. It requires development of appropriate adaptation strategies to offset the impact of climate change.

Production of Breeder seed of potato is a major mandate of this institute. A total of 2416.16 tonnes of breeder seed was supplied to various Government and private agencies. Moreover; 3,45,937 minitubers were produced, out of which 37,399 minitubers have been produced from microplants, 1,297 from microtubers and 3,07,241 from aeroponics, respectively.The methodologies for the estimation of phytic acid and ascorbic acid were developed and based on that, the best variety (KufriChipsona4) was selected as the candidate for fortification of chips with iron and zinc. Two patents viz., "Dehydration of potatoes" and "Development of dipsticks for glucose estimation in potatoes" were filed during the year. Salicylaldehyde proved to be an efficient natural sprout inhibitor of potatoes up to 7 months of storage. It is absolutely necessary to transfer innovative technologies developed by the institute to farmers and other end users in order to achieve higher production and productivity. To achieve this, the institute organized a Model Training Course on processing aspects and several training programmes for farmers and extension functionaries from different states of India.A large number of demonstrations were also laid out to create awareness about new potato varieties and technologies amongst the farmers.

I would like to take this opportunity to congratulate the entire team of scientists and other staff of the institute for carrying out all the research and development activities as per plan and bringing out the results in a very comprehensive manner as reflected in this report. I also thank Chairman and all the members of RAC who helped in giving direction to the R&D activities of the institute. Thanks are also due to the members of editorial committee for making this report crisp, comprehensive and highly informative. I am extremely grateful to Dr. Trilochan Mahapatra, Secretary, DARE and Director General, ICAR, Dr. S. Ayyappan, Former Secretary, DARE and Former Director General, ICAR for their constant support and guidance. I would also place on record my thanks to Dr. N. K. Krishna Kumar, DDG (Horticultural Science), Dr. T. Janakiram, ADG (HS I), Dr. B.K. Pandey, PS (HS), Dr. Manish Das, PS (HS), and Dr. Vikramaditya Pandey, PS (HS) for their suggestions and encouragement.

(SK Chakrabarti)
Director

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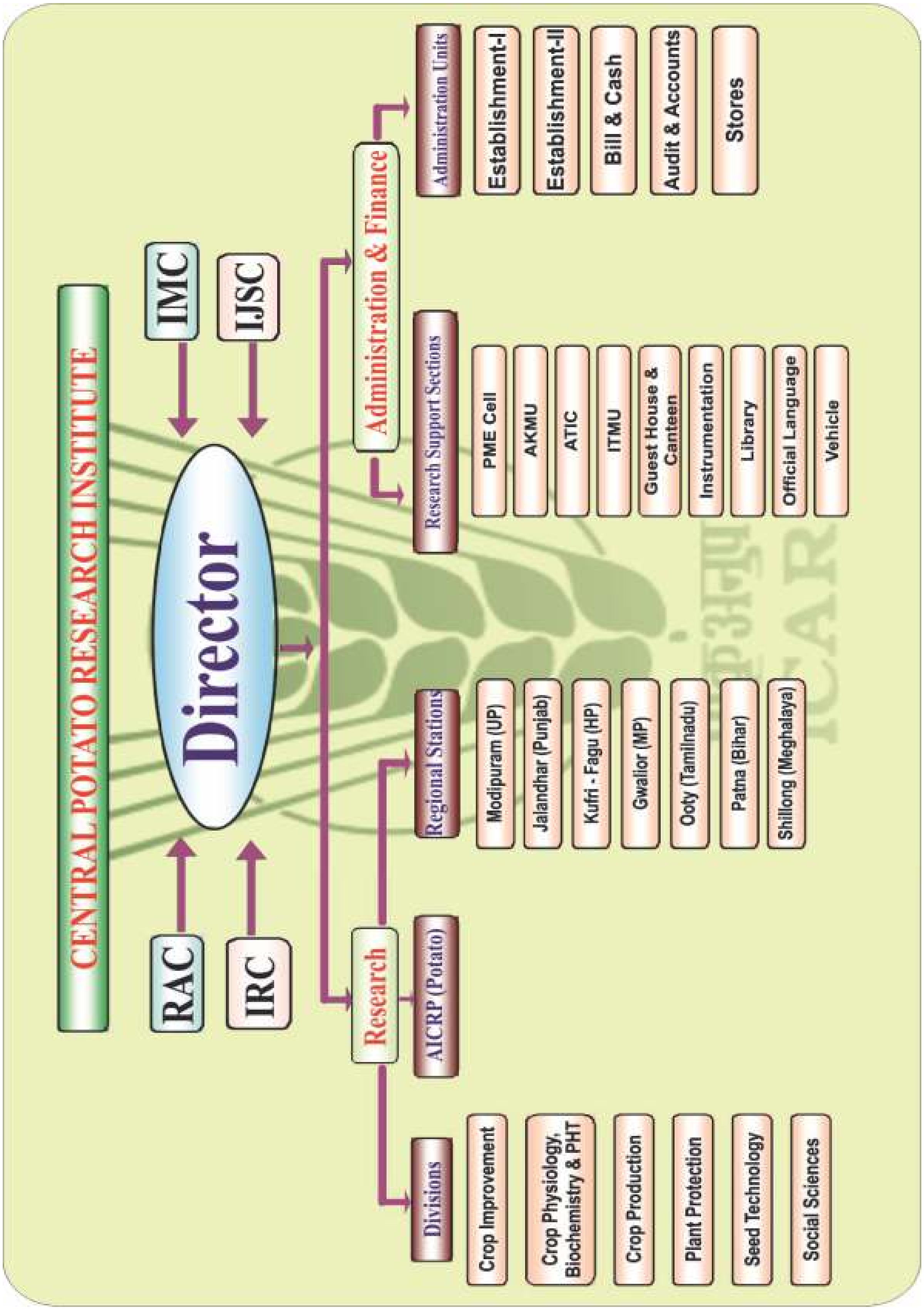
ICAR-CPRI: An Introduction

The ICAR-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 (Meghlaya) 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 co-ordinated research project on potato (AICRP-Potato) is also located in the institute and has



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

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 not only develops new varieties and technologies for potato growers of the country but also takes care of dissemination of these technologies to the ultimate consumers through various trainings, demonstrations, farmers fair, exhibitions etc. Currently the institute has a dedicated team of 74 scientists, 141 technical staffs and 78 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 ICAR-Central Potato Research Institute is a nonprofit scientific institution under the Indian Council of Agricultural Research, working exclusively on potato. The institute has played a key role in popularizing potato cultivation and utilization under sub-tropical 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 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 under 10 well defined research programmes and one service project on potato seed production. In addition to regular research programme, a total of 19 externally funded research projects sponsored by different agencies viz. ICAR, ABSP-II (USAID), PPV & FRA, DBT, CIP, IASRI and UPCAR 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 594 sanctioned staff strength comprising of 107 scientific, 178 technical,102 administrative and 207 supporting staff excluding RMP. The staff position as on 31.03.2016 was 418 including 74 scientific, 141 technical, 78 administrative and 125 supporting staff. The expenditure of the institute for the year (Plan & Non Plan) was Rs54.61 crores and receipts Rs. 7.01 crores. The ICAR-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. During the year, 14 scientists joined the institute, 2 retired, 10 were transferred from the institute and 10 were promoted under CAS. In technical category, 29 technical staff were promoted, 13 retired and 1was transferred. In administrative category, 15 persons were promoted, 7 retired and 4 were transferred within institute. In skilled supporting staff, 5 were promoted under MACP and 3 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 ICAR-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 ICAR-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.

Executive Summary

Division of 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, 30 accessions were added to cultivated germplasm collection from 7 different countries. Present potato germplasm collection at ICAR-CPRI consists of more than 4,300 accessions of cultivated and wild species from 30 countries. Cryopreservation of potato germplasm was standardized for conserving germplasm in form of pollen and shoot tips. The droplet vitrification method for the cryopreservation of the potato shoot tips resulted in 50-60% survival and regeneration up to 20-30%. Potato germplasm was evaluated for various traits viz., foliage late blight resistance under field (232 accessions), foliage and tuber late blight resistance under lab conditions (130 accessions), vitamin C (73 accessions), Water use efficiency (23 accessions), PCN (62 accessions), viruses (155 accessions), adaptability in plains (391 accessions), keeping quality & processing traits (75 accessions), micro nutrients (Zinc & Iron) (46 accessions) and foliage maturity (311 accessions).

The second programme is 'Breeding to evolve trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses' which aims at developing improved varieties for table and processing purposes having resistance to important diseases and pests. A new table potato variety, Kufri Mohan was recommended for release during the 33rd AICRP (Potato) group meeting held during September 19-21, 2015 at GBPUAT, Pantnagar, Uttrakhand which is suitable for northern and eastern plains of the country. Based on consistently good performance over the years, seven advanced hybrids namely J/8-85, J/8-91, J/8-119, PS/09-16, PS/09-9 (table purposes); MP/9-28 (chips) and HT/07-1329 (heat stress) were identified for introduction in AICRP for multi-location trials. Late blight and virus resistant genotypes viz., Toluca (*blb2*) and Sarpo Mira *(R3a, R3b, R4, Ny-Smira, Rpi-Smira1 and Rpi-Smira2)* were validated for the presence of respective genes for introgression of *S. bulbocastanum* and *Sarpo Mira* derived resistance genes into breeding programme using MAS. Besides, validation of PLRV resistance genes, *Rladg* and *Plrv.4* was also done using markers.

The third programme on "Genetic Enhancement of Potato through Molecular and Genomic Tools" aims at use of molecular and genomics tools in potato improvement. During the year, whole genome sequencing of *Rhizactoniasolani* (Anastomosis Groups (AGs)) strain RS-20 was completed. Mitochondrial genome of *Phytophthorainfestans* (A2 mating type) was sequenced and mapped. The *RxLR* effector genes were predicted in the *P. infestans* (causes potato late blight) genome (isolate HP10-31, A_2 mating type, 162 Mb) using homology search method and identified of flanking genome sequence in RB Transgenic event KJ77 and SP951 by affinity-based genome walking method. To discover the new resistance genes, total RNA sequencing of wild species *Solanum demissum* was performed on the Ion Proton platform. Genetic transformation of potato cultivar with *Proline rich protein, Steroid binding protein, SGT* and gene of unknown function for late blight resistance was performed. Moreover, transcriptome analysis in response to drought stress in potato showed differential expression of ~120 genes >10 fold. In silico analysis of potato SWEET gene family of sugar transporters for enhancing the productivity, phenotyping for heat stress tolerance of potato, expression analysis of Constans (CO)/SP6A genes involved in potato tuberization, allele mining for late blight resistance genes of potato wild species were also investigated. Somatic hybrids between *Solanum tuberosum* C-13 and *Solanum cardiouphyllum* were analyzed for hybridity confirmation by molecular markers (RAPD, ISSR, SSR and AFLP). To unravel the sequence variations among the genes involved in nitrogen metabolism pathways for improved nitrogen use efficiency (NUE), genes were studied for the various pathways such as N uptake/ transporters, utilization and assimilation.

Division of Crop Production

WOFOST crop growth model predicted that under the combined effect of CO_2 and temperature in West Bengal, the highest decline of 6.1% in productivity of Kufri Pukhraj is expected followed by 5.9% in Kufri Jyoti and 5.1% Kufri Badshah in 2020, with corresponding figures of 12.0, 10.5 and 8.8% in 2055. From the simulation studies, it appears that Kufri Badshah has greater resilience against climate change and could be more suitable cultivar in the future climates than Kufri Jyoti and Kufri Pukhraj at all the locations. The negative effect of climate change on potato productivity can be counter balanced to some extent through change in date of planting and/or selection of suitable varieties. WOFOST model has also been calibrated and validated for heat tolerant variety Kufri Surya and medium maturing variety Kufri Sadabahar in Uttar Pradesh using time course data on potato crop growth parameters generated at CPRIC Modipuram and CPRS, Jalandhar during 2011-12 to 2014-15. A close match between simulated and field data for total dry matter production and tuber dry matter yield was obtained.

QUEFTS model was calibrated for SSNM (site-specific nutrient management) of NPK in potato crop in Uttar Pradesh. For calibration of QUEFTS model, extensive review of literature was carried out and the data were collected and compiled on initial nutrient status, nutrient applied, uptake and yield under different experiments carried out at different locations in Uttar Pradesh during last 15 years.

In order to generate precise fertiliser recommendations very specific to site while maintaining the productivity of soil ,experiments were conducted on hilly soils and at CPRIC, Modipuram using omission plot technique. In hilly soils of Shimla (Himachal Pradesh) only nitrogen was found to be the only yield limiting nutrient in the absence of FYM application. In plains followed by nitrogen and by sulphur, K (6.85 t/ha) and P were found to be the yield limiting nutrients thus highlighting the importance of soil test based nutrient application. Nitrogen application based on real time N monitoring showed the possibility to decrease the amount of N to be top dressed by at least 10% by increasing the number of splits of N based on SPAD value without compromising on yield and neem cake coating of urea at 5% (100%NPK) produced highest total tuber yield thereby improving the nitrogen use efficiency.

To develop variety specific water and nutrient management schedule under limited water availability field experiment was conducted at CPRI Campus, Modipuram, Meerut (UP) during *rabi season* of 2015-16. The potato yields were in the order of Kufri Garima = Kufri Khyati> Kufri Sadabahar>Kufri Pukhraj>Kufri Bahar. The productivity of all potato varieties were maximum at higher moisture regime when irrigations given at IW:CPE ratio of 2.5 and was lower with irrigations applied at critical stages of crop growth (PE, SF, TIS, ETES & LTES). The productivity of all varieties was maximum at N applied at the rate of 210 kg /ha and was found statistically at par with the 180 kg N/ha.

Effect of climate change on survival of *R. solanacearum* in soil as free living cells in potato growing districts of plateau region was studied on 60 potato growing districts of eight states in the country. A logical mathematical model based on daily mean soil temperature was developed. In Tamil Nadu and Kerala the bacterium is likely to disappear 0-05 days earlier in 2020 and 05 to 15 days in 2055. In Karnataka the bacterium is likely to disappear 0-08 day earlier in 2020 and 11-15 days in 2055. In Andhra Pradesh and Maharashtra, 3-8 and 11-20 days in Odisha and 3-5 and 11-15 days in Jharkhand in 2020 and 2055, respectively. The bacterium is likely to disappear 3-8 days earlier in 2020 and 5-15 days in 2055 in Madhya Pradesh and 3-5 days earlier in 2020 and 11-26 days in 2055 in Gujarat. In Rajsthan, The period is likely to reduce by 0-5 days in 2020 and 5-15 days in 2055.

Potato is grown in many parts of North-central and North-western parts of India as early cash crop to fetch high remunerative price in the market. However, Early crop is affected by various insects-pests; the most important among these are thrips (*ThripspalmiKerny*) and whitefly (*Bemisiatabaci* G). Keeping the importance of thrips as a vector for transmission of stem necrosis disease in early planted potato crop in Central India, field experiment was carried on six planting dates under protected and unprotected conditions with the objective to collect the information on incidence of thrips and stem necrosis in relation to weather parameters during 2015. The data revealed that highest thrips population (36.1/ 5 plants) was recorded in the 10th November, resulting in incidence of stem necrosis disease (17.4%) in 25th September planted crop, however climatic conditions were more favorable for transmission of disease when crop was planted on 15th September (23.33%) and 20th September (24.25%) under unprotected condition having more virulent population of thrips. The data revealed that weather parameters (temperature, humidity, rainfall) plays an role in buildup of thrips, whitefly population on potato crop for table purpose will required better management practice right from planting in this region to reduce the incidence of vectors on crop.

Concentrations of Fe and Zn were analysed in 46 potato varieties grown under uniform management practices and non-nutrient limited conditions at CPRIC Modipuram. The iron content in tuber flesh on dry weight basis ranged between 17.75 to 40.74 mg/kg while zinc content ranged from 9.54 to 21.00 mg/kg . The association between two elements was significant ($r=0.33$, $p<0.05$) suggesting feasibility of simultaneous improvement of both traits. For taking round the year minituber production of important varieties under long day and short day conditions under aeroponics varietal behaviour at different dates of plantings was studied. Mid- March planting resulted in negligible tuberization in Kufri Jyoti, Kufri Chipsona-3 and Kufri Girdhari. Average number of minituber production in Kufri Chipsona-4 was significantly higher in all planting dates as compared to remaining test varieties. Based on results, Kufri Chipsona-4 may be considered as a day neutral and photo-insensitive variety for hill aeroponics. Use of *Kanamycin* (25 to 75 mg/l) in micro propagation medium of potato was found beneficial to minimize microbial contaminants as well as for improving the micro-plantlet vigour.

Production behaviour of small size aeroponic tubers was studied under protected conditions and small size tubers (<1g, 1-2g and 2-3g) were planted under poly-house during *Kharif* season at Fagu. Proportion of large size (>20g) tubers ranged from 42.9 to 51.1% and the highest proportion of large size tubers was produced with 2-3g seed tubers. Recycling of small sized aeroponic tubers under aphid proof protected conditions can be practiced successfully to improve the size of progeny tubers for making them worth multiplying in field. Aeroponically produced mini tubers of nine potato cultivars were also evaluated in net house at Modipuram. Emergence of mini tuber was very good for all cultivars (> 94%), except for Kufri Surya (80%) and Kufri Badshah (90%). Over all field performance of aeroponically produced mini tuber was very good.

For augmenting production of mini-tubers in aeroponics, and breeder seed in plains a new design of commercial scale aeroponic system to augment minituber production was fabricated at Modipuram. System consists of new design of grow boxes made of bricks and concrete instead of styrofoam sheets to provide more stability, durability and comparatively easier maintenance and a mechanical system for lifting the plants for tuber picking has been made to avoid injury to plants during picking and it also makes pickings more convenient. System for preventing lodging of plants has also been taken care off. The unit is equipped with automatic dosing pump to maintain pH of solution.

In order to understand the performance of cv. Kufri Jyoti for time of planting in Punjab conditions, *in vitro* plants hardened in liquid media produced highest tuber weight per plant in crop transplanted in third week of November. At commercial scale in Punjab Kufri Chipsona-3 followed by Kufri Chipsona-1, Kufri Badshah and Kufri Pukhraj produced highest mean minituber tuber number per plant.

Possibility of growing two potato crop in Aeroponics was explored. since at present available time for cultivation under aeroponics in N-W India is only about 6 months and it is not possible to take 2 potato crops in traditional way. Optimization of hardening along with modified transplanting methodology indicated the possibility for taking 2 crops in a season for Kufri Khyati, Kufri Surya and Kufri Himalini.

Currently, one potato crop is taken under net house in a year. Planting of two potato crops in a crop season in plains of N-W India under net house conditions can favourably boost the seed production potential from available net area. In an experiment on six cultivars and with dual dates of planting at CPRS Jalandhar for multiplying early generation potato seed fast it was observed that shift from single planting to dual planting resulted in increase of 1.71 times production cost, and 3.01 times tuber production and profit, with overall decrease in cost of production from Rs. 3.29 to Rs. 1.88 per tuber.

Recent potato varieties Kufri Shailja required 150 kg N/ha for optimum yield, whereas Kufri Jyoti and Kufri Himalini required 187.5 kg N/ha and Kufri Himsona produced optimum yield with 112.5 kg N/ha. *Metribuzin* brought out significantly the highest improvement in potato productivity when applied after 14 days of crop emergence under rainfed conditions in Shillong.

Two systems of groundnut – potato – maize + moong - bean and cowpea-potato-okra + French bean observations were recorded on pest population and their management with eco-friendly methods at Modipuram. Sprays (0.5% summer oil) were given at interval of 8-10 days to control leafhopper as soon as the adults (1-2/plant) were recorded on lady's finger plant resulted in good control of leafhopper. Dried neem leaves resulted in the least number (6-8/plant) of leaf hoppers/plant in combination with foliar sprays of summer oil @ 0.5%.

For ware crop, Kufri Khyati, Kufri Mohan, Kufri Sadabahar, Kufri Pushkar, MS/0-3808 and MS-0/3740 were found better genotypes under organic farming as they had better marketable tuber yield and yield maintenance over popular varieties Kufri Bahar and Kufri Pukhraj. In chipping varieties, Kufri Himsona, Kufri Chipsona-1 and Kufri Chipsona-3 are good genotypes. French fry hybrid MP-04/578 also attained fair productivity.

In second years study, organic system (CRR) achieved 75.4% of marketable and 77.5% of total tuber yield of inorganic source in Kufri Garima. Organic system (IA) could maintain 68.6% of marketable and 72.3% of total tuber yield in comparison to first year crop, where this treatment had 62.4% of marketable and 64.9% of total tuber productivity of inorganic nutrition. Dry matter content was marginally higher in inorganic treatments as compared to organic one. Mean reducing sugars in cv. Kufri Chipsona-3 were lower in inorganic treatments over organic source. Potato fertilized with 75% inorganic+25% organic sources retained minimum of reducing sugars (53.8 mg/100g FW).

In long term plant nutrition studies in potato based cropping systems average system productivity (SP) was highest in Maize-Potato-Onion cropping systems (47.6 t/ha) followed by Groundnut- Potato-Green gram (40.0 t/ha). Lowest SP was recorded in Rice-Potato-Wheat (38.9t/ha). Integrated application of organic amendments (vermi-compost, crop residue etc.) along with chemical fertilizer could be the best management practices for enhancing C sequestration in soil and sustainable crop production. In Potato-Wheat-Paddy sequence, it was recorded that incidence of *bakane disease* of rice was more in inorganic treatments than the organic one. Incidence of sheath blight disease of rice was more in treatment consisted organic sources than the inorganic sources, however treatment consisting of 100% organic or part of organic manure recorded low incidence of whitefly and corresponding development of disease as compared to 100% inorganic nutrition along with control treatments, respectively.

Studies on identification of suitable potato hybrid (combined resistance to late blight and viruses) for *kharif* crop in plateau region revealed that SM/92-338 (21.2 t/ha) performed best among all hybrids/ varieties evaluated at Hassan and recorded 13.4 % more tuber yield over second best hybrid LBY-15 (18.57 t/ha).Among the hybrids/ varieties evaluated, hybrid LBY-15 showed notable resistance against late blight and it had recorded 6.25 % disease spread at 75 days after planting followed by SM/92-338 (8.5 %). Among the hybrids/varieties evaluated at Hassan, AICRP-P-16 recorded higher yield of 12.91 t/ha which was at par with AICRP-P-17 (12.59 t/ha). Lowest late blight intensity of 1.47 % was observed in AICRP-P-18 followed by AICRP-P-17 (2 %) and AICRP-P-18 (2.12%).

Ten front line demonstrations were conducted during *kharif* season of 2015-16 at Hassan (Karnataka) to evaluate the performance of potato varieties. Recommended package of practices of the region were followed for crop cultivation. Cultivar Kufri Jyoti, Kufri Surya and Kufri Himalini were planted on ridges (60 x 20 cm) during first week of June, 2015 and crop was harvested at full maturity in second week of September, 2015. Observations viz. marketable and non-marketable tuber number and yield were recorded at each location from six different places selected randomly from the planted crop area for the varieties. Variety Kufri Himalini performed better than other two varieties namely Kufri Surya and Kufri Jyoti. In all the locations, Kufri Himalini recorded maximum yield and it gave highest yield of 28.6 t/ha in Annenahalli (Chandrayapatna). Average yield of Kufri Himalini (21.6 t/ha) was 42% higher than Kufri Jyoti (15.2 t/ha) and 55% higher than Kufri Surya (14.0 t/ha). Similar trend was also noticed in case of marketable tuber yield and numbers. In four locations, Kufri Surya performed better than Kufri Jyoti.

Mechanical damage is a major concern for potato industry. For improved mechanical technologies for potato cultivation studies were conducted at CPRS Jalandhar. A tractor operated two row potato elevator digger was tested for assessment of damage index on harvested potato. Total damage percentage of tubers at tractor's forward speed of operation of was least (6.75 %) at 3.2 km/hr. A grader has been designed to grade the potatoes in four size grades e.g. < 20 mm, 20-32 mm, 32 -52 mm and > 52mm. Two-row tractor operated trailed type potato combine harvester with provision to split ridge, lift loose material, separate soil & clods and collection of tubers in to bags simultaneously, was improved and field tested.

To develop advanced soilless production system for increasing potato mini-tuber production and reducing input cost a new design of commercial scale aeroponic system was developed and tested at Jalandhar. Plant lodging prevention system enhanced production by 25-30% and lifting mechanism reduces manpower requirement by 25-30%. In styrofoam grow boxes, average temperature on twenty four hour basis was 7°C less in chilled grow box as compared to normal one. Average temperature was 10°C less in solution tank with chiller as compared to normal tank. In concrete grow box type system, average temperature of grow box and solution tank had difference of 1.7°C on twenty four hour basis.

Aeroponic system developed for conducting experiments on potato had problem of unusual temperature rise inside the grow box during last two season. Modified unit showed least temperature rise. There was normal plant and root growth in modified unit III while in unmodified unit there was crop failure due to high temperature inside the grow box.

Division of Plant Protection

Late blight severity in central Uttar Pradesh was significant this year. No change in mating types, metalaxyl tolerance and mitochondrial haplotyping was observed in *Phytophthorainfestans*, however, the tested isolates of *P. infestans* were observed sensitive to new molecules (cymoxanil, dimethomorph and fenamidone). *P. infestans* population in the country is polyploid consisting of diploids, triploids and tetraploids. However, frequency of different polyploids varied from region to region. Preliminary results of comparative genome analysis of *P. infestans* revealed existence of variation between Indian and European isolate. Potato virus Y (PVY) strains like PVY^{N}, PVY^{O+C} were common in most of the areas. Targeted PVY^{N} strain of PVY for whole genome sequencing and could sequence four fragments out of five for comparative analysis with PVY^{O} strain. Developed RT-PCR protocol for detection of quarantine pathogens, duplex RT-q PCR assay for detection of ToLCNDV-potato along with PVX and PLRV, Loop mediated isothermal amplification (LAMP) assay for detection of ToLCNDV-potato, multiplex RT-PCR protocol for the simultaneous detection of PVV, PMTV, TMV and TRV, and quantum dots for detection and localization of PVX & PVY. The polyclonal antibody (Pab) developed against ToLCNDV-potato by bacterially expressed coat protein of ToLCNDV-potato and was validated. Studies on epidemiology of polyploids of *P. infestans* revealed that diploids are more aggressive than other polyploids. The host plants like *Abutilon*, *Bitter gourd*, *Kundru (Cocciniagrandis),* Brinjal, Golden duranta, *Acalyphasp*., Dahlia, *Commelinabenghalensis*, *Solanum nigrum* and Chilli are the reservoir of ToLCNDV-potato virus during off season and play an important role in the epidemiology of the virus. Validated Indo-Blightcast across the agro-ecologies through AICRP (P) centres and IMD which forecasted late blight appearance accurately. Results of microarray analysis performed to identify differentially regulated genes during ToLCNDV-potato infection in a resistant (Kufri Bahar) and a susceptible (Kufri Pukhraj) cultivar revealed that responses of two cultivars were quite different and transcripts involved in stress responses, signal transduction pathways, protein binding, defence related proteins/R genes and other biological and metabolic processes were altered. Symptom expression studies using infectious clones of ToLCNDV-potato indicated that though DNA A can maintain itself and cause infection but severe symptoms are produced only when both DNA components (DNA A& DNA B) are present. Results of flanking sequence analysis of ToLCNDV transgenic events revealed that no conserved domain has been detected from the potato genome indicating that inserted site has no implications on functional protein of the potato genome. Rhamnolipid based formulation with botanical was effective against late blight under field conditions. Prophylactic spray with mancozeb (0.2%) followed by azoxystrobin+ tebuconazol (0.1%) at onset of the disease and one more spray with azoxystrobin+tebuconazol after 7 days recorded lowest disease severity of late blight. Application of phosphorous acid (2%) was also found effective against late blight. Besides, dsRNA based fungicide has been developed for management of late blight. About seven endophytes, isolated from various parts of potato, have shown promising results against *P. infestans, Ralstonia solanacearum and Streptomyces scabies under in-vitro* studies.

Regular monitoring for population dynamics of aphids, whiteflies, leafhoppers and other pests in seed and ware potato were done during crop season at Shimla, Jalandhar, Modipuram, Gwalior and Patna. Aphids and whiteflies first appeared during fourth week of June and their population was very low during crop season and could not reach critical limit at Shimla. At Jalandhar, *Myzus persicae first* appeared during first week of November on ware potato and crossed critical limit in first week of December and reached its peak in last week of December. *M. persicae* crossed the critical level after first week of December in unsprayed potato crop at Modipuram. Gwalior witnessed a very low vector pressure during the year under report. At Patna, aphids first appeared during first week of December and crossed critical limit during third week of December. Monitoring the incidence of potato tuber moth (PTM) and South American tomato pinworm, *Tuta absoluta* on potato using pheromone traps at five locations in India revealed PTM occurrence was very high at Pune, slight incidence at Gwalior and no incidence at Raipur and Bhubaneswar. *T. absoluta* was not observed on potato at any of the locations. Aphids sampled from potato growing areas of Hisar, Deesa, Modipuram, Patna, Jalandhar, Pune, Aligarh, Chhindwara and Gwalior during October to January were identified as *M. persicae, A. gossypii, Aulacorthum solanii, Rhopalosiphum rufiabdominalis and Rhopalosiphum padi. R. padi was* recorded on potato crop at Hisar which was not reported earlier. Leafhoppers from Jalandhar were identified as *Amrasca biguttula biguttula* and at Pune as *Amrasca biguttula biguttula* and *Empoasca* sp. *M. persicae* from Jalandhar, Hisar and Shimla were carrying the PVY while Patna and Gwalior were free from PVY. These aphid samples were processed for PLRV and were found negative. Developed and validated squash and tissue print PCR protocol for simultaneous detection of ToLCNDV-potato along with internal control in individual whitefly vector in a single reaction. Among eleven wild potato germplasm evaluated for their resistance to green peach aphid, *M. persicae* under glasshouse conditions, two germplasms (TRF 37 and VER 59) showed significantly lower survival and multiplication of aphid. Kaolin @1.0 and 1.5 per cent was found to significantly reduce (35 per cent) aphid population and mineral oils @3% was found effective in reducing sucking pests including aphids and whiteflies in potato at Jalandhar. Flonicamid @4gm/10 litres was found highly effective in reducing aphids followed by whiteflies in large scale field trial conducted at CPRIC, Modipuram. Residue analysis of commonly used insecticides in potato revealed that all the insecticides like thimet (10G@10kg/ha), oxydemeton methyl (0.2%), imidacloprid (0.04 %), flonicamid (0.02%, 0.03%, 0.04%) were below detectable levels (BDL) indicating that they are safe and leave no residues except spiromesifen (@0.04%) which had 0.033 ppm residues. Planting of Kufri Jyoti as trap crop for two seasons (summer & autumn) resulted in maximum reduction in cyst populations of PCN. Management module followed for eradication of PCN in Nilgiris has shown that trap crop + solarisation + furadon @ 2 kg a.i./ha + neem cake @ 5t/ha (organic amendment) could suppress 47.02% PCN population. Dazomet @ 50 g/m^2 reduced 12.87% of PCN population. Cauliflower as cruciferous biofumigant was effective in reducing PCN population when planted with susceptible variety Kufri Jyoti.

Division of Seed Technology

During 2014-15, a total production of 3080.17 tons nucleus and breeder seed was achieved through both conventional and hi-tech seed production system from an area of 147.08 ha in plains. This includes 2131.65 tons nucleus and breeder seed produced through conventional system from 104.35 ha whereas, 948.52 tons from 42.73 ha through hi-tech system. The percentage of breeder seed from conventional system was 69.21% while, 30.79% through hi-tech system. Total 2416.16 tons of breeder seed was supplied to various Government and private agencies from plains. A total of 3,45,937 minitubers were produced, out of which 37399 minitubers have been produced from microplants, 1297 from microtubers and 3,07,241 from aeroponic respectively. During 2015-16, a total production of 78.34 tons of nucleus and breeder seed was achieved in both conventional and hi-tech seed production system from an area of 5.39 ha in hills. Presently, 86.24% nucleus and breeder seed has been produced through conventional system whereas, 13.76% through hi-tech system in hills. Total 53.90 tons breeder seed was supplied to different Government and private agencies. A total 138 virus-free in vitro culture tubes of basic seed material comprising 17 different varieties viz., Kufri Jyoti, Kufri Bahar, Kufri Khyati, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Pukhraj, Kufri Frysona, Kufri Chandramukhi, Kufri Lauvkar, Kufri Surya, Kufri Badshah, Kufri Girdhari, Kufri Himalini, Kufri Gaurav, Kufri Garima and Kufri Mohan were supplied to 21 different seed producing organizations in India.

Division of Crop Physiology, Biochemistry and Post-Harvest Technology

The assessment of physiological and pathological losses is being done in potatoes stored under different storage systems (2-4°C, 10-12°C and non-refrigerated storage). The interview schedule was developed and a survey of 60 farmers was completed in Punjab during the year. Large scale studies were conducted in walk-in-chambers (25q of potatoes) to evaluate potential naturally occurring volatile compounds for sprout suppression in potatoes as a replacement for chemical suppressants. Tuber treatment with salicyladehyde effectively controlled sprouting at 12°C up to 7 months of storage without any adverse effect on processing quality, taste and flavour of tubers. A study was initiated to identify the proteins and key genes responsible for the delayed dormancy/sprouting during storage in potatoes and it showed differential expression of the proteins in varieties having distinct differences in their dormancy. Glycaemic index was estimated through estimation of resistant starch (RS), amylose, reducing sugars, sucrose and glucose. The results showed that boiled and freeezed potatoes as well as roasted potatoes are healthier as they contain high content of RS along with low free glucose levels. Potatoes are known to contain high lysine content and their protein content is considered of high biological value due to high lysine content. Lysine content in potato protein ranged from 1.7% (K. Chipsona-3) to 15.1% (K. Shailja). In the past, work on resistant starch has been done in our laboratory. But resistant starch is not the only prebiotic in potato, inulin is also present in low concentration. Inulin content varied from 0.13% (KufriFrysona) to 1.14% (Kufri Gaurav) in oven dried samples of Indian potatoes. Colour of potato flesh is very important quality attributes for processors and consumers. To eliminate the errors of subjective judgment, colour evaluation of potato flesh was done using RGB (Red Green Blue) colour cube for all the potato varieties. A non-destructive and rapid method (application) for determination of dry matter (DM) and moisture content (MC) in potatoes was standardized using near infrared spectrophotometer (NIRSp) system, which showed per cent error in MC and DM prediction to vary from 0.86 to 3.20% and 2.70 to 9.43%, respectively. *In-vitro* Protein Digestibility of all potato cultivars was evaluated and almost 20 cultivars were having IVPD more than 90% which mainly consisted of table cultivars. In breeding for nutritional improvement of potatoes, 15 crosses were attempted involving 10 parental lines with high resistant starch, good potato flavor and high antioxidants. The evaluation of hybrids for the desired traits is continued. Final patent application for "Dehydration of potatoes" was submitted to IPO in April 2015. Another patent on "Dipsticks for glucose estimation in potato tubers and the method thereof" was also filed. An MoU for the technology entitled "Dehydration of potatoes" was signed during the year for commercialization on non-exclusive basis. MoU for another technology entitled "Processing of potatoes into chips, French fries and other products" has also been signed with an agency. For nutritional enhancement, fortification of products with desired nutrients in permissible quantities was done. New methodologies were developed for screening of varieties for phytate and ascorbate concentration through ELISA plate reader and based on the low phytate to ascorbate ratio, variety Kufri Chipsona-4 (0.431) was preferred for fortification. Potato chips were fortified with three GRAS fortificants for zinc fortification using vacuum impregnation and one salt was selected for further studies due to its low cost and highest level of incorporation compared to other two salts. Similarly, Iron fortified potato chips were prepared using six GRAS fortificants through vacuum impregnation. Iron concentration in control and fortified chips with 0.05, 0.15, 0.25, 0.35, 0.50, 0.65 and 0.75% concentration was 4.9, 12.02, 29.40, 39.90, 44.80, 58.5, 68.30 and 73.60 mg/ 100g, respectively (confirmed through Atomic Absorption Spectroscopy).Flavouring compounds viz. AMP and GMP were estimated from zinc and iron fortified potato chips prepared through vacuum impregnation. Flavouring compounds ranged from 3.65µg/g FW to 7.34µg/g FW and were the highest in chips with 0.25% concentration of zinc salt, whereas, they were the maximum in potato chips prepared with 0.35% concentration of iron salt. A method for synthesis of potato starch nanocrystals was optimized by using the 'Top Down' approach of nanotechnology. These starch nanocrystals of potato starch are eco-friendly (biodegradable) in nature which are easy to prepare and cost effective also as compared with other nanoparticles.

Division of Social Sciences

During this year, a survey was conducted in Madhya Pradesh and Gujarat to find the seed potato utilization pattern and constraints faced by potato growers. Variety wise potato area was assessed. In Madhya Pradesh, processing varieties Kufri Chipsina-3 (26.5% area) and Kufri Chipsona-1 (24.3% area) were the leading potato variety while in Gujarat, Kufri Pukhraj (42.4% area) was the leading potato variety closely followed by Kufri Badshah (37.1% area). Getting quality seed of Kufri Chipsona-1 was difficult in MP while in case of Gujarat; Kufri Lauvkar seed was not easily available to the farmers. Nearly 48.2 percent of farmers in Madhya Pradesh and

32.5 per cent in Gujarat reported that "non availability of quality seed" was the number one constraint for them.

Another survey of 210 potato growers was carried out in Assam and Meghalaya states of North East India. In Meghalaya, the average size of total land holding was about 2.5 acres. Out of total cultivated land, nearly 49 % acreage was occupied by the potato in the region. Incidence of late blight and white grubs was major limiting factor of potato cultivation in Meghalaya. No assured irrigation facility was available in this region. Most of the farmers used their own planting material of potato. There was no cold storage facility in this region and farmers store their potato in their local wooden storage. Kufri Jyoti, Kufri Megha and Kufri Giriraj were major varieties grown in Meghalaya. In case of Assam, out of cultivated land, 38 per cent area was under potato cultivation. The major disease of potato i.e late blight was locally known as blood bimar rog in Assam, caused severe losses in potato productivity. The lack of suitable variety, quality potato seed and cold storage facility were major constraints of potato cultivation in Assam. Cost of planting material was almost four-five times higher than sale price of potato.

Overall, 30 demonstrations were laid out in different locations of HP namely Shimla, Mandi and Kullu districts to assess the performance of potato variety Kufri Himalini and Kufri Girdhari at farmers' field. Analysis of data revealed that Kufri Himalini and Kufri Girdhari performed better than local variety Kufri Jyoti at all these locations. In Uttar Pradesh, 14 field demonstrations were conducted at 7 various of three locations like Hapur, Meerut and Muzafarnagar districts of Uttar Pradesh at farmers' field During the year 2015-16. In demonstrated variety Kufri Garima, there was 20.3% increase in yield recorded over yield of popular variety of Kufri Bahar. In East Champaran district of Bihar, 50 FLD were conducted at Farmer's field using Seed Plot Technique for production of good quality foundation seed of potato. A comparison of seed yield between demonstrated practice (Seed Plot Technique) and farmers' practices/local practice revealed that potato variety Kufri Pukhraj attained highest yield of 221.88 q/ha which was subsequently followed by Kufri Khyati (201.14 q/ha), Kufri Sindhuri (196.32 q/ha), Kufri Jyoti (194.77 q/ha) and Kufri Ashoka (191.25). It was also observed that the average yield of demonstrations (201.07 q/ha) was 44.32 per cent higher than the average yield of farmers practices, which is only 139.32 q/ha.

During this period, Social Sciences Division conducted an 8-days Model Training Course on "Post Harvest Management & Processing of Potatoes". A total of 22 scientists/researchers from 9 states attended this training. The impact of this training course revealed that average increase in knowledge of trainees before and after training was estimated at 22.0% which shows that training was successful in significantly increasing the knowledge of the respondents. Nearly 80-90% of trainees were fully satisfied with boarding and lodging facilities as well as training content and faculty. At the end of the training course the reaction of the training was ascertained with the help of pre-structure schedule. The training was rated as excellent by 80% of the participants as very good by 20% of them. In addition, 14 more trainings were conducted at CPRI, Shimla and several 1 to 5 days trainings at its regional stations to train farmers in improved methods of potato cultivation. Potato School on All india Radio was also organized during the crop season in higher hills of HP. The experts from institute also took part in 12 live phone in programmes/agricultural talk on Shimla, Doordarshan. Innovative extension programmes like Mera Gaon, Mera Gaurav and Jai Kisan Jai Vigyan were organized at Headquarters as well as Regional Stations of ICAR-CPRI, Shimla.

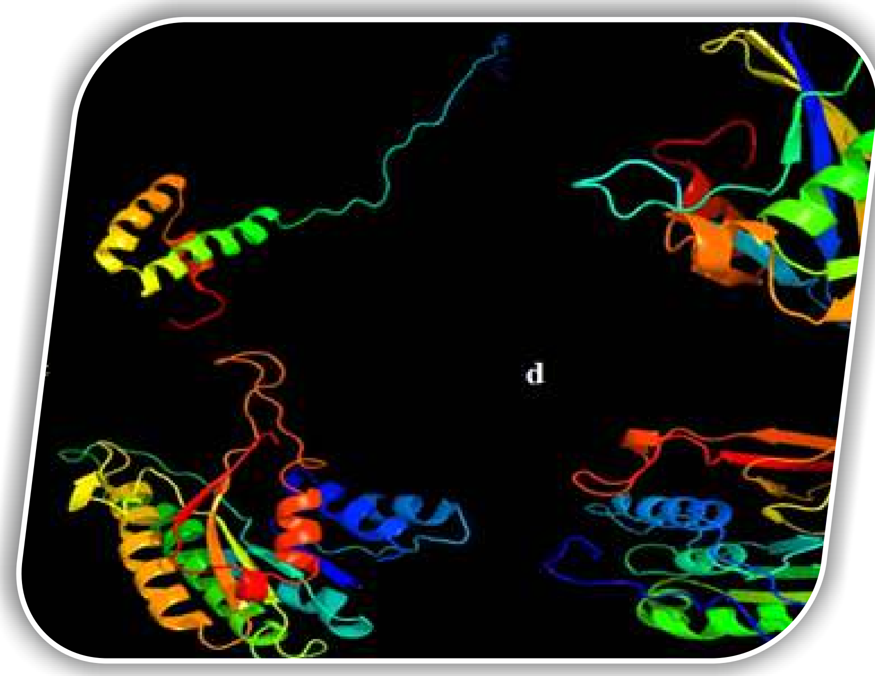
Research Programmes

Research Programmes, Programme Leaders and Associates for the Year 2015-16

1.	Management and enhancement of Potato Germplasm	**PI: Dr. Vinod Kumar. Associates:** Drs. Vinay Bhardwaj, Rajinder Singh, JK Tiwari, Dalamu, G Vanishri, Tanuja Buckseth, Raj Kumar, Ratna Preeti Kaur, SK Luthra, Shambhu Kumar, R Sudha, Ashiv Mehta, Name Singh, Bandana, S Roy, Kamlesh Malik, Sanjeev Sharma, Jeevalatha A, Baswaraj R, Ravinder Kumar, MS Gurjar, Aarti Bairwa, Jagdev Sharma, Som Dutt, Anil Gupta, KR Naik, Kiran Kumar, Shruti Gupta, Kameshwar Sen, Vineet Kumar.
2.	Breeding to evolve trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses	**Dr. SK Luthra. Associates:** Drs. VK Gupta,Raj Kumar, RP Kaur, Shambu Kumar, Mehi Lal, Sanjay Rawal, Vinay Bhardwarj, Bandana, Ashiv Mehta, SK Kaushik, Rajendra Singhy, Dalamu, G Vanishree, R sudha, Sanjeev Sharma, Malkhan Singh, S Sundaresha, Baswaraj Raigond, Jeevalatha, AartiBairwa, JS Minhas, Brajesh Singh, Devendra Kumar, Name Singh, SomDutt, Rinki, Raja Shankar, Vinod Kumar, M Nagesh, EP Venkatasalam, Sarla Yadav, Babita Chaudhary, Maharishi Tomar
3.	Genetic enhancement of potato through molecular and genomic tools	**Jagesh Tiwari. Associates:** Drs. Som Dutt, VU Patil, JK Tiwari, S Sundaresha, Vinay Bhardwaj, Raja Shankar, Hemant Kardile, Brajesh Singh, Shashi Rawat, Ashiv Mehta, JS Minhas, Raj Kumar, SK Luthra, Dalamu, Pinky Raigond, BaswarajRaigond, A Jeevalatha, Rajendra Singh, VK Dua, Sanjeev Sharma, Clarissa Challam, Vinay Sagar, R Sudha, Rinki, Aarti Bairwa
4.	Climate change impact adaptation strategies for potato Crop.	**Dr. VK Dua. Associates:** Drs. Devendra Kumar, Jagdev SharmaShashi Rawat, JS Minhas Sanjay Rawal, SK Singh, SP Singh, Sanjeev Sharma, Mehi Lal, Kamlesh Malik, Anuj Bhatnagar, Vinay Sagar, Prince Kumar Sushil Kumar, Islam Ahmad,
5.	Integrated nutrient and water management for improved productivity of potato	**Manoj Kumar, Associates:** Drs. VK Dua, Name Singh, Jagdev Sharma, MA Khan, Raj Kumar, Prince Kumar, SP Singh, Bapi Das, Shashi Rawat, Pooja Chaukhande, Dalamu, VU Patil, SK Yadav, Sushil Kumar, Yogesh

6.	Biology, epidemiology, modelling and management of insect pests, vectors, and cyst nematodes of potato	**Dr. (Mrs.) Kamlesh Malik, Associates:** Drs. Anuj Bhatnagar, Sridhar Jandrajupalli, Vallepu Venkatswarlu, AartiBairwa, Jeevalatha Arjunan, Baswaraj Raigond, Ravinder Kumar, S Sundaresha, JK Tiwari, VK Dua, Raja Shankar, RP Pant, Vinod Kumar, Murlidhar Sadawarti, Sanjeev Sharma, EP Venkatesalem, Shashi Rawat, Vinay Sagar, Vinay Bhardwaj, R Sudha, Kapil Kumar Sharma, Mohamad Abas Shah, Priyank Matre
7.	Re-defining epidemiological parameters and management approaches for potato pathogens	**Dr. Sanjeev Sharma. Associates:** Drs. Vinayy Sagar, A. Jeevalatha, Baswaraj R, S. Sundaresha, Ravinder Kumar, S Roy, RP Pant, Mehi Lal, Rahul Bakade, Shashi Rawat, Anuj Bhatnagar, MA Khan, PM Govindakrishnan, Vinay Bhardwaj, AartiBairwa, EP Venkatasalam, M Nagesh, VU Patil, VallepuVenkataswarlu, J Sridhar, Kamlesh Malik, Prince Kumar, MJ Sadawarti, Scientist, Pinky Raigond, Murari Lal, Sh. Subhash Chand, Islam Ahmad, YP Singh, Mohamad Abas Shah, Priyank Matre
8.	Post harvest management and nutritional enhancement of potatoes	**Dr. Brajesh Singh. Associates:** Drs. Ashiv Mehta, Vinay Bhardwaj, Vinay Sagar, SomDutt, Pinky Raigond, BaswarajRaigond, Bandana, S Sundaresha, RatnaPreeti Kaur, Dalamu, Dhiraj K Singh, Sanjay Rawal, Hemant Kardile, Pynbiangland Kharumnuid, Abhijit Kar, Vineet Sharma, Yogesh Gupta, Shelly Chopra
9.	Resource optimization in potato based cropping system.	**Dr. Sanjay Rawal. Associates:** Drs. KK Pandey, Ashwani Kumar Sharma, Dhiraj Kumar Singh, Tanuja Buckseth, Pynbiangland Kharumnuid , Divya K Lekshmanan, Brajesh Nare.
10.	Assessment of potato technologies and its transfer to stakeholders for improving potato production	**Dr. NK Pandey. Associates:** Drs. Dhiraj K Singh, Pynbianglang Kharumnuid, M. Nagesh, Ashok Chauhan, SK Yadav.
11.	Production of nucleus and breeder seed of important notified varieties of potato	**Dr. RK Singh. Associates:** Drs. BP Singh, Tanuja Buckseth, Vinod Kumar, Ashwani Kumar, SK Kaushik, Vinay Singh, Dhruv Kumar, JS Minhas, Prince, Ratna Preeti Kaur, S Roy, SP Singh, MJ Sadawarti, Manoj Kumar, RK Singh, Rahul Bakade, TK Bag, EP Venkatasalem, Parvesh Jassal, Sumita Sharma, RK Verma, Balak Ram, KP Singh, Harveer Singh, NK Sood, Jasvir.

Division of Crop Improvement



Management and enhancement of potato germplasm

Collection:

Efforts were continued to augment the potato germplasm collection at CPRI, Shimla which is the designated National Repository for Potato germplasm. During the year , 8 accessions were imported from USA, 4 from New Zealand, 8 from The Netherlands, 1 from Canada, 5 from France, 2 from UK and 3 from Germany. In total, 31 accessions were imported from 7 countries and among them 30 accessions were added to cultivated germplasm collection after quarantine clearance. The present germplasm collection at CPRI consists of more than 4,300 accessions of cultivated and wild species from 30 countries.

Conservation:

Field conservation: One thousand five hundred and twenty Tuberosum accessions, 768 Andigena accessions and 69 indigenous samples were maintained in fields at Jalandhar. Nearly 1425 Tuberosum accessions and 90 indigenous samples were maintained in fields at Kufri. Ten dihaploids of Indian commercial varieties were maintained in glasshouses at Shimla. In wild species, 490 accessions (both in tuber and TPS forms) of 128 species are conserved at CPRI, Shimla.

***In-vitro* conservation:** Nearly 2150 Tuberosum accessions were maintained in *in-vitro* form. Minitubers of 76 accessions from in-vitro repository were produced and added to the germplasm collection maintained under field conditions at Jalandhar & Kufri. 190 mericlones of 13 varieties were tested for their freedom from all viruses and 9 varieties namely Kufri Gaurav, Kufri Garima, Kufri Chipsona-1, Kufri Badshah, Kufri Mohan, Kufri Sadabahar, Kufri Chipsona-3, Kufri Chipsona-4 and Kufri Girdhari were found free from all viruses. Besides, mericlones of 9 advanced hybrids were also tested and three hybrids namely PS/6-88, PS/6-24 and MS/04-2261 were found free from all viruses.

Cryopreservation of potato germplasm: Pollen of six potato varieties namely Kufri Girdhari, Kufri Himalini, Kufri Himsona, Kufri Kanchan, Kufri Jyoti and Kufri Shailja were cryopreserved after packing in gelusil capsules, kept in cryo-vials and immersed in liquid nitrogen cryocan **(Fig. 1).** The pollen viability of cryopreserved pollen grains was tested after 24 hrs of cryopreservation (sample drawn after from a single lot of cryopreserved pollen) using in vitro germination of pollen grains. Three kinds of pollen were observed a) viable pollen with germinating pollen tubes of variable sizes, b) putative viable pollen showing no germination, and c) inviable pollen showing only stained pollen walls and somewhat shriveled shape. The number of germinating pollen grains in the medium were less than the total number of viable pollen observed on the basis of staining. The inviable pollen may reportedly be due to abnormal meiotic segregation inherent to potato. The proportion of the pollen types varied in varieties with 4.6 % in Kufri Jyoti to 24.6% in Kufri Himalini. The lengths of the pollen tube also varied within a sample, which may be due to differences in pollen vigour. Significant differences as expected were obtained between cryopreserved and heat killed; and fresh and heat killed pollen grains for pollen germination, whereas fresh and cryopreserved pollen showed non-significant differences.

Fig. 1. Pollen extraction from potato anthers, B: Packing of extracted pollen in empty gelusil capsules and cryovials, C: in vitro pollen germination observed in potato.

Improved droplet vitrification method for the cryopreservation of the potato shoot tips

Cryopreservation has been proved to be efficient method for long term preservation of the potato shoot tips. Several cryopreservation methods viz., vitrification, droplet vitrification, encapsulation-vitrification and encapsulation-dehydration have been employed for potato shoot tips. We have optimized the procedure for Droplet Vitrification in which expalnts were submitted to pre-culture in liquid medium containing various concentration of sorbitol and DMSO. Six different media were used for regeneration of cryo treated shoot tips with varying concentration of Pluronic F-68 (0.001% to 0.5%). The pretreatment with 0.5M sorbitol and 0.01M DMSO, LS treatment for 20 min, PVS2 for 15 minutes and regeneration media with 0.001% and 0.01% Pluronic F-68 gave 50-60% survival rate. But regeneration rate is 20-30% **(Fig 2).** The efforts are being made to improve regeneration rate to make cryopreservation technique more efficient and more economical to compliment *in-vitro* conservation.

Fig. 2. Stepwise regeneration of the potato shoot tips using improved Droplet Vitrification method.

Evaluation:

A large number of accessions were evaluated for various biotic and abiotic stresses and also for adaptability and physcio-biochemical traits. Promising accessions identified in these evaluations are listed in Table 1.

Table 1. Evaluation of potato germplasm

Character	Location	No. of accessions evaluated	Promising accessions*
Adaptability	Kufri	155	CP Nos. 4051, 4070, 4116, 4297.
	Jalandhar Spring	100	None out yielded the best control Kufri Jyoti (390 g/plant).
	Modipuram Autum (early)	69	CP Nos. 3853, 3891, 3905 were better than Kufri Surya.
	Autumn (Main)	67	CP Nos. 2251, 2254, 3889, 3900, 3902, 3238, 4254, U597/28, U521/21, MS/97-644, MS/95-4904.
Late blight Foliage	Kufri (field)	155	18-HR; 9-R; 37-MR (CP Nos: 1012, 1085, 1187, 1319, 2003, 2320, 4051, 4065, 4071, 4091, 4106, 4118, 4138, 4171, 4179, 4221, 4229 and 4238).
	Shillong & Ooty (field)	77	Nine accessions (CP Nos. 1319, 2132, 3605, 3630, 3768, 3774, 3776, 3787 and 3841 were promising at both the locations).
	Shimla(Lab)	65	6-HR (CPNos.3539, 3645, 3656, 3825, 3836, 4000).
Tuber	Shimla(Lab)	65	2-HR (CP Nos: 1538 & 4125).
Viruses PVX & PVY	Shimla		23- R (PVX and PVY); 50-R (PVY); 24-R (PVX).
PSTVd	Shimla	100	20 accessions were infected & 80 were free.
Leaf hopper and Mites	Modipuram	159	9 accessions (CP Nos. 3546, 3605, 3621, 3970, 3776, 3681, 3696, 3767 and 3784) had < 5% mite burn. Results were inconclusive for hopper burn.
Cyst nematodes	Ooty	62	7 accessions viz., CP No;s: 3485, 3539, 3541, 3585, 3636, 4164 and 4211 were resistant to both the species of PCN.
Keeping quality	Jalandhar	75	20- Best keepers; 24-Good keepers.
Chipping	Jalandhar	75	8 accessions viz. CP Nos. 2012, 2033, 2294, 3174, 3514, 3646, 3647 and 3702 were found to be suitable for chipping. Out of these, 5 accessions (CP 2012, CP 3174, CP 3646, CP 3647 and CP 3702) were ranked as best keeper also.
Vitamin C	Modipuram	73	CP Nos.1701, 1717, 1722, 1727, 1736, 1746, 1764, 1765, 1777 and 1796.
Micro nutrients (Zinc & Iron)	Shimla	46	For Zinc content: CP Nos. 1435, 1978, 1812, 2067 and 3443. For Iron content: CP Nos. 1239, 1435, 2067, 3443 and 3772.
Water use efficiency	Modipuram	23	2 accessions viz., CP 2148 & CP 2340.
Foliage maturity	Patna	311	60 accessions were early maturing having 80% foliage maturity at 70 days crop duration.

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

Genetic enhancement of Tuberosum

At Jalandhar, in F_1C_2 generation, 271 clones were planted and 135 were selected. These clones will be evaluated for late blight resistance and foliage maturity with the objective to select early maturing late blight resistant clones. Further, 144 F_1C_3 clones were evaluated for late blight at Kufri and 15 clones were highly resistant, 11 were resistant and 10 were moderately resistant.

Wild species

Development of new mapping population for late blight resistance

A total 58 diploid wild species/accessions were used to develop mapping population for late blight resistance. These species were screened previously for resistant/susceptible by challenge inoculation of *P. infestans* under controlled conditions **(Fig.3)**. The wild species were raised *in-vitro* and planted in the earthen pots in the glass house at Kufri conditions. The diploid wild species resistant to late blight were used as male parent namely *S. cardiophyllum* (5 accessions), *S. berthaultii* (3 acc.), *S. iopetalum* (2 acc.), *S. jamesii* (3 acc.), *S. lesteri* (3 acc.), *S. microdontum* (2 acc.), *S. pinnatisectum* (6 acc.), *S. polyadenium* (13 acc.), *S. polytrichon* (4 acc.), *S. trifidum* (9 acc.), *S. verrucosum* (5 acc.). Whereas late blight susceptible parents (one acc. of each) were used as female parents namely *S. vernei, S. acaule, S. commersonii,* dihaploid *S. tuberosum* C-13. Based on the synchronous flowering behaviours of the wild species a total 2128 true potato seeds were obtained for the different cross combinations.

Fig. 3. Wild species evaluation

Molecular diversity analysis of the wild potato species by SSR markers: A total of 84 wild potato species/accessions were analyzed for molecular diversity using 14 SSR markers. Each 84 wild species were PCR amplified following standard procedures using SSR markers and then amplified fragments were analyzed in '3500 Genetic Analyzer'. Then data matrix of presence (1)/ absence (0) was prepared **(Fig. 4)**. A similarity matrix was calculated by the Jaccard's coefficient and dendrogram was constructed using unweighted pair-group method (UPGMA) clustering method with the program DARwin 6.0.11. Tree showed diversity among the wild species that are useful for exploitation in potato.

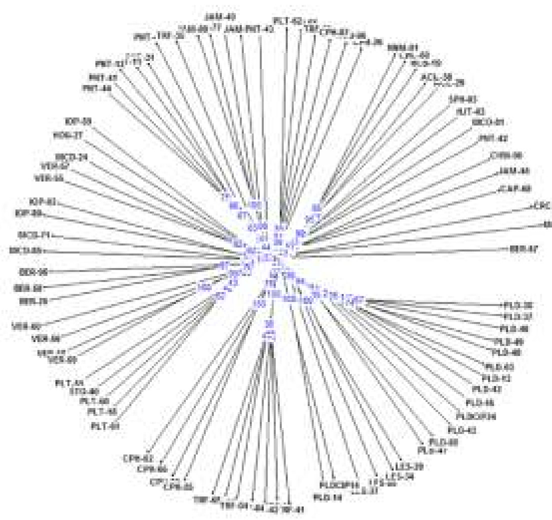


Fig. 4. Dendrogram showing molecular diversity among the wild species.

Evaluation

Screening for Late blight resistance in open condition:

At Kufri, 69 clones of 32 accessions of 20 species along with susceptible control Kufri Jyoti and resistant control Kufri Girdhari were evaluated. Based on data recorded thrice during the cropping period, four clones viz. SS. Nos. 1764-19 (*S. alandiae*), 2058-01, 2064-0 (*S. tuberosum ssp.andigena*), 2206-01(*S. albicans*) were resistant while five clones (SS. Nos. 1725-10(*S. spegazzinii*), 1763-27 (*S. albicans*), 1767-08 (*S. ambosinum*), 2051-0 (*S. tuberosum ssp.andigena*), 2192-02 *(S. oplocense)* were moderately resistant.

Screening for Late blight resistance under lab condition:

By detached leaf assay 73 clones of 38 accessions of 18 wild species were screened **(Table 2)** and 15 clones were highly resistant (lesion area up to 1.0 cm^2), 21 resistant (lesion area 1.1 to 2.5 cm^2) and 12 moderately resistant (lesion area 2.51 to 6.0 cm^2).

Table 2. Promising wild species clones obtained by detached leaf testing

Resistance level	Promising wild species
Highly resistant	SS. Nos. 2344-02 (*S. bukasovii*), 2169-04, 2682-05 (*S. bulbocastanum*), 2635-08 (*S. demissum*), 2610-08 (*S. microdontum*), 2644-15 (*S. phureja ssp.phureja*), 2616-09, 2658-11 (*S. pinnatisectum*), 2687-07 (*S. raphanifolium*), 2709-0 (*S. stoloniferum ssp. stoloniferum*), 2706-06 (*S. stenophyllidium*), 2044-14, 2686-10, 2686-12, 2781-29 (*S. tuberosum ssp.andigena*)
Resistant	SS. Nos. 2332-03 (*S. bukasovii*), 2173-04 (*S. bulbocastanum ssp.bulbocastanum*), 2422-01 (*S. demissum*), 1874-0 (*S. gandavillasii*), 2610-0, 2610-09, 2612-12 (*S. microdontum*), 2195-09 (*S. oplocense*), 2644-14, 2653-17 (*S. phureja ssp.phureja*), 2657-0, 2705-07 (*S. pinnaetisectum*), 2712-0 (*S. stoloniferum ssp. stoloniferum*), 2051-01, 2686-02, 2686-04, 2686-06, 2686-07, 2686-11, 2781-28, 2051-01 (*S. tuberosum ssp.andigena*).
Moderately resistant	SS. Nos. 1773-01(*S. avilesii*), 2691-09 (*S. berthaultii*), 2332-03 (*S. bukasovii*), 2190-09 (*S. oplocense*), 2452-0 (*S. papita*), 2706-07 (*S. stenophyllidium*), 2710-12 (*S. stoloniferum ssp. stoloniferum*), 2781-09, 2781-30, 2781-33, 2686-09, 2686-15 (*S. tuberosum ssp. andigena*)

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.

Breeding to evolve trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses

Research activity 1: Breeding for table potato varieties

Hybridization: In all, 7,17,875 true potato seeds were obtained from the 163 successful crosses at Jalandhar, Modipuram and Patna.

Seedling stage: A total of 83,148 seedlings were raised in field by sowing 2,78,926 true potato seeds of 119 crosses. At harvest, 6,439 promising clones were selected.

Initial clonal stages: In initial clonal stages (F_1C_1, F_1C_2 and F_1C_3), 5587 clones were evaluated at 60/75/90 days and 1349 promising clones were selected.

Replicated yield trials: In all, 136 advanced stage hybrids were evaluated in 15 yield trials at 60/75/90 DAP at Jalandhar, Modipuram and Patna and 46 promising hybrids were selected. In nine preliminary yield trials, 33 promising hybrids namely J/10-91, J/10-118, J/10-127, J/10-148, J/10-59, J/10-150, J/10-155, J/10-175, J/10-31, J/10-102 and J/10-178 (Jalandhar), MS/11-664 MCIP/11-163, MP/11-472, MS/12-636, MS/12-655, MS/12-682, MS/12-935, MS/12-283, MS/12-2116 and MS/12-2241 (Modipuram), PS/11-13, PS/11-16, PS/11-20, PS/11-26, PS/11-31, PS/11-33, PS/11-34, PS/11-46, PS/11-47 PS/11-82, PS/11-84 and PS/11-86 (Patna) were selected from 101 hybrids evaluated. In three confirmatory yield trials, eight promising hybrids namely J/9-141 (Jalandhar), MS/11-938, MS/11-1123 (Modipuram), PS/10-2, PS/10-22, PS/10-17, PS/10-10 and PS/10-1 (Patna) were selected from 21 hybrids evaluated. In three final yield trials, five advanced hybrids namely J/8-85, J/8-91, J/8-119 (Jalandhar) and PS/09-16 PS/09-9 (Patna) were selected from 14 hybrids evaluated.

Promising advanced stage hybrids identified: Based on consistently good performance over the years, five hybrids J/8-85, J/8-91, J/8-119, PS/09-16 (white skin) and PS/09-9 (red skin) were identified **(Table 3 & 4, Fig. 5 & 6)**. J/8-85 yielded 22 % and 16% higher than control K. Khyati at 60 and 75 days harvests, respectively. Hybrid produces yellow, ovoid flattened tubers with shallow eyes and cream flesh. J/8-91 yielded 26% and 12% higher yield than control K. Khyati at 60 and 75 days harvests, respectively. The hybrid produces white, ovoid tubers with shallow eyes and white-cream flesh. J/8-119 yielded 13% and 8% higher yield over control K. Khyati at 60 and 75 days harvests, respectively. The hybrid produces yellow, ovoid tubers with shallow eyes and yellow-cream flesh. Tuber dry matter of hybrids J/8-85 and J/8-91 was at par with control, K. Khyati. The hybrid, PS/9-09 (J/ 96-84 x CP3774) with tuber yield of 31 and 40 t/ha showed advantage of 4% and 19% at 75 and 90 days than K. Lalit (30 and 34 t/ha). It produces red ovoid tubers with fleet eyes and light yellow flesh having 19.5% tuber dry matter, medium dormancy and moderate level of resistance to late blight. The hybrid PS/9-16 (J/94-144 x CP2340) with tuber yield of 43 t/ha showed advantage of 12% at 90 days than K. Pukhraj (39 t/ha). It produces white round tuber with fleet eyes and cream flesh having 19.3% tuber dry matter, medium dormancy and moderate level of resistance to late blight.

Fig. 5. Tubers of hybrids J/8-85, J/8-91 and J/8-119

Fig. 6. Tubers of hybrids PS/9-09 and PS/9-16

Advanced hybrid introduced in AICRP: Advanced stage hybrid MS/9-2196 recommended by Institute Research Council 2015 was introduced in AICRP for multi-location testing. MS/9-2196 (J/93-77 x J/97-243) produced 39%, 24%, 13% and 22% higher total tuber yield than K. Bahar, K. Garima, K. Pukhraj and K. Sadabahar, respectively at 90 days. The hybrid produces attractive yellow, ovoid tubers with shallow eyes and yellow flesh colour **(Fig. 7).** The hybrid possesses moderate tuber dry matter (15%) and good keeping quality. MS/9-2196 showed slight resistance (AUDPC 276) to late blight than K. Bahar (AUDPC 705) at Modipuram.

Fig. 7. MS/9-2196- Leaf, flowers, tubers and sprout

Release of new potato variety: Advanced hybrid MS/5-1543 **(Fig. 8)** was recommended for release as potato variety, Kufri Mohan in 33rd AICRP Potato group meeting held during September 19-21, 2015 at GBPUAT, Pantnagar, Uttrakhand. This variety is medium maturing (75-90 days) with yield potential of 40 t/ha, possesses moderate level of late blight resistance, good keeping and culinary quality. It has edge over cultivar K. Bahar in northern plains and K. Jyoti in eastern plains, the two most predominant varieties in the country. It produces attractive white-cream ovoid uniform tubers with shallow to medium eyes and cream flesh colour.

Fig. 8. Morphological and tuber attributes of Kufri Mohan

Optimizing of NPK requirement of newly released variety Kufri Mohan: Kufri Mohan at 90 days showed that economic optimum dose of nitrogen (219.0 kg N/ha) and potassium (81.0 kg K_2O/ha) is required based upon total tuber yield, where average potato price (Rs. 6/kg) and price of N (Rs.13.07/kg) and K_2O (Rs. 27.33/kg) were taken into account. K. Mohan did not respond to phosphorous application as soil available P was in medium range (29.2- 36.4 kg/ha), whereas it's total P uptake varied between 15.9-18.4 kg P/ha. Hence, a moderate basal dose of 40 kg P_2O_5/ha is recommended for cultivation this variety in west central plains **(Fig. 9)**.

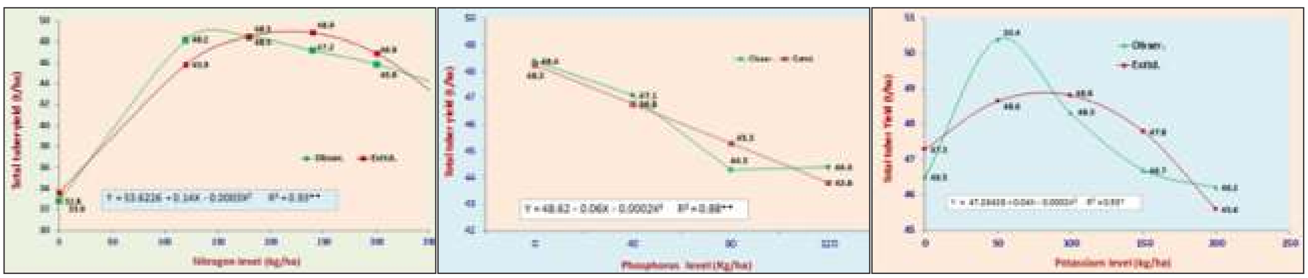


Fig. 9. Response curve of expected and observed total tuber yield in K. Mohan for Nitrogen, Phosphorus and Potash

Optimizing NPK requirement for advanced hybrid MS/06-1947: The hybrid possess additional character of water stress tolerance. The hybrid MS/06-1947 at 90 days **(Fig. 10)** crop showed that N level of 240 kg/ha had significantly better marketable tuber yield (44.0 t/ha) over control and lower or further higher levels (28.8- 39.9 t/ha). MS/06-1947 exhibited response towards P_2O_5 application up to 80 kg/ha and had statistically superior marketable tuber yield (45.1 t/ha) over control (42.6 t/ha), which were comparable to higher doses. Moderate potassium application (50 kg K_2O/ha) was better for improving tuber yield in MS/06-1947 as this level attained significantly better marketable tuber yield (43.8 t/ha) over control (38.5 t/ha), and that was also comparable to higher levels.

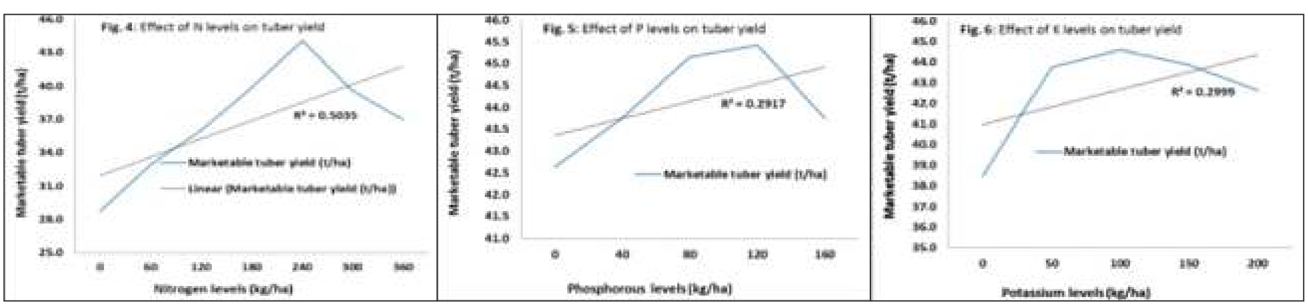


Fig. 10. Response curve of expected and observed total tuber yield of MS/06-1947 for nitrogen, phosphorus and potash

Evaluation of advanced stage hybrids for late blight resistance at Modipuram: Seventy genotypes along with 12 control varieties were evaluated for late blight resistance in field as well as in the lab. Late blight disease severity was recorded at different intervals (80, 86, 91, 100 & 109 days). All hybrids showed less area under disease progress curve (AUDPC) than control variety, K. Bahar (905.35). Among 70 genotypes, minimum AUDPC was recorded in 14 genotypes viz., CP4386 (9.73), CP4403 (10.25), CP4401 (16.07), CP4395 (53.57), CP4392 (57.58), CP4389 (60.20), MCIP/12-349 (28.67), MCIP/12-353 (48.10), MCIP/12-51 (51.40), MCIP/12-185 (74.75), MP/10-595 (68.93), MS/12-935 (79.33), MS/12-900 (90.90) and MS/12-636 (91.83) as compared to K. Bahar (905.35) and their rAUDPC were also less.

Table 3. Promising advanced hybrid identified at Jalandhar

Genotypes	Tuber yield (t/ha)							
	2012-13		2013-14		2014-2015		Average	
	60 DAP	75 DAP	60 DAP	75 DAP	60 DAP	75 DAP	60 DAP	75 DAP
J/8-85	32.3	44.8	36.5	47.4	29.4	38.5	32.7	43.6
Kufri Pukhraj	27.5	40.4	28.1	38.1	23.1	33.0	26.2	37.2
Kufri Khyati	28.6	40.4	28.4	39.0	23.4	33.0	26.8	37.5
CD (0.05)	2.29	2.44	2.77	3.55	2.0	2.58		
J/8-91	30.3	43.0	35.7	44.7	31.7	37.0	32.6	41.6
Kufri Pukhraj	27.0	39.1	28.1	38.1	23.1	33.0	26.1	36.7
Kufri Khyati	25.5	39.4	28.4	39.0	23.4	33.0	25.8	37.1
CD (0.05)	1.65	2.26	2.77	3.55	2.0	2.58		
J/8-119	32.2	42.6	36.5	47.4	29.4	38.5	30.1	39.9
Kufri Pukhraj	29.5	37.1	28.1	38.1	23.1	33.0	26.9	36.1
Kufri Khyati	28.4	38.4	28.4	39.0	23.4	33.0	26.7	36.8
CD (0.05)	3.14	4.27	2.77	3.55	2.0	2.58		

Table 4. Promising advanced hybrid identified at Patna

Genotypes	Tuber yield (t/ha)							
	2012-13	2013-14	2014-15		2015-16		Average	
	75 DAP	75 DAP	75 DAP	90 DAP	75 DAP	90 DAP	75 DAP	90 DAP
PS/9-09	32.23	25.58	35.68	36.69	31.89	43.99	31.35	40.34
PS/9-16	33.08	34.75	36.69	42.31	35.65	42.98	35.04	42.65
K. Khyati	33.80	-	37.36	37.74	22.33	34.17	31.16	35.96
K. Lalima	30.09	23.81	29.56	32.15	26.10	33.38	31.16	35.96
K. Lalit	-	-	30.58	31.92	29.90	35.90	30.24	33.91
K. Pukhraj	34.07	29.61	39.05	41.31	34.01	37.25	34.75	38.15
K. Sindhuri	-	-	27.93	28.42	23.98	32.51	25.96	30.47
CV (%)	2.96	2.50	3.52	4.84	3.99	5.18		
CD (0.05)	2.17	1.08	2.12	3.03	1.97	3.34	-	-

Research activity 2: Breeding for processing varieties

Hybridization A total of 100723 TPS of 62 crosses were produced at Kufri and Modipuram.

Seedlings stage: A total of 100723 TPS of 62 crosses were used for seedling raising and 765 clones were selected from 19080 seedlings transplanted at Modipuram.

Initial clonal generations: A total of 1079 clones of F_1C_1, 202 clones in F_1C_2 and 60 clones in F_1C_3 stage were evaluated and 274, 69 and 20 clones were retained respectively based on tuber characters and chip colour at Modipuram.

Preliminary yield trials: In F_1C_4 stage, seven genotypes namely MP/11-33, MP/11-34, MP/11-37, MP/11-112, MP/11-142, MP/11-221 & MP/11-463 were selected from 15 hybrids tested at Modipuram.

Confirmatory yield trials: Thirteen (13) advanced stage hybrids along with six control varieties were evaluated at 75 and 90 DAP in two trials and on the basis of total tuber yield, processing grade yield, chip colour & dry matter, six hybrids namely MP/9-22, MP/09-28, MP/9-45, MP/9-73, MP/9-86 and MP/10-172 were selected for chips/flakes.

Promising hybrids identified: Advanced hybrid, MP/9-28 (K. Chipsona-1 x CP1911) for chips is identified based on consistence performance during last two years at Modipuram **(Table 5, 6)**. MP/9-28 produced 19% higher processing (29 t/ha) and 10 % higher total (34 t/ha) tuber yields than K. Chipsona-3 (24 and 31 t/ha) and K. Chipsona-4 (24 and 30 t/ha) at 90 days. It produces attractive white cream, ovoid tubers with shallow eyes and cream flesh. The hybrids possess 22% dry matter and acceptable chip colour score (2.2).

Evaluation at Burdwan (West Bengal): Among the 13 hybrids and 5 control varieties evaluated at 90 DAP, MP/08-1900, MP/6-39 (38 t/ha), MP/09-21, MP/09-45 (35 t/ha) were found to be superior on the basis of yield and quality attributes than respective controls.

Evaluation at Amirgarh (Gujarat): Among the 4 hybrids tested at 99 DAP, MP/06-39 (49 t/ha) was found to be superior for French fries than other hybrids and their respective controls.

Advanced hybrid introduced into AICRP: MP/8-1900 (MP/98-172 x QB/A-92-4) for chipping was introduced into AICRP for multi-location testing, based on performance at Modipuram (2012-2015) and Burdwan (2014-15). It produced higher processing (32 t/ha) and total (39 t/ha) tuber yields than Kufri Chipsona-3 (29 and 36 t/ha). MP/8-1900 produces attractive white cream, ovoid tubers with shallow eyes and cream flesh **(Fig. 11).** The hybrids possess 22% dry matter and acceptable chip colour score (2.8).

Fig.11. MP/8-1900: Leaf, tuber and sprout

Evaluation at Jalandhar: Among the 15 genotypes evaluated at 90 DAP, all hybrids recorded yield at par or better than controls. Maximum total tuber yield was recorded in MP/04-816 followed by MP/04-578, MP/09-21 and MP/06-39. All hybrids recorded > 20% dry matter (DM) at harvest except MP/06-39 (19.10%). Reducing sugars (RS) contents remained within acceptable limits (<150mg /100g fr wt) in all the hybrids except MP/04-578, MP/04-816 and MP/06-39. RS contents were higher (>150mg/100g fr wt) in K. Chipsona-3, K. Chipsona-4 and K. Frysona. Minimum sucrose contents were recorded in MP/08-62 (156.4 mg/100g fr wt) and MP/08-57 (176.0 mg/100g fr wt) which were significantly lower than control cultivars. Acceptable colour French fries were found in all genotypes at the time of harvest. Chip colour was found acceptable in only four hybrids *viz.* MP/06-39, MP/08-62, MP/08-57 and MP/08-1900.

Processing quality during storage at 10-12°C with CIPC (2015 storage) at Jalandhar: Among the 12 advanced hybrids except MP/06-39, all hybrids recorded more than 20% DM at 0 day and during storage. Hybrids, MP/08-57 and MP/08-172 recorded mean maximum DM contents (>25%). Initial (0 day) reducing sugar (RS) contents were acceptable (<150 mg/100 g fr wt) for chips in all genotypes except in K. Chipsona-4 and MP/06-39, which were however acceptable for making French fries. RS contents increased during storage with mean minimum contents recorded in hybrids MP/08-1622 (134 mg/100 g fr wt) and MP/08-57 (138 mg/100 g fr wt). Sucrose contents also increased during storage with mean minimum contents recorded in MP/08-329 (254.5 mg/100g fr wt). Chip colour remained acceptable up to 90 DOS in all genotypes. Chip colour deteriorated after 120 DOS but remained acceptable up to 150 days in hybrids MP/09-91 and up to 180 days in MP/08-57 and MP/08-1622. Fry colour however remained acceptable in all genotypes up to 150 DOS.

Storability of advanced processing hybrids in heaps at Jalandhar: Three advanced hybrids *viz.* MP/04-578, MP/04-816 and MP/06-39 were stored in heap along with controls, K. Chipsona-1 and Lady Rosetta with or without CIPC treatment. Total losses up to 90 DOS in untreated (control) potatoes were minimum in Lady Rosetta (7.41%), followed by MP/06-39 (10.41%) and MP/04-578 (11.9%). Losses remained lower than K. Chipsona-1 (12.68%). Similar trend was observed in CIPC treatment as well. DM content in all genotypes was more than 20% except in MP/06-39. Reducing sugar (RS) contents were higher at 0 day of storage in three hybrids. RS contents decreased during storage in heaps and chip colour improved to acceptable levels after 60 DOS in heaps. Results showed that these processing genotypes can be safely stored in heaps and used in the processing industry up to 90 days of storage.

Evaluation at Shimla: Processing hybrids along with controls were tested at Kufri and Shimla at 120 days. At Kufri, among 12 hybrids tested, MP/07-214 out yielded the best control in total tuber yield besides its late blight resistance was also statistically at par with K. Himsona. The other hybrids viz., MP/08-1467, MP/08-1900, MP/08-329 and MP/08-53 also yielded higher and statistically remained at par with the best control. K. Chipsona-1 was the best control for total tuber yield (t/ha), while for late blight resistance (AUDPC), K. Himsona was the best control. At Shimla, among 14 hybrids tested, MP/07-214, MP/08-1467, MP/08-172, MP/08-329 and MP/09-45 yielded higher than the best control for total tuber yield. K. Chipsona-3 was the best control for yield (t/ha). Advanced hybrids, MP/07-214, MP/08-1467 and MP/08-329 yielding higher in both the trials have been selected for confirmation of results. The late blight resistance of these hybrids is also high with MP/07-214 being highly resistant.

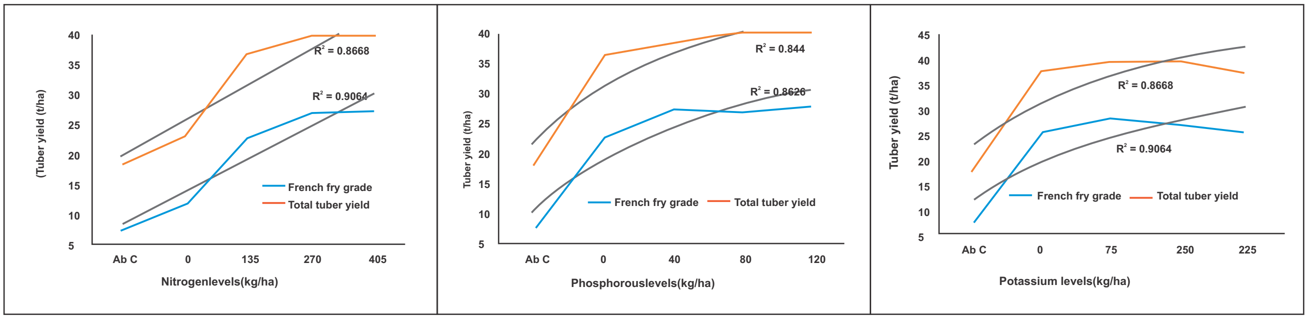


Fig.12. Response to NPK in MP/04-578

Optimizing NPK requirement of advanced processing hybrid for French fry MP/04-578: In MP/4-578 **(Fig. 12)**, Nitrogen (270 kg/ha) recorded French fry grade (26.6 t/ha) and total tuber yield (39.7 t/ha), which were significantly better over lower doses and comparable to highest N level of 405 kg. Phosphorous (40 kg/ha) had French fry grade (26.9 t/ha) and total tuber yield (38.1 t/ha) and were statistically superior over control (22.4 & 35.6 t/ha), while remained at par with higher P_2O_5 levels. Potassium (75 kg/ha) attained markedly higher French fry grade (28.1 t/ha) and total tuber yield (39.5 t/ha) as compared to control (24.9 & 37.2 t/ha), which remained at par with higher K_2O levels. Quality traits viz., specific gravity (1.079) and French fry colour score (3.80) were also in acceptable limits at 270-40-75 kg N-P-K/ha.

Optimizing crop geometry for French fry hybrid MP/04-578: The hybrid MP/04-578 **(Fig. 13)** recorded highest and significantly better French fry grade (19.9 t/ha) tuber yield with plant spacing of 25 cm in comparison to 15 cm and also had highest proportion of French fry grade tubers (58.1%). Quality parameters i.e. specific gravity and French fry colour were not distinctly influenced by varying plant spacing.

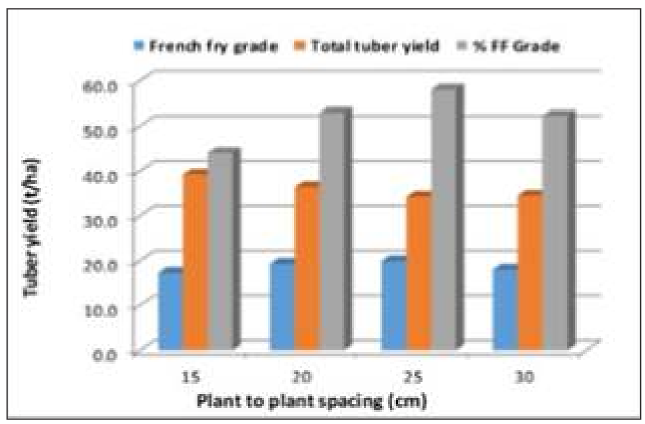


Fig.13. Crop geometry in MP/04-578

Table 5. Promising advanced hybrid MP/9-28 identified for chips at Modipuram

Genotypes	Processing grade yield (t/ha) at 90 DAP				Total tuber yield (t/ha) at 90 DAP			
	2015-16	2014-15	2013-14	Mean	2015-16	2014-15	2013-14	Mean
MP/9-28	32.95	23.99	30.32	29.09	40.81	28.93	33.32	34.35
K.Chipsona-1	24.21	15.95	26.02	22.06	34.21	26.50	29.74	30.15
K.Chipsona-3	25.02	21.67	24.97	23.89	35.85	29.58	28.55	31.33
K.Chipsona-4	27.12	20.10	25.96	24.39	34.83	27.28	27.74	29.95
ATL	29.28	20.82	22.79	24.30	33.63	27.07	24.65	28.45
CV (%)	6.20	5.88	4.67		5.00	3.89	4.78	
CD (0.05)	2.80	1.93	1.92		3.02	1.74	2.24	

Table 6. Quality attributes of advanced hybrid MP/9-28 at 75 DAP (2013-14 to 2015-16)

Genotypes	Tuber dry matter (%)				Chip Colour				Reducing Sugar		
	2015-16	2014-15	2013-14	Mean	2015-16	2014-15	2013-14	Mean	2015-16	2014-15	Mean
MP/9-28	20.8	20.6	23.02	21.47	1.5	2.5	2.5	2.2	32.6	85.4	59.0
K.Chipsona-1	21.1	21.2	22.65	21.65	2.4	4.0	3.2	3.2	87.8	110.7	99.3
K.Chipsona-3	19.8	21.3	22.03	21.04	1.5	4.0	2.8	2.8	68.1	201.7	134.9
K.Chipsona-4	21.1	20.8	22.41	21.44	3.3	5.9	4.6	4.6	119.9	155.2	137.6
Atlantic	21.1	-	22.64	21.87	3.0	-	3.4	3.2	60.2	-	60.2

DAP = Days after Planting, RS/Sucrose= reducing sugar/ Sucrose (mg)/ 100g Fresh weight

Research activity 3: Breeding for biotic stresses (late blight, viruses & cyst nematodes)

Hybridization: In all 1,28,707 true potato seeds were achieved from 113 successful crosses at Shimla, Shillong and Ooty.

Seedling stage: At Shimla, 14,350 seedlings of 22 crosses were screened under controlled conditions against complex races of *Phytophthora infestans* and a total of 1126 resistant seedlings were obtained and transplanted. At Shillong, 2827 seedlings from 10,300 true potato seeds of 34 crosses were transplanted and at harvest, 195 promising clones were selected.

Initial clonal evaluation (F_1C_1 to F_1C_3): In all, 1532 clones were evaluated at Shimla, Shillong &Ooty, and at harvest 1021 clones were retained.

Evaluation of advanced stage hybrids (F_1C_4, F_1C_5 & F_1C_7) at Kufri: Thirty four hybrids were evaluated in three replicated trials along with K. Jyoti (sprayed and non-sprayed), K. Girdhari and K. Himalini as controls. At harvest based on tuber yield components and late blight resistance, 21 hybrid were selected. In F_1C_7 stage, SM/03-23 and VMT 5-1 **(Fig.14)** yielded 8.5% and 12.9% higher than the best control, K. Himalini. Besides, hybrid, SM/03-70 also yielded at par with the best control K. Himalini and was selected for confirmation of results.

Medium maturing late blight and virus resistant hybrids: Among the three hybrids evaluated, SM/03-32 **(Fig.14)** and LBY-18 yielded significantly higher and were highly resistant to late blight incidence than the best control K. Himalini.

Fig. 14. Promising advanced hybrids: SM/03-23, VMT5-1 and SM/03-32

Evaluation of advanced stage hybrids at Shillong: Among the nine advanced hybrids, evaluated, hybrids SS/09-22, SS/09-36 and SS/09-34 were selected based on the tuber yield, tuber characters and late blight resistance.

Evaluation of advanced stage hybrids at Ooty: Five advanced hybrids were evaluated in replicated trial with check varieties K. Girdhari, K. Himalini, K. Neelima, K. Swarna, K. Jyoti (sprayed and unsprayed). OS/07-14 (23.53 t/ha) recorded 60 and 52% higher yield than K. Girdhari (14.69 t/ha) and K. Himalini (15.50 t/ha). The hybrids was found resistant to both species of potato cyst nematodes and field resistant to late blight.

Evaluation to identify photo-insensitive/day-neutral hybrids at Modipuram: Thirty-five hybrids were evaluated along with controls in three trials for adaptability under subtropical plains. Hybrids, SM/00-120, SM/01-07 and VMT 5-1 (Trial-1) yielded significantly higher than the K. Jyoti and statistically at par with the K. Bahar.

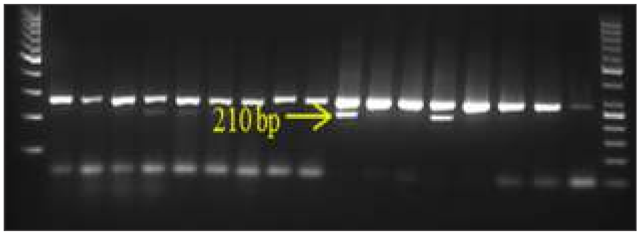


Fig. 15. Screening of late blight resistance gene R1 by CosA marker showing 210 bp product.

These hybrids are resistant to late blight also. Hybrids with combined resistance to late blight and PVY viz., LBY-2 & LBY-17 and 4 meiotic tetraploids (MTs) viz., HR 2-2, HR 5-1, HR 7-5 and HR 9-4 (Trial-2) yielded statistically at par or higher than the best yielding control K. Bahar. Four MTs viz., VMT 2-3, VMT 3-1, VMT 5-3 & VMT 11-7 **(Trial-3)** yielded statistically at par or higher than the best control.

Molecular Breeding

Hybridization and early evaluations: Hybridization was done so as to combine multiple resistance genes in a common genotypic background mainly for late blight (R1 and R3a), PVY (Ry*adg*, Ry*sto*) and potato cyst nematodes (*H1, HC_QRL* and *Gro1-4*) resistances using molecular markers. A total of 19,157 hybrid TPS were obtained from 10 successful crosses. Fifty clones were selected from seedlings transplanted from 6000 TPS of 8 crosses based on the agronomic traits and late blight resistance. Identified clones with stacked R genes for late blight resistance and phenotypic traits were promoted to advanced generations (**Fig. 15**).

Parental acquisition and molecualr characterization: Two recently imported novel late blight and virus resistant genotypes viz., Toluca (blb2) from The Netherlands and Sarpo Mira (R3a, R3b, R4, Ny-Smira, Rpi-Smira1 and Rpi-Smira2) from Denmark were validated for the presence of respective genes for introgression of S. *bulbocastanum* and Sarpo Mira derived resistance genes into breeding programme using MAS. Besides, five germplasm accessions viz. CP4496, CP4500, CP4490, CP4491 and CP4493 possessing Potato leaf roll virus resistance were imported from CIP, Lima, Peru. Validation of PLRV resistance genes, Rladg and Plrv.4 was done using SSR marker STM0013 and SCAR marker RGASC 850, respectively **(Fig.16).**

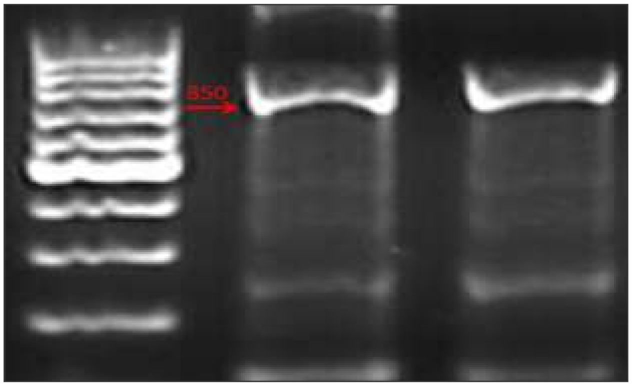


Fig. 16. Validation of PLRV gene Rl adg gene in resistant positive CIP clones (390478.9 & 3930.73.197) using SCAR marker RGASC 850. PCR product corresponds to band at 850 bp. marker.

Characterization of parental lines & advanced hybrids for PCN resistance: A total of 77 genotypes including parental lines, cultivars and advanced hybrids were genotypically screened for PCN resistance with reported molecular markers. Sixty one genotypes were positive for *H1* gene (*G. rostochiensis*), while 3 genotypes viz., CP2066, CP3252 and K. Swarna possessed *Gpa5/Gpa6* genes and 24 genotypes possessed *HC_QRL* conferring resistance against *G. pallida*.

Research activity 4: Breeding for abiotic stresses (Heat and water)

Breeding for heat tolerance

Hybridization: In all 2,76,262 true potato seeds from 84 successful crosses were obtained from hybridization at Kufri/Modipuram involving parents having heat tolerance and earliness.

Seedling stage: In all 5,970 seedlings were recovered from 18,569 TPS of 6 crosses and at harvest, 252 selections were made. At Shimla 1600 seedlings from 13 crosses were screened in a heated glass house and 110 selections were made.

Initial clonal stages: At Modipuram 338 clones of F_1C_1, F_1C_2 & F_1C_3 were multiplied and evaluated during normal planting season and at harvest 56 clones were retained.

Evaluation of advanced stage hybrids at Modipuram: Forty one advanced hybrids of F_1C_4 to F_1C_6 were evaluated in two trials during early planting conditions under heat stress at 75 DAP. In preliminary yield trial, eight hybrids were selected including HT/12-751 (20 t/ha) and HT/12-0830 (15 t/ha) as compared to K. Surya (14 t/ ha). In confirmatory yield trial, nine hybrids were selected including HT/10-1559 (18 t/ha), HT/10-2816, HT/10-908 HT/7-1329 (16 t/ha) compared to K. Surya (16 t/ha).

Evaluation of advanced stage hybrids at Satara and Ladol: At Satara (Maharashtra), among the nine advanced hybrids evaluated along with two controls in replicated trial under Kharif planting season at 80 DAP, HT/7-1329 (16 t/ha) and HT/7-620 (15 t/ha) produced high tuber yield as compared to K. Jyoti (14 t/ha) and K. Surya (11 t/ha). At Ladol (Gujarat), among, eight advanced hybrids evaluated along with two control varieties in replicated trial under early planting season at 90 DAP, the significantly higher total tuber yield was obtained in HT/10-1559 (76 t/ha), HT/7-620 (72 t/ha) and HT/10-1540, HT/7-1329 (68 t/ha) as compared to K. Surya (58 t/ha).

Identification of promising advanced hybrid: Based on two year performance during early planting season at Modipuram (UP), Ladol (Gujarat) and Pune (Maharashtra) advanced stage hybrid HT/07-1329 (LT-9 x CP1748) has been identified. It produced 6%, 12% and 23% higher total tuber yields at Modipuram, Pune and Ladol respectively over the best control K. Surya. It produces white cream, oval tubers, shallow eyes and light yellow flesh. Hybrid possesses 20% dry matter, medium dormancy period and very good keeping quality under country store conditions **(Table 7, 8).**

Assessment for leaf hopper and mite burn at Modipuram: Due to negligible population of leafhopper hence there was less hopper-burn. Among the 54 genotypes tested HT/10-123, HT/11-2912, HT/12-34, HT/12-106, HT/12-399 and HT/12-751 had around ≤10% mite burn 10% and hopper burn ranged from 0-5.0%.

Fig.17 Leaf, Tubers and Sprout of HT/7-620

Advanced stage hybrids introduced in AICRP: The hybrid HT/07-620 (K. Jyoti x K. Surya) was introduced into AICRP for multi-location testing based on two year performance during early planting season (2013 and 2014) at Modipuram, Ladol (Gujarat) and Satara (Maharashtra). It produced 55%, 33% and 26% higher total tuber yields at Modipuram, Satara and Ladol respectively over the best control K. Surya. It possesses light yellow, round oval tubers, shallow eyes and light yellow flesh **(Fig.17).**

Screening of advanced hybrids for heat tolerance under controlled conditions: Seventeen advanced hybrids (in two sets) along with K. Surya, K Lauvkar and K. Chandramukhi were tested for their ability to tuberize at 24/24 °C and 24/22 °C day/ night temperature by leaf bud cutting technique. In both the sets, hybrids HT/10-1559, HT/10-1540 and HT/10-1907 had better tuberization efficiency at both 22 and 24C night temperatures **(Fig 18).**

Biomass allocation with reference to growing degree days for heat tolerance in early planted crop: Biomass distribution were carried out in K. Bahar (popular variety of the region) and K. Surya (heat tolerant) in early and main planted crop. Growing degree days (GDD) were calculated by taking average of the daily maximum and minimum temperatures compared to a base temperature (8°C) following equation: [{(Tmax +Tmin)/2}-8] with the temperature data starting from the day of seed withdrawal from cold store. K. Surya showed its distinct habit of growth pattern as it invested more biomass in stem (4.8 g/plant) and root (4.22g) as compared to K. Bahar (3.24 and 2.22 g/plant, respectively) at around 1000 GDD in early crop. Leaf area expansion in K. Surya was fast and higher (3300 cm^2) than in K Bahar (2800 cm2) and plant height was lesser than K. Bahar giving a compact canopy, a preferred trait for heat stress conditions. This trend was repeated at 60 days as well suggesting a better tolerance in K. Surya **(Table 9).**

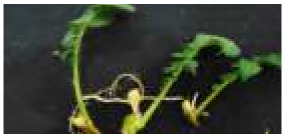
Variety/ hybrid 24/22C	**K. Surya** 	**HT/10-1559** 	**HT/10-1540** 	**HT/10-1907** 
24/24C				

Fig.18. Photographs showing tuberization efficiency in advanced hybrids

Evaluation of K. Khyati for early planting at Jalandhar: The performance of K. Khyati was compared with K. Surya and K. Pukhraj during early planting (planting on 1st &10th September and harvesting at 60, 75 & 90 days after planting). Tuber yield increased in all the varieties with advancing date of planting as well as date of harvesting. K. Surya is best suited for first fortnight of September planting and K. Pukhraj for planting after first fortnight of September.

Breeding for drought tolerance

Seedling stage: 181 clones were selected from 6350 seedlings transplanted from sowing of 44000 seeds of 15 crosses.

Initial evaluation stage: In initial clonal stages, 1506 clones of F_1C_1, F_1C_2, F_1C_3 & F_1C_4 were multiplied and evaluated during normal planting season and at harvest 257 clones were retained.

Evaluation of advanced hybrids of WS/2010 series for drought tolerance: Six genotypes along with control. K. Bahar and K. Pukhraj were assessed under water stress and well-watered control. Response to root pulling force (RPF) varied among genotypes and total tuber yield was recorded better in genotypes showing enhanced (> 20 Kg/plant) RPF values at 50 to 55 DAP under stress conditions. Considering the yield performance only three hybrids WS/10-705, WS/10-808 and WS/10-819 were picked up for further evaluation in replicated trial.

Evaluation of advanced hybrids of WS/2007 & WS/2009 series for drought tolerance: Six hybrids were assessed under water stress and well-watered control along with K. Bahar and K. Pukhraj. Irrigations were regulated to be in equal quantity of water, using Parshall Flume. Total irrigations were three (10 and 27 Nov.2015 and 22 Dec, 2015) in control and two (10 Nov, 2015 and 4th Jan 2016) in water stress plots. Besides, winter rains were received in single spell (7.0 mm on 5th Nov 2015). Based on total yield both under control and stress conditions along with crop vigour and tuber traits, hybrids WS/05-605 and 625 were selected.

Evaluation of drought tolerant hybrids at Jalandhar: Seven advanced hybrids were evaluated along with three varieties K. Lauvkar, K. Pukhraj and K. Arun under water stress conditions at 90 DAP. Treatments included control plots (T1) irrigated when evaporation in the open pan reached 20 mm and stress treatments (T2) by restricting irrigation till evaporation in the open pan reached 40 mm. Controls received 5 irrigations and the stressed treatment received 4 irrigations. Rainfall during the crop season was 23.2 mm in one spell during October. WS/07-145 and K. Lauvkar did not show any reduction in yield due to stress, whereas other genotypes showed 4-23% reduction in yield due to stress. Hybrid WS/07-113 followed by WS/07-132 showed highest yield under both treatments. All the seven hybrids were retained for further confirmation.

Evaluation of advanced hybrids for higher yield and water use efficiency: Advanced hybrids WS/07-113 and WS/07-131 along with K. Bahar and K. Pukhraj were evaluated (90 DAP) at three soil moisture regimes *viz.* 0.20-0.25, 0.40-0.45 & 0.60-0.65 bars/atm. The total water (including effective rainfall) was applied viz. 350, 300 and 250 mm under wet, moist and semi-dry regime, respectively during entire crop season. WS/07-113 and WS/07-131 produced tuber yield significantly at par with K. Bahar at all soil moisture regimes. These were also found promising for higher water use efficiency comparison to variety K. Bahar. However, these advanced hybrids were found less productive in than K. Pukhraj at wet, moist and semi-dry soil moisture regimes (0.20-0.25, 0.40-0.45 and 0.60-0.65 bars) when total 350, 300 and 250 mm irrigation water was applied, respectively.

Evaluation of advance hybrid for fertilizer dose under water stress: Advanced hybrids WS/07-113 was evaluated along with control K. Bahar at 90 days at three fertilizer levels 75, 100 and 125% of 180-60-100 N-P-K kg/ha. WS/07-113 (23.5 t/ha) attained significantly better mean marketable tuber yield (30.6%) over control K. Bahar (18.0 t/ha). Hybrid WS/07-113 (22.3 t/ha) recorded maximum marketable tuber productivity under mild water stress, which was 51.0% higher over control K. Bahar (14.7 t/ha). Application of 100% N-P-K was sufficient for this hybrid (25.4 t/ha) as it was markedly better over 75% N-P-K (23.6 t/ha), while remaining comparable at 125% of N-P-K (25.1 t/ha.

Optimizing NPK requirement of WS/05-146 under water stress conditions: The hybrid under mild water stress (3 irrigations) showed that N level of 180 kg/ha had significantly better marketable tuber yield (24.7 t/ha) over control and lower levels (12.0- 21.5 t/ha), while it remained statistically at par with 240 kg N and better over 300 kg N/ha **(Fig 19)**. Hybrid WS/05-146 exhibited no response towards P_2O_5 application in term of tuber productivity due to medium and higher availability of phosphorous in soil. Moderate potassium application (100 kg K_2O/ha) was better for improving tuber yield in hybrid WS/05-146 as this level attained maximum and significantly better marketable tuber yield (23.8 t/ha) over control and lower dose (18.9- 21.6 t/ha).

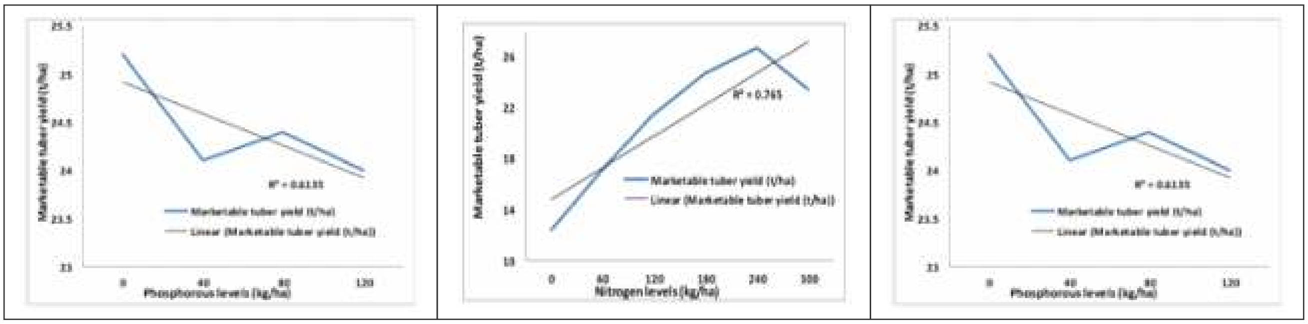


Fig. 19. NPK requirement of WS/05-146

Proteomic dynamics of potato plants in response to drought stress: In order to see how the proteome of potato plants behaves in response to drought stress, plants were subjected to drought stress and leaf and roots were harvested and used for protein extraction.

Extracted proteins were separated using two-dimensional gel electrophoresis. Comparison of protein profiles of drought stresses vis-a-vis control plants revealed number of proteins differing in the abundance ***(Fig. 20).*** These proteins differed in their molecular weights and isoelectric points. Identification of these proteins is in progress.

Evaluation of dwarf transgenic lines for plant height and tuber yield: Four dwarf transgenic lines were investigated for morphological and tuber yield attributes. Transgenic lines were shorter than the control K. Surya except KS1 which had plant height similar to control plants. Tuber number/plant was higher in transformed plants. All the transgenic lines yielded better than control with KS-13 giving the highest yield of 220g/plant followed by KS-1 (160 g), KS-8 (155 g) and KS-11 (140 g) compared to control K. Surya (110 g/plant). Twenty two dwarf transgenic lines of K. Himalini were also evaluated. Only two transgenic lines showed plant height lower than control, however their tuber yield was lower than control ***(Table 10).***

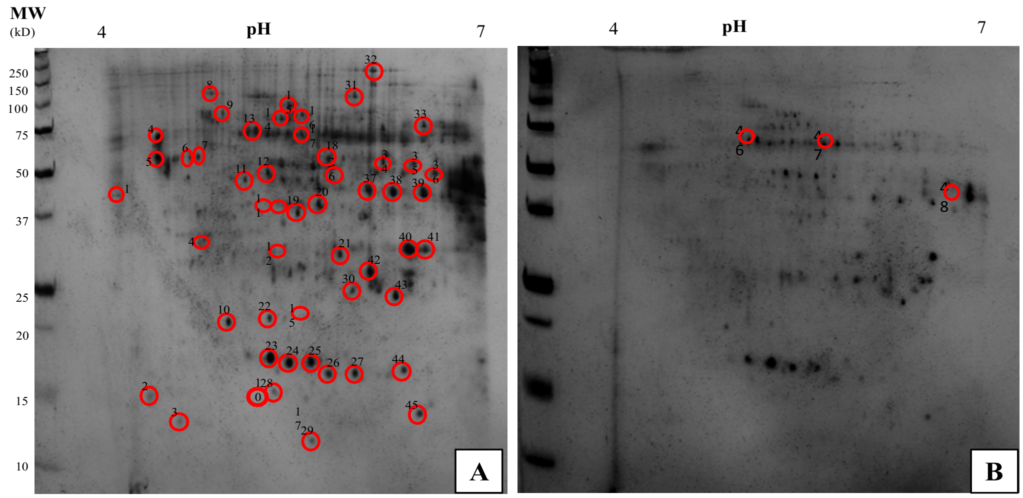


Fig. 20. Two dimensional gel electrophoretic analysis of proteins of roots from potato plants. A: roots of control plants; B: roots of drought stressed plants.

Research activity 5: Breeding for Kharif potatoes

Thirty five parental lines identified for kharif potato breeding were used for hybridization and 42355 true potato seeds were obtained from 45 successful crosses.

Table 7. Performance and attributes of advanced hybrid HT/7-1329 at Modipuram

Genotypes	MTY/ha		Mean	TTY/Ha		Mean	DM%		Mean	% Mite burn*	% TWL #
	2014	2015		2014	2015		2014	2015			
HT/07-1329	8.59	12.95	10.77	9.81	15.54	12.68	20.50	20.33	20.42	20	8.5
K. Lauvkar	6.88	10.99	8.94	7.81	12.71	10.26		17.14	17.14	65	-
K. Surya	7.36	14.37	10.87	8.31	15.56	11.94	19.2	19.06	19.13	15	10.6
CV (%)	9.77	9.04		8.56	8.79			2.18			
CD (0.05)	1.35	2.03		1.33	2.18			0.68			

*Leaf hopper did not occur, #Total wt loss after 75 days of storage

Table 8. Performance and attributes of advanced hybrid HT/7-1329 at Ladol and Pune

Genotypes	Ladol							Pune			
	Marketable tuber yield t/ha			Total tuber yield t/ha			General impression	Total tuber yield t/ha			Foliage Maturity
	2014-15	2015-16	Mean	2014-15	2015-16	Mean		2014	2015	Mean	
HT/7-1329	41.43	66.62	54.03	42.33	68.08	55.21	4.70	18.33	15.67	17.00	70.30
K Surya	31.52	55.93	43.73	31.86	57.86	44.86	4.80	19.16	11.24	15.20	65.00
K Jyoti	-	-	-	-	-	-	-	-	13.80	13.80	68.30
CV (%)	4.098	3.82		4.588	3.69			4.08	4.26		
CD (0.05)	2.392	4.32		2.758	4.29			1.39	0.96		

Table 9. Effect of growing degree days (GDD) on morpho-physiological traits and biomass distribution pattern in potato varieties

Days / GDD	Variety	Plant height (cm)	Leaf area (cm^2)	Tubers/plant	Dry weight (g/plant)					AG/ BG@
					Leaves	Stem	Root	Tuber	Total	
Early Crop (planted on 29/9/2015)										
35 (1019)	K.Bahar	19.1	2800	0.0	8.61	3.24	2.22	0.00	14.07	5.34
	K.Surya	16.6	3390	0.0	6.36	4.80	4.22	0.00	15.38	2.65
60 (1323)	K.Bahar	24.3	6322	5.7	8.43	2.72	1.68	9.05	21.89	1.04
	K.Surya	25.0	5515	5.3	6.69	4.55	1.15	9.45	21.84	1.06
Main Crop (planted on 22/10/2015)										
35 (654)	K.Bahar	17.6	6403	5.8	7.56	2.69	1.36	9.34	20.95	0.96
(1437)*	K.Surya	17.0	5228	4.4	8.28	2.71	1.33	10.36	22.68	0.94
60 (864)	K.Bahar	20.2	4042	3.4	7.81	5.27	2.52	13.24	28.83	0.83
(1741)*	K.Surya	19.6	7109	4.0	9.12	3.07	3.06	11.49	26.74	0.84

*Seed was withdrawn in September, @ Ratio of above ground biomass to below ground biomass

Table 10. Performance of dwarf transgenic lines in net house at Jalandhar

Transgenic lines/controls	Shoot length (cm)			Number of leafs			Tubers/plant	Tuber yield (g/plant)
	50 DAP	70 DAP	90 DAP	50 DAP	70 DAP	90 DAP		
KS1	63.5	67.8	73.3	13.3	14.5	15.9	4.3	160
KS8	13.8	15.5	17.0	12.3	12.8	13.5	3.4	155
KS11	13.3	14.0	15.5	11.9	12	12.9	3.1	140
KS13	31.6	32.5	33.4	12.8	12.9	13.5	3.6	200
K. Surya	59.2	65.4	72.5	12.2	14.2	15.5	2.7	110
KH44	35.8	44.0	46.6				6.8	200
KH45	24.0	27.8	31.4				6.2	160
K. Himalini	75.6	81.0	89.4				9.8	220

Genetic enhancement of potato through molecular and genomic tools

Structural and functional genomics

Genome Sequencing of *Rhizactonia solani* [Anastomosis Groups (AGs)] strain RS-20, causes stem canker and black scurf of potato: The fungus *Rhizoctonia solani* Kühn (teleomorph *Thanatephorus cucumeris* [A. B. Frank] Donk) is responsible for many economically important plant diseases worldwide and anastomosis groups (AG's). AG3-PT (The potato type) is the main causal agent of stem canker and black scurf of potato in India. Looking at the importance of the pathogen, whole genome sequencing of the Rhizactonia solani (AG3-PT), strain RS-20 was carried out. Two shotgun sequences yielded high quality 2,827,025 reads amounting to 1031,371,409 bases amounting to 17-fold coverage of its estimated 80 Mb genome. The GS De Novo Assembler (version 2.5.3) yielded 21,475 contigs (over 500 bp). The draft genome of strain RS-20 has G-C content of 48.3%, and gene prediction using the eukaryotic GeneMark.hmm (Version 2.2a) and AUGUSTUS revealed a total of 11,431 protein coding regions (CDSs). This number is very close to the predicted genes number of *AG1-IA* (10,489), *AG1-IB* (12,616), *AG2-IIIB* (11,897), *AG3*, *strain Rhs-1AP* (12,726) and *AG8* (13,964) **(Table 11).**

Table 11: List of sequenced *Rhizactonia solani* species complex and their genome characters

Rhizactonia solani-AG	Strain	Host	Seqd Size (Mb)	Contigs reported	GC Content (%)	Genes Predicted	tRNA	rRNA	Reference
AG3-PT	RS-20	Potato	55.85	30,594	48.30	11,431	181	31	This study
AG1-IA	AG1IA	Rice	37.80	2,648	47.61	10,489	153	18	Zheng *et al.* 2013
AG1-IB	7/3/14	Rice	52.74	23,355	48.10	12,616	187	22	Wibberg *et al.* 2015
AG8	WAC10335	Potato	35.92		48.80	13,964	105	20	Hane *et al.* 2014
AG3	Rhs_1AP	Potato	52.50	6,040	48.40	12,726		17	Cubeta *et al.* 2014
AG2 IIIB	BBA69670	Sugar Beet	56.02	5,826	48.34	11,897	135	15	Wibberg *et al.* 2016

Mapping of the mitochondrial genome of *Phytophthora infestans* [A2 mating type]: Mitochondrial genome of *Phytophthora infestans* (A2 mating type) was sequenced and mapped. The genome size of 37,767 bp, possesses a GC content of 22.38%. Total 53 protein coding genes were predicted on both strands which included 25 tRNA, 2 rRNA, and 18 respiratory protein coding genes. The gene order of A2 mating type was consistent with that established in all haplotypes of A1 types, despite of high level of polymorphism in both coding and non-coding regions. The highest variation was observed in non-coding region. A large spacer flanked by the gene coding for tRNA-Tyr (trnY) was found that varied in size with all A1 types. The mt DNA of A2 mating was found to have 99.5 and 99.4% homology with Ia and Ib and 94.7 and 94.3% with

IIa and IIb haplotypes of A1 mating types respectively **(Fig. 21).** The study of repeats revealed that a dinucleotide (AT)9 is found to be specific to A1 mating type. Homology study of complete cox1 gene sequence revealed the relationship among 50 different Phytophthora species.

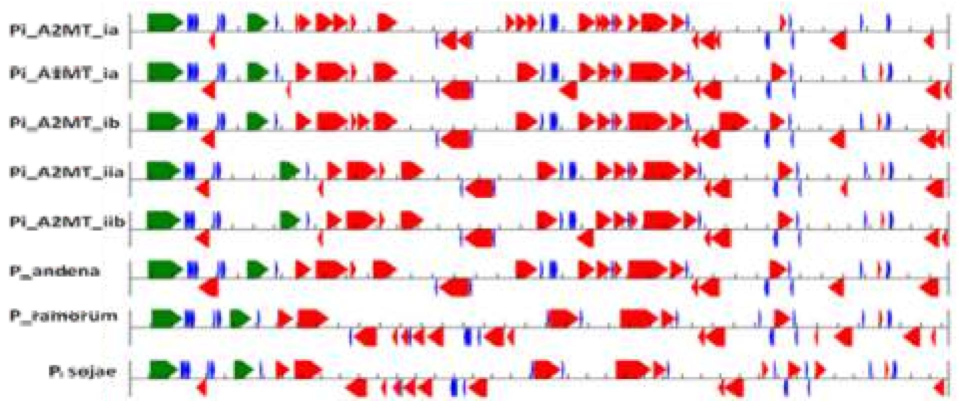


Fig. 21. The mitochondrial genome homology among the Phytopthora infestans

In Silico prediction of RxLR effectors of Phytopthora infestans: *P. infestans* is one of the most destructive pathogen of potato causes late blight disease. Protein effectors of pathogenicity are instrumental in modulating host immunity and disease resistance. *RxLR,* a class of cytoplasmic effectors characterized by highly conserved region and abet in parasitic colonization of this hemibiotrophic pathogen by modifying the host defense system. The *RxLR* effector genes were predicted in the *P. infestans* genome (isolate HP10-31, A_2 mating type, 162 Mb) using homology search method. The evaluation of resultant structure by RAMPAGE, ERRAT and VERIFY-3D program showed the acceptability of residues in the predicted structure. Nudix motif, NAD(P) and S-adenosyl methionine conserved domains were identified in the proteins along with Clefts and ligand binding sites **(Fig. 22).**

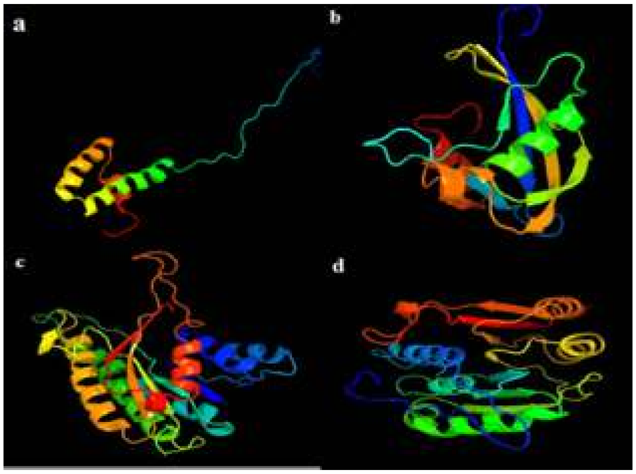


Fig. 22. Predicted 3D structure of RxLR effectors of Phytopthora infestans HP-10-31 (N to C terminus). a) contig28905_8; b) contig20412_6; c) contig15921_2; d) contig06738_6

RNA sequencing of *Solanum demissum* for late blight resistance: The wild species *S. demissum* is one of the major sources of resistance to late blight. To discover the new resistance genes, total RNA sequencing of this species was performed onto the Ion Proton platform to analyse the novel trascriptomes. Expression profiles obtained from the transcriptome data and mapping to the potato reference genome it showed differential responsive genes 651 (at 24 hpi), 989 (48 hpi) and 926 (at 96 hpi). To identify the unique gene for each stage, developed venn diagram depict 199 common genes, which are uniformly distributed/expressed **(Fig. 23)**. Most of the highly upregulated genes belong to cellular and signalling network genes, like ubiquitin mediated F-box protein, cellular response, resistance related metabolites as well as R genes and pathogenesis related genes etc. These ubiquitin protein complexes, F-Box were hypothesised as activating downstream signalling process involved in various cellular activities including defense mechanism.

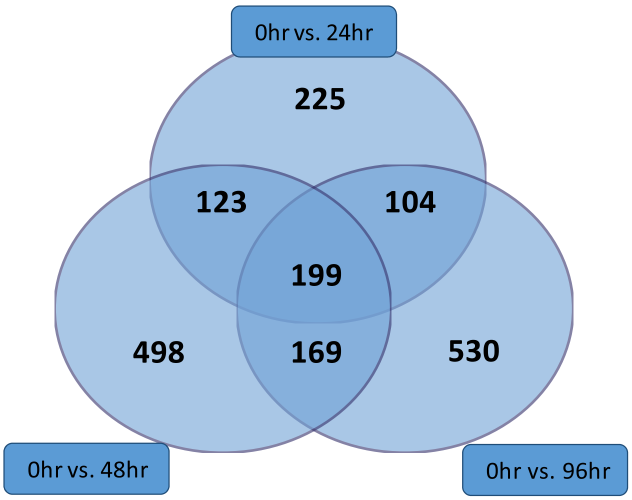


Fig 23. Venn diagram depicting the unique genes of Phytophthora infection in Solanum demissum.

Genetic transformation of potato cultivar with *Proline rich protein, Steroid binding protein, SGT* and gene of unknown function for late blight resistance: Differentially expressed genes of Kufri Gridhari in response to *P. infestans,* revealed 532 genes at 10 fold expression change, and validated 10 genes for authenticity of microarray expression profile. Five genes belong to cellular and R gene upstream signalling network were selected for enhancing late blight resistance in potato cultivars. All five genes were amplified, sequenced and cloned in plant binary vector pRI201 harbouring CaMV35S and translation enhancer promoter. Used *Agrobacterium tumefaciens* GV1301 for genetic transformation of Kufri Jyoti, Kufri Bahar using internodal stem cuttings as explant and regenerated 50-100 calli for each constructs **(Fig. 24).**

Fig. 24. Restiction digestion of EHA105 plasmid confirmed the integration of 1.16 kb of SGT into plant transformation binary vector pRI201 and genetic transformation into potato cultivar Kufri Jyoti.

Transcriptome dynamics in response to drought stress in potato: Water being one of the major inputs for potato cultivation and frequent occurrence of drought has posed a major challenge for its management. In order to have broader picture of the effect of drought stress on transcriptomes dynamics in potato, leaf and roots tissue from control and drought stressed plants. mRNA sequencing libraries were constructed and sequencing was performed on Ion Torrent™ platform. Comparative analysis of the leaf transcriptome revealed that in response to drought stress expression of ~120 and 410 genes were found to increase by > 10 and 5 fold, respectively. Similarly, ~140 and 560 genes exhibited > 10 and 5 fold decrease in their expression in response to drought stress. In case of roots, drought stress resulted in >10 and 5 fold increase in expression of ~950 and 1490 genes, respectively **(Fig 25)**.

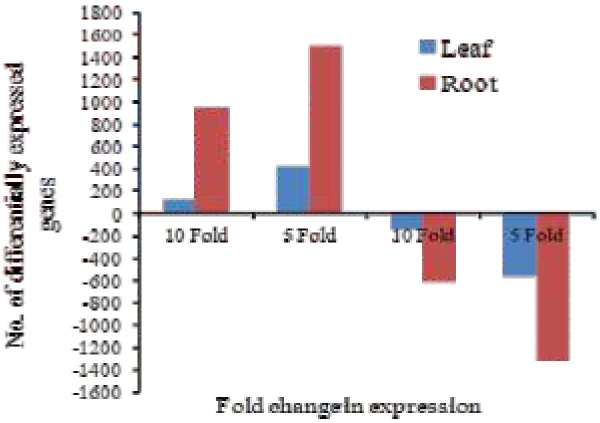


Fig. 25. Number of up- and down-regulated genes in response to drought stress in potato.

Potato SWEET gene family of sugar transporters for enhancing the productivity: SWEET (*Sugars Will Eventually get Exported Transporter*) proteins are novel family of sugar efflux transporters having involvement in diverse physiological functions such as sugar efflux, apoplasmic phloem loading, biotic and abiotic stresses and reproductive tissue development. Genome-wide identification and expression profiling of SWEET genes have been performed in potato. A total of 37 potato SWEET genes were identified and mapped to their respective chromosomes. On the basis of TMDs, potato SWEET proteins were categorized as SWEETs (62%) and Semi-SWEETs (38%). Our results indicated the highest number of cis-acting for abiotic stress (StSWEET220), biotic stress (StSWEET5), hormone-responsive (StSWEET36) whereas, all SWEETs are enriched with light-responsive elements **(Fig 26).**

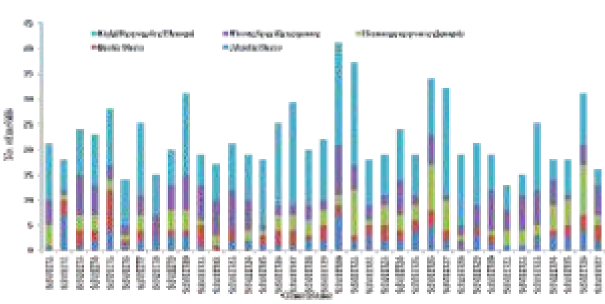


Fig. 26. Kinds and numbers of cis-acting elements in the upstream regions of potato StSWEET genes

Phenotyping for heat stress tolerance of potato: Developing an accurate method for thermotolerance phenotyping is essential for breeding heat tolerant varieties. Three methods were adopted for thermotolerance phenotyping of potato viz., tuberization in potted plants, leaf bud cuttings and *in-vitro* microtuberization. Four potato genotypes namely Kufri Surya (tolerant), Kufri Chandramukhi (sensitive) and two germplasm (CP4398 and CP4054) were screened. Both cuttings as well as whole potted plants were grown under temperature treatments (24/18^{0}C day/night and 24/24^{0}C day/night) with a 12-h photoperiod. Tuber formation was observed on 21 day in cuttings and potted plants. Tubers were formed in Kufri Surya (KS) at 18^{0}C and 24^{0}C whereas heat sensitive genotype, Kufri Chandramukhi (KCM) tuberized only at 18^{0}C. CP4398 also tuberized at both the temperatures and thus had at par thermotolerance with KS **(Fig. 27).** CP4054 did not show any tuberization at both the temperatures after 21 days and therefore could be late maturing. Both methods, tuberization in potted plants and leaf bud cuttings were clearly able to discriminate the thermotolerance levels of potato genotypes, while *in-vitro* tuberization method was not conclusive for screening potatoes.

Expression analysis of Constans (CO)/SP6A genes involved in potato tuberization: Expression of five genes of CO/SP6A axis, i.e., StSP6A, StSP5G, Gigantea, StCO and StCDF was studied using real time PCR in 8 genotypes including thermo-tolerant variety, Kufri Surya and thermo-sensitive Kufri Chandramukhi. At elevated temperature (24 °C) 3 genes viz., StSP6A, Gigantea, and StCDF were up-regulated, while StSP5G and StCO were down regulated in thermotolerant variety Kufri Surya. Other thermotolerant genotypes like CP4398, also presented similar expression pattern **(Fig.28)**.

Fig 27. Tuberization in whole potted plants and leaf bud cuttings methods potato genotypes CP 4398, Kufri Surya and Kufri Chandramukhi (KCM) at 24^{0}C

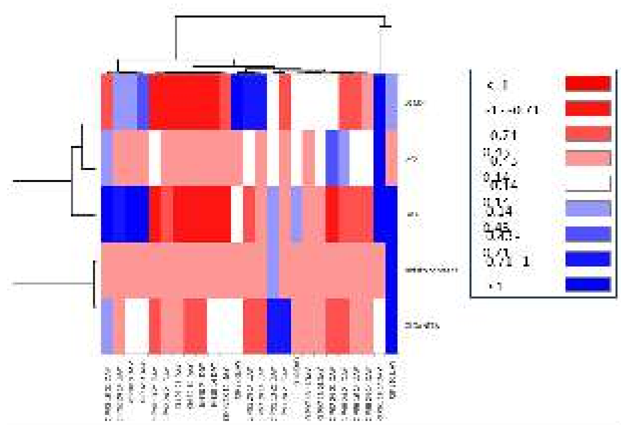


Fig. 29. RT-PCR expression analysis of genes related to tuberization in potato

Allele mining for late blight resistance genes of potato wild species: Eleven highly resistant wild species were identified for late blight resistance through testing by challenge inoculation of *P. infestans* for allele mining of potato R (resistance) genes. The selected species were namely S. *berthaultii, S. cardiophyllum, S. iopetalum, S. jamesii, S. lesteri, S. microdontum, S. pinnatisectum, S. polyadenium, S. polytrichon, S. trifidum* and *S. verrucosum*. The potato R genes *(Rpi-pta1, Rpi-edn1.1*, EDNR2GH7, *Rpi-hjt1.1*, SNKR2GH5, *Rpi-snk1.1, Rpi-blb1/RB, Rpi-vnt1.1, Rpi-bt1, Rpi-sto1, Rpi-blb2*, *RGA1, RGA3* and *RGA4)* conferring resistance to late blight were used for allele mining through cloning of full genes from these wild species. From these above species, homologues of *Rpi-pta1* gene was isolated from the wild species S. *microdontum*, cloned into a binary vector pRI101-AN and checked the insert with restriction enzymes *KpnI-Eco*RI & PCR **(Fig. 30b, c, d).** The phylogenetic analysis of the nucleotide of identified/isolated genes so far and the known late blight resistance genes was carried out using the software program Molecular Evolutionary Genetics Analysis 6 (MEGA6) using the Neighbor-Joining method with 1000 replications **(Fig. 31).**

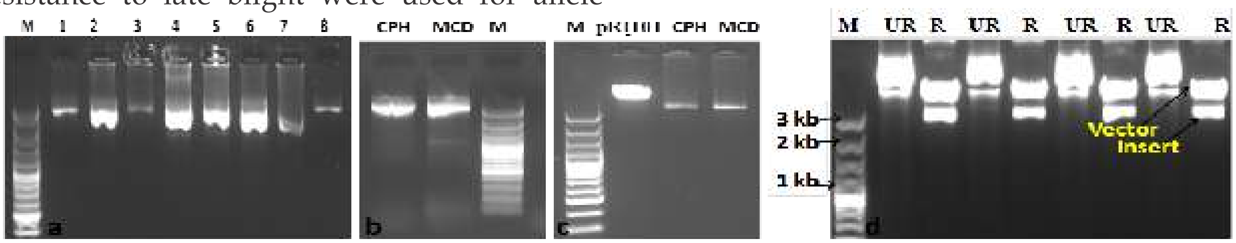


Fig. 30. a) PCR amplification and cloning of late blight resistance genes isolated from the wild potato species. CPH: S. cardiophyllum; MCD: S. microdontum

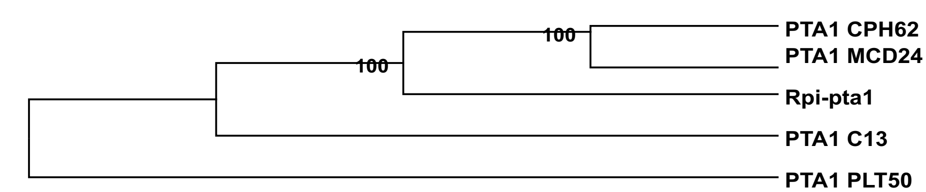


Fig. 31. A phylogenetic analysis of the sequences of isolated genes from the wild species S. cardiophyllum and S. microdontum with known potato R gene.

Somatic hybridization

Hybridity confirmation by molecular markers: Four hybrids (Crd-6, Crd-10, Crd-16 and Crd-23) were confirmed as true somatic hybrids by RAPD, ISSR, SSR and AFLP markers. True somatic hybrids were confirmed by the presence of diagnostic bands of the parents C-13 and S. cardiophyllum. To illustrate, **Fig. 32** shows STI0012 profiles of somatic hybrids with three diagnostic peaks (168, 170 and 183 bp), two in common with C-13 (170 and 183 bp), and another with *S. cardiophyllum* (168 bp). In addition, somatic hybrids were analyzed with 26 SSR markers on a high resolution gel, of which three (STM0031, STM1052 and STI0003) confirmed hybridity. In AFLP analysis there were several parental fragments identified in somatic hybrids that distinguished the hybridity.

Flow cytometer analysis: The ploidy level of the somatic hybrid regenerants was determined by flow cytometer (Partec PA II) following manufacturer's instructions. Ploidy level of the somatic hybrids was estimated by flow cytometry based on the nuclear DNA content of dihaploid control C-13. The nDNA content of all four somatic hybrids ranged between 3.72-3.81 pg/2C closed to the tetraploid control variety Kufri Jyoti (nDNA = 3.84 pg/2C). As a result it confirmed the tetraloid level of the somatic hybrids. Moreover, tetraploid level of the somatic hybrids was confirmed by the similar histogram peak position with Kufri Jyoti (4x) **(Fig. 33).**

Phenotypes and late blight resistance assay: Somatic hybrids were evaluated for phenotypes (leaf, tuber and flower traits) and found intermediate type to their parent **(Fig. 34i)**. Further, hybrids were tested twice for late blight resistance by challenge inoculation of *P. infestans* under controlled conditions. Hybrids were highly resistant (HR) (AUDPC = 0) in comparison to the susceptible control (Kufri Jyoti; AUDPC = 180-190) and highly resistant control (Kufri Girdhari; AUDPC = 25-30). In the assay, the susceptible controls Kufri Jyoti and C-13 (AUDPC = 155-160) were fully infected with late blight, while somatic hybrids and wild parent S. *cardiophyllum* had no infection of *P. infestans* under the controlled conditions ***(Fig. 34ii).***

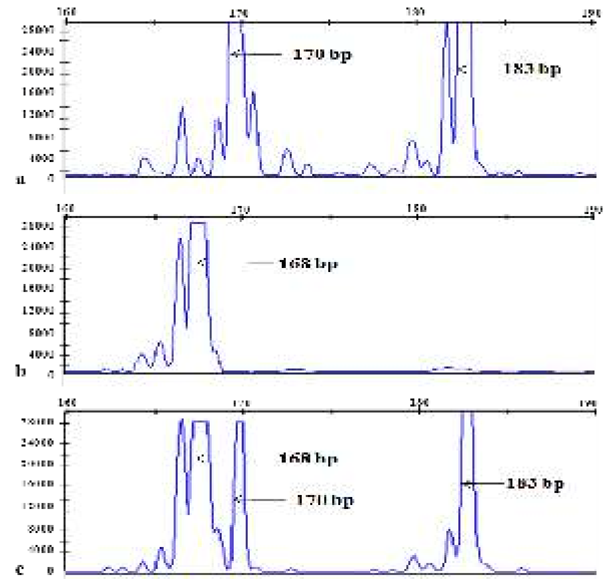


Fig. 32. SSR marker STI0012 confirmed hybridity of potato somatic hybrids C-13 (+) S. cardiophyllum possessing parental bands as indicated by arrow (a) C-13, (b) S. cardiophyllum, and (c) somatic hybrid.

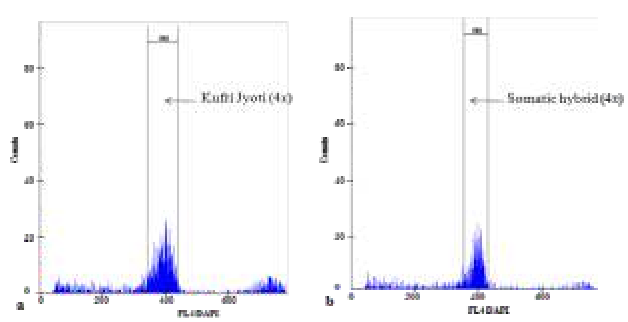


Fig. 33. Ploidy confirmation of somatic hybrids with control variety by flow cytometry analysis

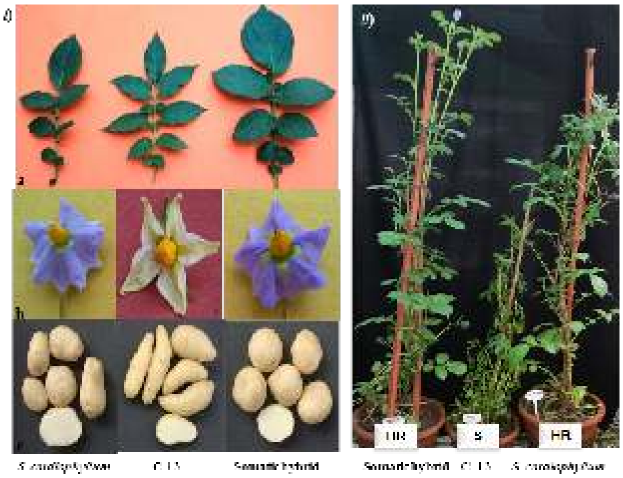


Fig. 34. i) Somatic hybrids between C-13 and S. cardiophyllum confirmed by phenotypes, and ii) late blight resistance test of somatic hybrids.

Evaluation of somatic hybrids under field conditions: Somatic hybrids (Crd 6, 10, 16, 23) derived from interspecific symmetric somatic hybridization between androgenic dihaploid C13 and wild species *S. cardiophyllum* (PI341233) were evaluated along with both parents under field conditions in replicated yield trial at 105 days after planting. All the somatic hybrids and parent *S. cardiophyllum* showed late foliage maturity than parent C13, which showed medium maturity. Somatic hybrid Crd 23 performed very poorly with very poor tuber yield and general impression than both the parents. None of somatic hybrid could produce higher total tuber yield than parent C13 (11.54 t/ha), however Crd 6 (9.03 t/ha), Crd 10 (8.94 t/ha) and Crd 16 (9.15 t/ha) produced significantly higher total tuber yield than parent *S. cardiophyllum* (6.72 t/ha). The general impression of Crd 6, Crd 10 and Crd 16 was just at par with parent S. cardiophyllum, however, other parent C13 showed good general impression **(Fig. 35).**

Fig. 35. Somatic hybrids of C13 (+) S. cardiophyllum

Evaluation in F_1C_2 segregation population: Fifty eight (58) F_1C_2 clones of 9 crosses (developed using somatic hybrids (C13 + *S. pinnectisectum*) as parent in combination with indigenous varieties) were evaluated in 30 tuber trial (duplicate row trial) at 90 days crop duration. At harvest 17 promising clones of 4 crosses were selected for evaluation in F_1C_3 stage **(Fig. 36).** The total tuber yield range was observed from 288 g/plant (MSH/14-115) to 734 g/plant (MSH/14-137). The clone showing to proximity toward somatic hybrids produced higher number of tubers but comparatively less tuber yield and average general impression than clones showing proximity toward indigenous varieties, which showed at par tuber number, tuber yield and general impression.

Fig. 36. F_1C_2 clones from crosses between somatic hybrids and indigenous varieties

Nitrogen use efficiency (NUE)

To unravel the sequence variations among the genes involved in nitrogen metabolism pathways, a total of 20 genes-specific primer pairs were designed and synthesised. Genes were selected for the various pathways such as N uptake/ transporters, utilization and assimilation from the potato and a few from the tomato genomes. Leaf samples were PCR amplified using genes-specific primers of genomic DNA from potato cultivars Kufri Jyoti (least N efficient) and Kufri Pukhraj (most N efficient).

Annealing temperature for each gene/primer was determined by the gradient PCR followed by cloning and sequencing sequence analyses of the genes involved in nitrogen metabolism pathways in potato **(Fig. 37).**

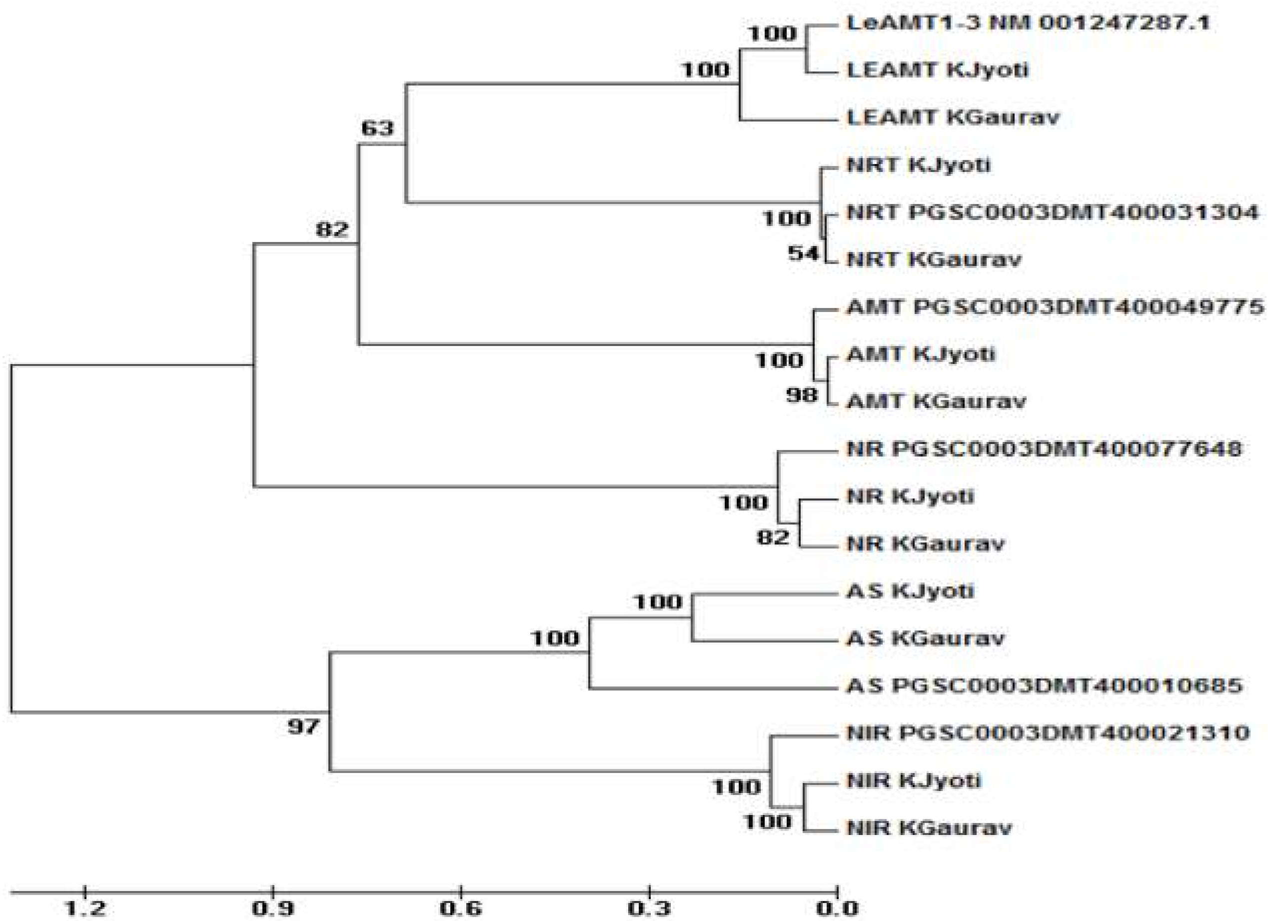


Fig. 37. Sequence variations of N metabolism genes in potato Kufri Jyoti (least N efficient) and Kufri Gaurav (most N efficient).

Division of Crop Production

Climate change impact and adaptation strategies for potato crop

Climate change has emerged as the most prominent of the global environment issues. Global climate has changed ever since industrial revolution. The atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have all increased since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases were 391 ppm, 1803 ppb, and 324 ppb, and exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all RCP (Representative Concentration Pathways) scenarios except RCP 2.6. It is likely to exceed 2°C for RCP6.0 and RCP8.5, and more likely than not to exceed 2°C for RCP4.5. Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Warming is expected to have grave consequences for mankind and the environment. CO_2 and temperature interactions are recognized as a key factor determining potato yield and damage from diseases and pests, thus necessitating the study of the impact of climate change on potato for developing suitable management strategies.

Climate change impact on potato productivity in West Bengal and adaptation strategies

The WOFOST (WOrld FOod STudies) crop growth simulation model was used to study the impact of climate change on potential potato productivity in West Bengal and also to devise the suitable management strategy to minimize the impact of climate change through selection of suitable variety and shifting the date of planting. The study was carried out for 13 locations of West Bengal. The simulation was done for baseline scenario and future climate scenario of 2020 and 2055 for three potato cultivars; Kufri Badshah (long duration), Kufri Jyoti (medium duration) and Kufri Pukhraj (short duration), for A1FI high emission scenario of temperature and CO_2. The potato productivity varied largely within the state under baseline scenario ranging from 31.2 to 46.9, 29.0 to 45.4 and 29.6 to 48.2, for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj, respectively. The mean productivity for respective cultivars was 38.9, 37.2 and 39.2 t/ha, when the point data of 13 locations was extrapolated over entire state using kriging. In general a decline in average productivity was observed on moving from Northern to southern part of the state to coastal parts ***(Fig. 1)***.

Simulation revealed that although the increase in temperature is likely to reduce the yield by 8.8 to 10.1% in 2020 and 23.7 to 28.8% in 2055, a corresponding increase in CO_2 may increase the yields by 4.5 to 4.7% in 2020 and 19.2 to 20.5 in 2055. However, under the combined effect of CO_2 and temperature, the highest decline of 6.1% in productivity of Kufri Pukhraj is expected followed by 5.9% in Kufri Jyoti and 5.1% Kufri Badshah in 2020, with corresponding figures of 12.0, 10.5 and 8.8% in 2055. Results further revealed that the negative effect of climate change on potato productivity can be counter balanced to some extent through change in date of planting and/or selection of suitable varieties. The model has shown that for Kufri Jyoti (2055 scenario) and for Kufri Pukhraj (both 2020 and 2055 scenarios) 10th November would be the best planting date. From the simulation studies, it appears that Kufri

Badshah has greater resilience against climate change and could be more suitable cultivar in the future climates than Kufri Jyoti and Kufri Pukhraj at all the locations. The productivity of Kufri Badshah was 4.3% higher than Kufri Jyoti in the base line scenario but in future scenario it increased to 5.2% (2055) and 8.2% (2020). Similarly, Kufri Badshah, which gave lesser yield than Kufri Pukhraj in the baseline year (2000), is likely to yield more than 3% higher in future climates. Hence with and advancement in 10 days in planting and by replacing the other two varieties with Kufri Badshah at all the five locations representing the state can bring down the reduction in yield from 5.7% in 2020 (without adaptation) to +1.3 to 4.4% (mean -1.5%) and in 2055 from 10.4% to -7.1%.

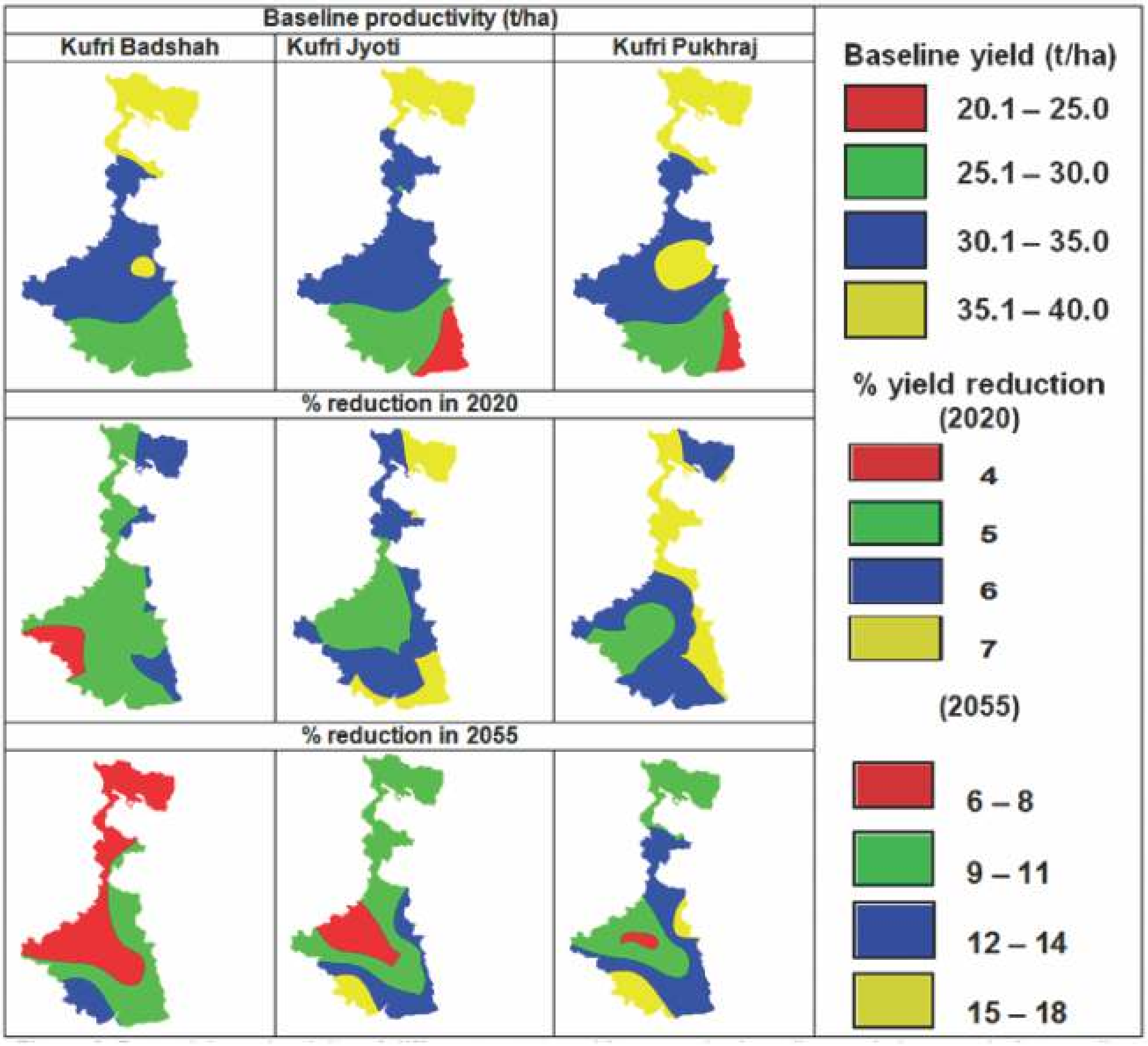


Fig 1. Likely productivity decline in different potato growing areas of West Bengal state under climate change.

Calibration of WOFOST crop growth model for potato cultivars Kufri Surya and Kufri Sadabahar.

WOFOST (WOrld FOod STudies) crop growth model estimates the growth of an annual crop, given a set of specific soil and weather conditions. Kufri Sadabahar is a medium maturing, main season, high yielding potato variety suitable for cultivation in Uttar Pradesh. Kufri Surya, released in 2006 is an early maturing, heat tolerant and hopper-burn resistant potato variety, meant for early (September) planting in north-western plains and for rabi and kharif plantings in peninsular India. WOFOST crop growth model was calibrated and validated for these two potato cultivars during current year using time course data on potato crop growth parameters generated at CPRIC Modipuram and CPRS, Jalandhar during 2011-12 to 2014-15. The model parameters used for calibration were; AMAXTB (maximum leaf CO_2 assimilation rate), DTSMTB (daily increase in thermal time as function of average temperature), TMNFTB (reduction factor of gross assimilation rate as function of low minimum temperature), DVS (development stage of crop), FLTB, FOTB, FSTB (Fraction of above ground dry matter increase partitioned to leaves, tubers and stems, respectively, as a function of development stage), SLATB (specific leaf area as a function of development stage), SPAN (life span of leaves growing at 35 ºC), TEFFMX (maximum effective temperature for emergence), TSUMEM (thermal time from sowing to emergence), TSUM1 (thermal time from emergence to tuber initiation), TSUM2 (thermal time from anthesis to tuber initiation).

The statistical performance analysis applied to model predictions is shown in ***Table 1*** below which shows a close match between simulated and field data for total dry matter production and tuber dry matter yield.

Table 1. Statistical indicators of performance of WOFOST model.

	Optimum value	Total DM yield (kg/ha)	Tuber DM yield (kg/ha)	Total DM yield (kg/ha)	Tuber DM yield (kg/ha)
		Kufri Sadabahar		Kufri Surya	
ME		1151	534	1250	1071
RMSE	0	7.56	6.47	7.54	10.49
CRM	0	0.03	0.06	0.05	0.03
EF	1	0.98	0.99	0.98	0.99
CD	1	1.01	0.94	1.09	0.95

Table 2. Comparison of measured (mea.) and simulated (sim.) values of some important parameters.

Parameter	Mea.	Sim.	Diff.	Mea.	Sim.	Diff.
	Kufri Sadabahar			Kufri Surya		
Emergence (days)	15	16	1 day	23	20	3 days
Tuber initiation (days)	28	32	4 days	48	45	3 days
Total DM yield (kg/ha)	15327	14176	7.5%	17854	16919	5.2%
Tuber DM yield (kg/ha)	9823	9647	1.8%	8225	8437	2.6%

Diff.= Difference

Effect of climate change on survival of *R. solanacearum* in soil as free living cells in potato growing districts of plateau region

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

Tamil Nadu and Kerala: Under the baseline climate scenario (2000), the bacterium survived till 18th March in soils of Idukki, Kannur, Malappuram, Pathanammitha, Wayanad districts of Kerala and Dharamapuri, and Virudinagar districts of Tamil Nadu and no changes are expected in 2020. However, in 2055, the bacterium is likely to survive in soil of these districts till 03 March only. The bacterium is likely to disappear 0-5 days earlier in 2020 and <5 to 15 days in 2055.

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

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

Jharkhand: Under the baseline (2000), the bacterium survived in soil till 27 April in Gumla and 17 May in Ranchi and Singhbhum. No change is expected in Gumla in 2020, however, in Ranchi and Singhbhum, the survival is likely to be up to 6th May only. In 2055, the soil survival period is likely to reduce to 20 April in these districts.

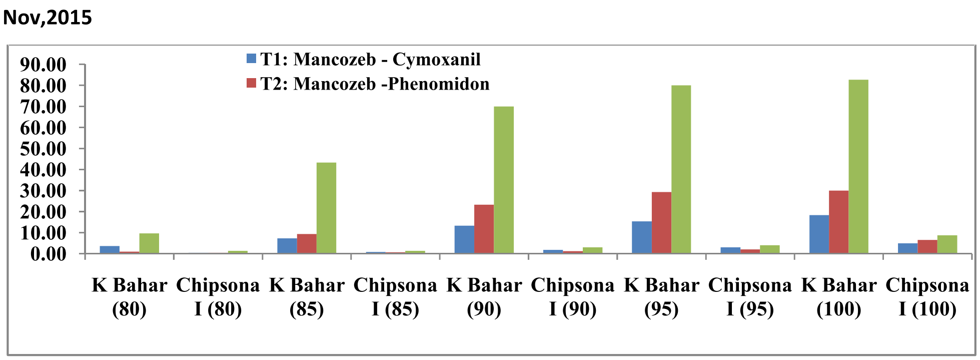
Madhya Pradesh and Gujarat: The bacterium survived in soil from 27 April to 17 May in different plateau districts of Madhya Pradesh and Gujarat in 2000. The bacterium is likely to disappear 3-8 days earlier in 2020 and 5-15 days in 2055 in Madhya Pradesh and 3-5 days earlier in 2020 and 11-26 days in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

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

In-vitro studies on *Phytophthora infestans*

Last year it was observed that the some isolates of *Phytophthora infestans* grew in-vitro at higher temperature. During 2014-15 and 2015-16, at field level symptoms of late blight was observed even at higher temperature (>27^{0}C). It seems that pathogen had adapted to higher temperature. Appearance of late blight in different climate analogous was collected. It was observed that at similar analogous late blight appeared at different dates. At Kannauj (27.055 ºN, 79.918 ºE) late blight appeared on first week of December, 2015 while its analogous Bijnor (29.313 °N, 78.377 °E) late blight appeared on second week of January, 2016. A difference in late blight appearance between the Kannauj and Bijnor was less during 2014-15, whereas during 2015-16 difference in late blight appearance between both analogous was more. Similarly, Patna is analogous of Agra late blight appeared at different dates. An experiment was conducted (2011-12, 12-13, 13-14, 14-15 and 15-16) for generating yield loss data due to late blight under different weathers on two different level of varieties viz resistant (Kufri Chipsona-1) and highly susceptible (Kufri Bahar) for developing yield loss assessment model. Planting was done on 3 dates at 15 days interval starting from 17 October and ending on 17 November. Crop was harvested for yield data recording after 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 and 100 days after planting. Disease severity ranged from 0.17-100% ***(Figs 2 and 3).*** 23.0% average loss of economic yield was observed during blight period in control treatment (unsprayed) in Kufri Bahar on 2nd November planting whereas 5.0% average loss of economic yield was observed in control treatment (unsprayed) in Kufri Chipsona I. Similarly, 6.0 % average loss of economic yield was observed during blight period in control treatment (unsprayed) in Kufri Bahar on 17th November planting whereas 5.0% average loss of economic yield was observed in control treatment (un-sprayed) in Kufri Chipsona I. Yield losses varied date of appearance of late blight and its severity with climatic factors. Four years data is used to generate yield loss equation for development of yield loss assessment model. Further, the parameters (tuber initiation, bulking stage, P days etc.) required for development of yield loss assessment model was standardized.

Fig 2. Late blight disease severity at different days interval on Kufri Bahar and Kufri Chipsona I planted on 2nd Nov. 2015



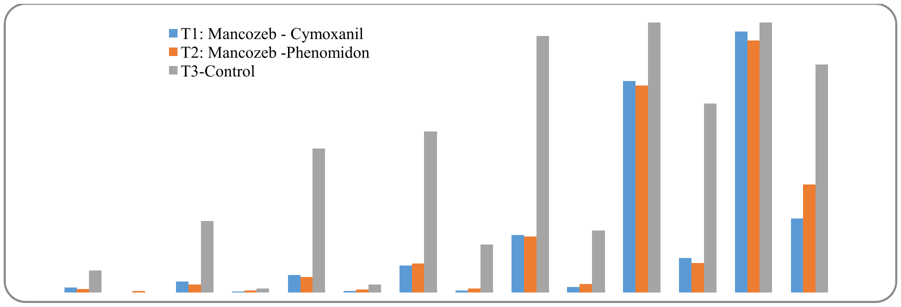


Fig 3. Late blight disease severity at different days interval on Kufri Bahar and Kufri Chipsona I at planted on 17th Nov. 2015

Effects of weather factors on incidence of insect vectors and transmission of disease under protected and unprotected condition at Gwalior

Potato is grown in many parts of North-central and North-western parts of India as early cash crop to fetch high remunerative price in the market. Early crop is affected by various insects-pests; the most important among these are thrips (*Thrip spalmi* Kerny) and whitefly (*Bemisia tabaci G*). With the increasing temperature due to global climate change, the incidence of thrips is expected to increase in Central India specially its hot spots like Gwalior. Keeping the importance of thrips as a vector for transmission of stem necrosis disease in early planted potato crop in Central India, a field experiment was carried on six planting dates (15th September, 20th September, 25th September, 30th September, 5th October, 10th October) under protected and unprotected conditions with the objective to collect the information on incidence of thrips and stem necrosis in relation to weather parameters during 2015.The data revealed that highest thrips population (36.1/ 5 plants) was recorded in the 10th of November, resulting in incidence of stem necrosis disease (17.4%) in 25th September planted crop, however climatic conditions was more favorable for transmission of disease when crop was planted on 15th September (23.33%) and 20th September(24.25%) under unprotected condition having more virulent population of thrips.

However, low incidence of thrips (0.38%) and stem necrosis disease (0.53%) was recorded in protected condition in October planted crop (Fig. 12b). The high temperature (30-35°C) and dry weather during early October is favorable for the development of stem necrosis disease. Thrips and whitefly activity also trigger on early crop due to high temperature and moderate humidity. Similarly, whitefly was low in protected treatments of planting dates as compared to unprotected crop (Figs. 12a and b). Tuber yield data revealed that early planted crop recorded significantly low total tuber yield (10.88 t/ha) as compared to late planted crop (21.80 t/ha) under unprotected conditions, whereas the yield level varied (13.33-23.43 t/ha) under protected conditions. The correlation study revealed significant positive correlation with incidence of thrips and stem necrosis disease; however it showed a negative correlation with tuber yield. The potato yield showed significant difference among the different dates of planting. Therefore, data revealed that weather parameters (temperature, humidity, rainfall) plays an role in buildup of thrips, whitefly population on potato crop grown for table purpose will required better management tactics right from planting in this region to reduce the incidence of vectors on crop. Due to change of climate, an extra plant protection measure is required to protect the crop against vectors.

Effects of weather factors on incidence of sucking insects at Modipuram

The early potato cultivation in Indo-Gangetic plains, suffers huge losses due to sucking pests. In last few years weather conditions remained erratic and hence change in behavioral pattern of insects have been noticed in early crop. Therefore an experiment was conducted to assess impact of weather parameters (temperature and humidity) on sucking pests. Potato crop was planted on 4 different dates during September (15/9, 20/9, 25/9, 30/9 in 2015) and two different dates of October (5/10 and 10/10 in 2015). Observations were recorded on number of *Bemisia tabaci, Amrasca biguttula, Aphis gossypii,* per cent hopper burn and per cent mite burn in unsprayed plots of each date of planting. Unsprayed plots of each date of planting were separated from each other by sprayed plots and two sprays of 0.03% imidacloprid and 0.03% spiromesifen were given for the control of leaf hopper, *A. gossypii,* whitefly and mite. In 2015, the data recorded in second week of October on percent emergence indicated that Kufri Bahar did very well from emergence point of view as crop planted on 15,th 20,th and 25th September resulted in 71, 86 and 90% emergence when respective maximum temperatures were 36.5, 35.0 and 32^{0}C. Whitefly was in abundance in all planting dates and highest was in 05.10.15 (40 adults/5 plants) planted crop. In the time period of 5 years of experimentation starting from 2011 to 2015 the leaf hopper population was highest in 2011 but in the later years mite population resulted in severe miteburn in all the planting dates. Number of leaf hopper/100 compound leaves was lowest in case in all planting dates except 10.10.15. The number of *A. gossypii*/100 compound leaves was lowest in 5th and 10th October planted crops. Mite, *P. latus* was major damaging factor in all the 6 dates of planting starting from 15th September to second week of October. The burning by mite was up to 80 per cent in September dates of planting. For development of pest management strategies under climate change scenarios, experiments were conducted for the control of sucking pests during last three years. It was recorded that amongst tested pesticides, first foliar spray of spiromesifen @4ml/10 litres of water at 25-30 days after planting would result in good control of whitefly, *Bemisia tabaci* and mite, *P. latus*; second foliar spray of imidacloprid @3ml/10 lits after first spray was further reduced the whitefly and leaf hopper and third spray of spiromesifen at similar dose also reduced the remaining population of sucking pests further. Regression analysis was performed for modeling pest dynamics using population data of whitefly, leaf hopper, *A. gossypii* and *M. persicae* and it was found that R^2 was significant in case of whitefly, leafhopper and *A. gossypii* but non-significant in case of *M. persicae.* Whitefly and leafhopper population was affected by change in maximum and minimum temperatures, *A. gossypii* is affected by maximum temperature only and *M. persicae* was not affected by maximum and minimum temperatures and morning evening relative humidity.

Effect of elevated CO_2 on potato growth and yield

Open top chamber (OTC) facility at CPRS Jalandhar was used to study the effects of increased levels of CO_2 on potato growth and yield. Kufri Pukhraj and Kufri Surya were chosen for the study, which were raised at ambient CO_2, 550 ppm CO_2, and 700 ppm CO_2. Study showed that the plant height increased linearly from emergence till about 60 DAP under all the conditions; however, the plant height at 550 ppm CO_2 was similar to control in both the varieties. It was about 14% higher in Kufri Surya and about 7% higher in Kufri Pukhraj at 700 ppm CO_2 ***(Fig. 4).*** The number of shoots per hill did not vary much during the entire life of the plant under all the conditions ***(Fig. 5).*** In both the varieties leaf number/plant was similar between control and 550 ppm CO_2. However at 700 ppm CO_2Kufri Surya and Kufri Pukhraj had 20% and 13% higher leaf numbers respectively at 60 DAP ***(Fig. 6)***. Leaf area per plant was calculated from length and breadth data of 4th leaf. Leaf area = l X b X 0.7 X Leaf number. Leaf area per stem was higher in Kufri Pukhraj at ambient and 550 ppm, however at 700 ppm CO_2, leaf area per stem was similar in both the varieties **(Fig. 7)**. In both the varieties leaf area increased up to 60-65 days and then declined rapidly. Decline in leaf area was higher at higher CO_2 concentration in both the varieties. There was about 50% increase in leaf area per stem in Kufri Surya at 700 ppm CO_2 whereas this increase was only about 10% in Kufri Pukhraj

(Fig. 7). The increase in tuber yield was substantial in Kufri Surya with 38% increase at 550 ppm and 70% increase at 700 ppm whereas in Kufri Pukhraj there was about 5% increase in yield at 550 ppm and 24% increase at 700 ppm. Tuber yield in both the varieties was at par at 700 ppm CO_2 whereas there was a large difference in yield at ambient CO_2 concentration ***(Fig. 8).*** The trend of biomass accumulation was similar to tuber yield in both the varieties ***(Fig. 9).*** Photosynthesis increased with increasing CO_2 concentration in both the varieties and the rate of photosynthesis was at par in both the varieties at each CO_2 concentrations ***(Fig. 10).*** Stomatal conductance decreased with increasing CO_2 concentration because increased CO_2 concentration leads to partial stomatal closure ***(Fig. 11).*** The results indicate that Kufri Surya is more responsive in increased CO_2 concentration as compared to Kufri Pukhraj.

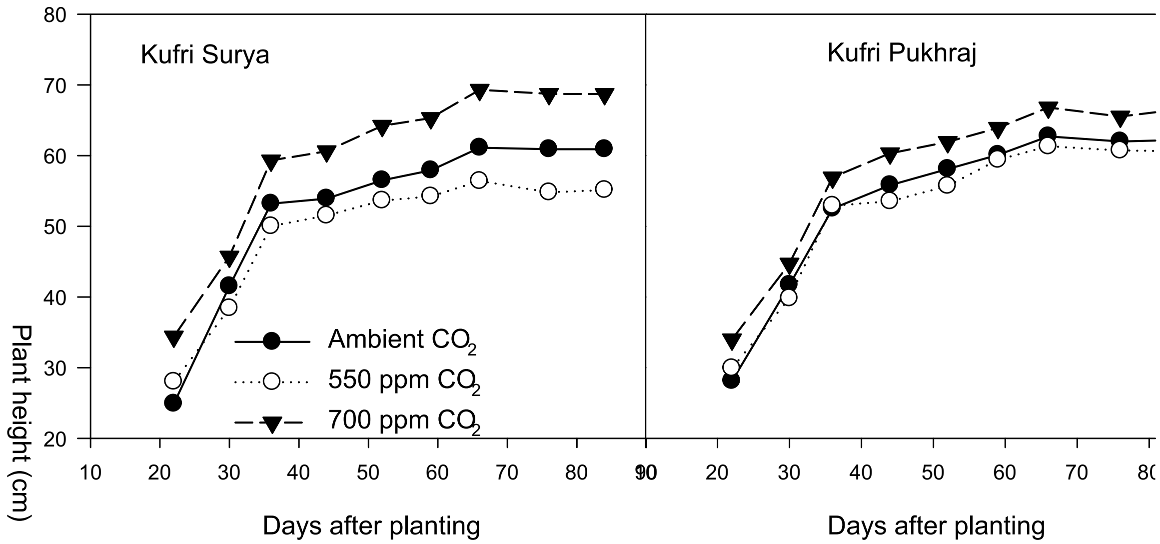


Fig.4 Plant height at different CO_2 concentrations

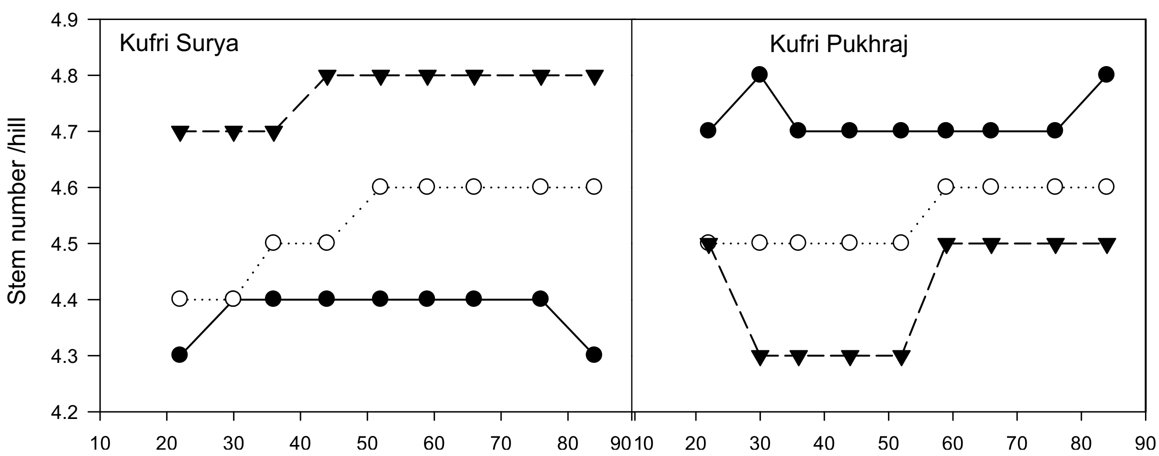


Fig. 5. Stem number/hill at different CO_2 concentrations

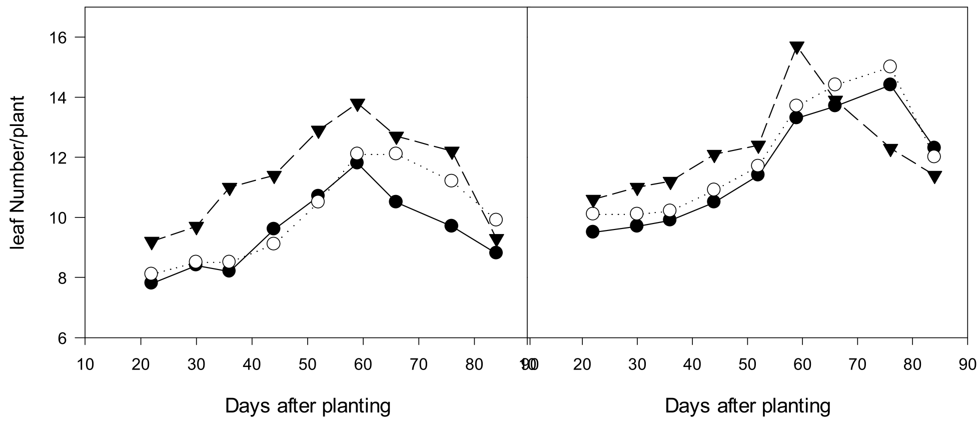


Fig. 6. Number of leaves per plant at different CO_2 concentrations

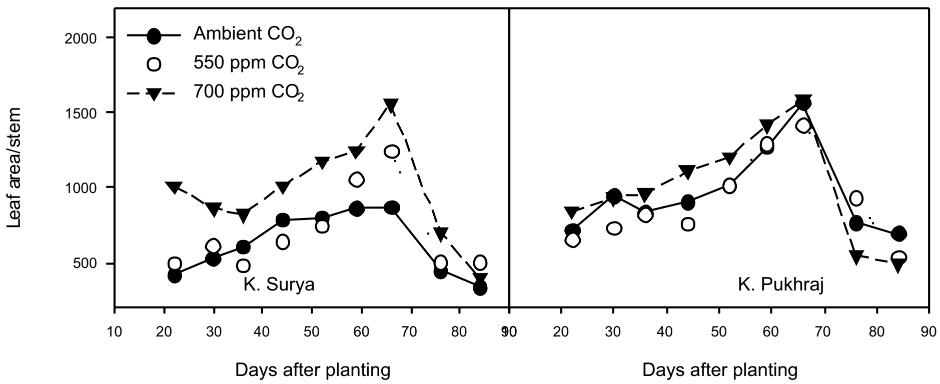


Fig. 7. Leaf area/stem at different CO_2 concentrations.

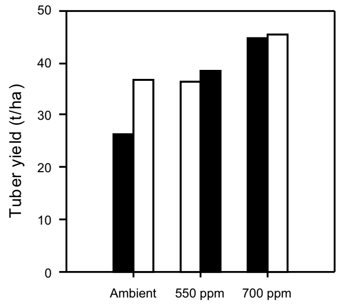


Fig. 8. Tuber yield at different CO_2 concentrations

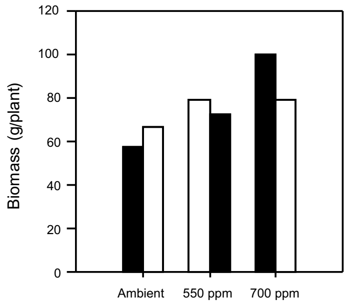


Fig. 9. Total biomass at different CO_2 concentrations

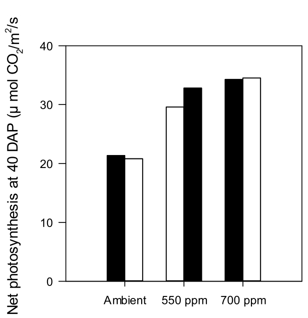


Fig. 10. Photosysnthesis at different CO_2 concentrations

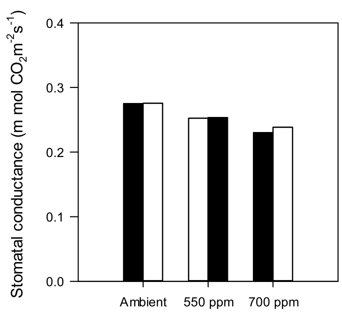


Fig. 11. Stomatal conductance at different CO_2 concentrations

Integrated nutrient and water management for improved productivity of potato

Soil health card mission is in place and decontrol of fertilizer prices and nationwide drought like situation warrant for the need of precise and efficient nutrient and water management system. In a couple of years, every potato grower is likely to have their soil available nutrient status ready with him and to match this development we must be prepared with recommendations, preferably through expert system (possibly online) access, to all potato growers. Recommendations must be very precise not only on quantity of applications but also on delivery mechanism to result into highest order of efficiency and minimum drift to the environment. This will help in reducing the cost of cultivation, improving the quantity and quality of produce and also in mitigating climate change. With all these considerations, activities were undertaken on development of site specific nutrient management techniques for precision farming and better soil health, modern techniques of irrigation and fertigation and development of nutrient and water efficient cultivars. Besides, activities were also undertaken on screening of existing cultivars and germplasm for their micronutrient content to assess the variability in their content in tuber and its potential to be used and developed as nutritional value food.

Development of site specific nutrient management (SSNM) techniques for precision farming and better soil health.

In order to develop site specific precise nutrient recommendations activities undertaken in the current year of report include calibration and recommendation of QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) model for Uttar Pradesh, real time N management using SPAD value and omission plot experiments at Modipuram and Shimla. The concept of SSNM is based on the hypothesis that in high yielding situations, the ability to predict soil nutrient supply and plant uptake in absolute terms rather than relative yield response is the basis for plant nutrient management. QUEFTS model was calibrated for SSNM of NPK in potato crop in Uttar Pradesh. For calibration of QUEFTS model, extensive review of literature was carried out and the data were collected and compiled on initial nutrient status, nutrient applied uptake and yield under different experiments carried out at different locations in Uttar Pradesh during last 15 years. For working out the relationship between yield and nutrient supply, four steps were followed in the model; determination of indigenous nutrient supply, determination of the uptake of N, P and K as functions of potential supply of N, P and K (from soil + fertilizer), estimation of yield ranges as functions of actual uptakes of N, P and K when they are maximally accumulated and maximally diluted, and estimating the final yield by combining three yield ranges (one each for N, P and K) considering NPK interactions ***(Fig. 1)***. The model will now be used to generate the data sets for developing decision support system (DSS) on NPK recommendation for potato crop in Uttar Pradesh based upon the soil nutrient status, target yield, and date of planting.

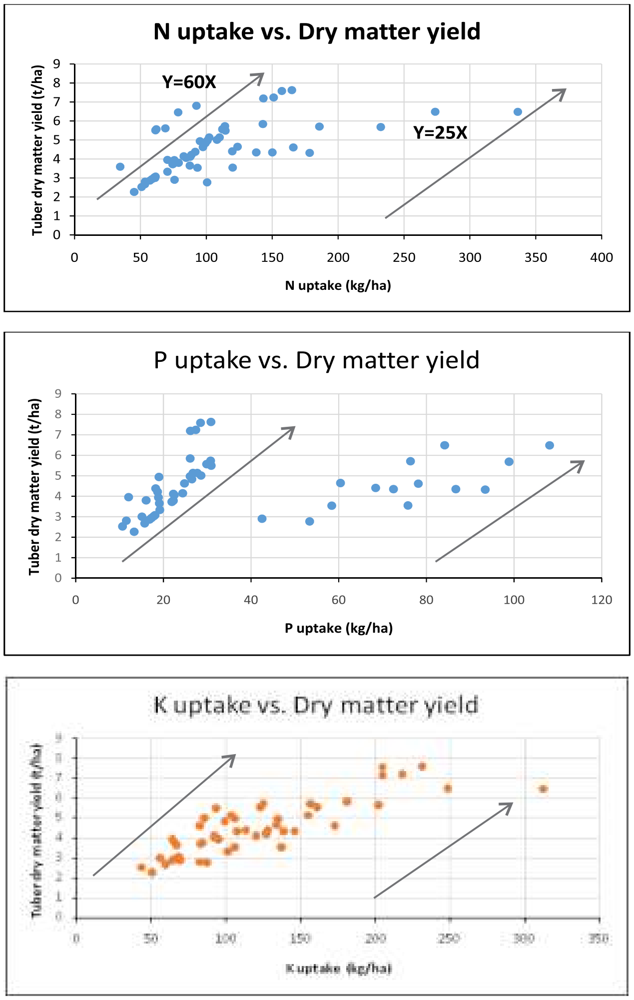


Fig 1. Relationship between tuber dry matter yield and NPK uptake. The upper and lowerlines indicate tuber yields with maximum dilution and accumulation of nutrients.

Real time N management using SPAD value

In continuation of last year experiments, to confirm the results of previous year's three varieties namely, Kufri Khyati, Kufri Jyoti and Kufri Pukhraj were evaluated for fine tuning of N top dressing based on SPAD value. Amongst three cultivars, the SPAD value of Kufri Pukhraj was always the highest followed by Kufri Khyati and Kufri Jyoti ***(Fig. 2a).*** However, Kufri Khyati and Kufri Pukhraj gave better response and yielded significantly better than Kufri Jyoti. The SPAD value of over fertilized plots in all the three varieties remain the highest almost throughout the season ***(Figs. 2b and c).*** However, there were fluctuations in the values as and when either N was top dressed or irrigation was given. In general, it tends to decrease with advancing of the season. When N was top dressed at 90% of the reference SPAD value, it showed higher chlorophyll index as compared to the plots which were fertilized at 80% of the reference SPAD value. The treatment where 20% recommended N was applied at 90% of the reference SPAD value produced yield similar to the recommended N level and was significantly higher than the treatment where N was top dressed at 80% of the reference SPAD value ***(Fig. 3).*** The former treatments yield level was also at par with over fertilized plots. Result indicated that there is possibility to decrease the amount of N to be top dressed by at least 10% by increasing the number of splits of N based on SPAD value in comparison to over fertilized reference plot without compromising on yield.

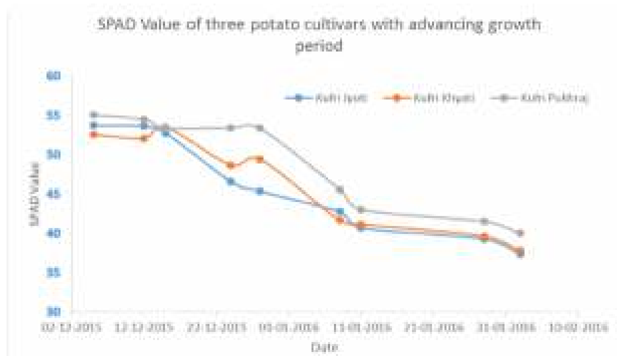


Fig 2a. SPAD of three potato cultivars with advancing growth period

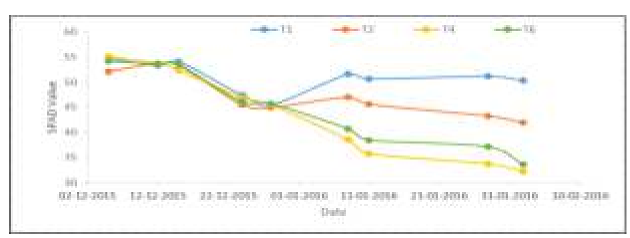


Fig. 2b. SPAD value of Kufri Jyoti as influenced by N top dressing with advancing crop age

Fig. 2c. SPAD value of Kufri Khyati as influenced by N top dressing with advancing crop age

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_4 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 80% SPAD value of $T_1$and T_6 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 90% SPAD value of T_1.

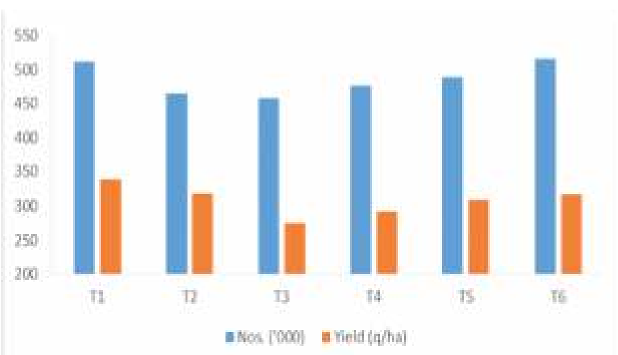


Fig. 3. Potato tuber numbers and yield as result of N scheduling

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 T_1; T_4 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 80% SPAD value of T_1; T_5 : 50% of recommended N at planting, 20% N at earthing up and 10% N at 90% SPAD value of T_1 and T_6 : 50% of recommended N at planting, 20% N at earthing up and 20% N at 90% SPAD value of T_1.

Omission plot experiments for SSNM

In order to identify and quantify nutrient requirements specific to the site, omission plot experiments were undertaken in plains (at Modipuram) and in hills ***(Fig. 4)***. In the trials conducted at farmers' field at Shimla, no response of N, P and K fertilisers was observed when FYM was applied (15t/ha) in soils having 2.30 to 2.55% organic carbon, 160-170 mg/kg available N, 157-180 mg/kg available P and 345 to 370 mg/kg available K. In other words none of the nutrient was limiting when inherent nutrient supply was supplemented with FYM ***(Fig. 5)***. On the other hand, N was only limiting element when FYM was not applied ***(Fig. 6)***.

Fig. 4. Experiments at farmers field at Shimla using nutrient omission plot technique

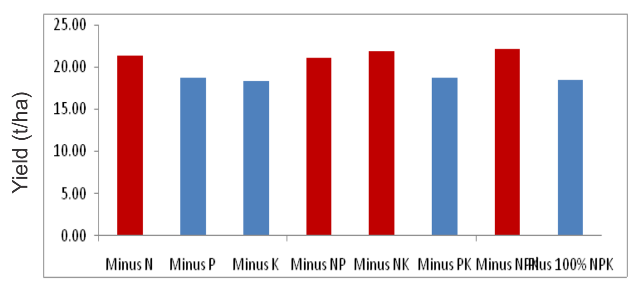


Fig. 5: Response to applied N, P and K at framers' field at Shimla with FYM application

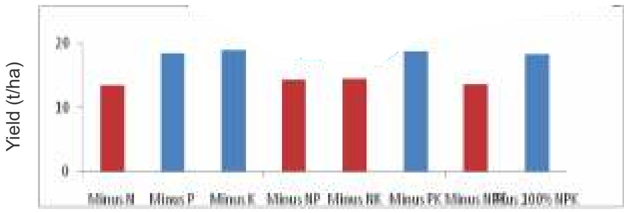


Fig. 6. Response to applied N, P and K at famers' field without FYM application.

In plains, experiment was conducted at Modipuram with potato cultivar Kufri Garima to see the limiting effects of seven elements (N, P, K, S, Mg, Zn and B) on the tuber yield of it. The maximum reduction in tuber yield was 16.1 t/ha in N omission plot as compared to over fertilized plot which was followed by S (8.1 t/ha), K (6.9 t/ha) and P (5.6 t/ha) omission plots. Nutrients other than N contributed 10.5 ton/ha in yield as it was 21.0 t/ha in N omission plot, whereas it was only 10.64 t/ha in control plot.

Nutrient status of the soils of Punjab: Majority of the soils in Punjab had optimum to very high contents of DTPA extractable micronutrient cations (Zn, Fe, Cu and Mn). Boron was the most deficient element and 100% soils were found to be deficient in this nutrient. Only 3% samples were found deficient in zinc and 13% were found sample deficient in iron.

Coating of urea to increase nitrogen use efficiency

Urea, the most used nitrogenous fertilizers, is lost from plant root zone within very short period after application due to its nature of high solubility, hydrolysability and further rapid transformations. Ubiquitousness of neem coated urea has given impetus to delayed activity of urease and nitrification enzymes, the presence of physical barrier can be of further great help in delaying the solubilization, thereby, reducing the loss of urea to the environment. With this objective urea was coated with locally available material at 5% and 10% rate before its application as basal and as topdressing. At harvest highest total tuber yield was recorded with 5% neem cake coating of urea (100% NPK) which was significantly higher all other treatments (Fig.7).

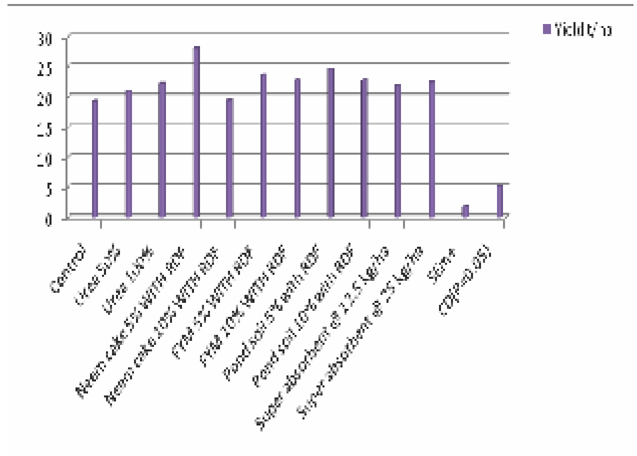


Fig. 7. Response to applied N, P and K at famers' field without FYM application

Develop/identify nutrients use efficient potato cultivars

In order to evaluate advanced hybrids/lines developed for high nutrient efficiency at Jalandhar, a replicated field trial of five advanced hybrids namely N/9-420, N/9-64, N/9-230 and N/9-260 along with three check varieties (Kufri Pukhraj, Kufri Jyoti, and Kufri Gaurav) were planted at four N levels (0, 80, 160 and 240 kg/ha) in four replications at Patna. At 85 days after planting, in plots where no nitrogen was applied, SPAD value of N/9-64 **(Figs. 8 and 9)** was maximum, followed by N/9-230. At 80 kg N/ha also the SPAD value of the N/9-64 was the highest followed by N/9-42 and N/9-260 which was better compared to all the three check varieties. At 95 days after planting SPAD value at 80 kg N/ha was highest for N/9-230 and N/9-64 among hybrids. These two hybrids also had highest SPAD values at N level of 240 kg/ha.

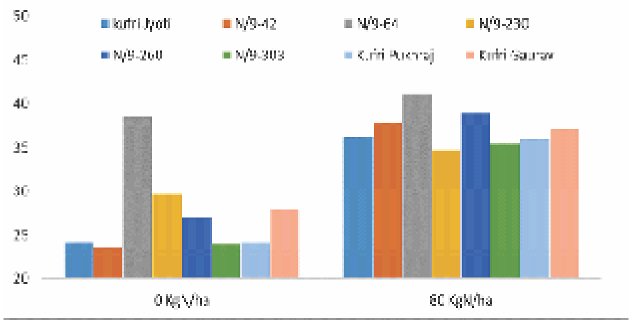


Fig. 8. SPAD value of different genotypes at varying N levels at 85 days after planting

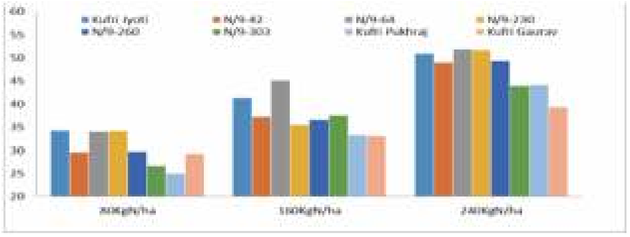


Fig. 9. SPAD value of different genotypes at varying N levels at 95 days after planting

At harvest, it was observed that at all the nitrogen levels, hybrids N/9-42 (35.8 t/ha) and N/9-260 (33.5 t/ha) were superior to all the three checks and also yielded significantly higher than control (24.2 to 29.7 t/ha). When no N was applied, hybrids N/9-260 was the highest yielder (25.4 t/ha) followed by N/9-42 (24.7 t/ha) which indicated their higher efficiency to utilize soil available N as compared to control and other hybrids. Similarly, overall efficiency was also highest for hybrid N/9-42 and much better than controls.

To develop nutrient use efficient varieties, hybridization among breeding lines/cultivars was carried out and a total of 180346 seeds of 62 crosses were obtained. Botanical seeds were used to raise F1 generation. A total of 23,718 F1, seedlings were obtained from germination of 50,462 seeds, which were transplanted in field and 6,130 selections were made on the basis of tuber characters such as colour, shape and eye depth. In clonal generations F1C1 (3,524), F1C2 (722) and FIC3 (94) clones were evaluated for tuber characters and respectively 653, 208 and 35 were selected. Nine hybrids were selected out of 41 evaluated in preliminary yield trials and in confirmatory yield again nine hybrids were selected out of thirteen evaluated at 90 days harvest using Kufri Gaurav and Kufri Pukhraj as controls. Selected hybrids were: N/10- 15, N/10-74, N/10-91, N/10-96, N/9-42, N/9-64, N/9-230, N/9-260 and N/9-303. In second year trial N/10-15, N/10-74 and N/10-96 out yielded the controls. In third year trial hybrids N/9-42 and N/9-64 gave significantly higher yield than control Kufri Gaurav and Kufri Pukhraj.

Develop / identify water use efficient potato cultivars/ hybrids.

Out of 100 genotypes/hybrids evaluated during six consecutive years, during the year 2015-16, three promising genotypes/hybrids viz. J 93-58, J 92-167 and JN-2207 produced maximum yield (48.1, 41.9 and 47.4 t/ha, respectively) in comparison to popular var. Kufri Bahar (38.7 t/ha) and Kufri Pukhraj (41.7 t/ha) at higher moisture level, but, at low soil moisture regime these genotypes gave higher yield (41.0, 37.6 and 34.1 t/ha, respectively) against Kufri Bahar only which produced 33.9 t tubers/ha. These 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:

A hydroponics (solution culture) study with plantlets of three cultivars namely Kufri Jyoti, Kufri Gaurav and Kufri Pukhraj developed from the scooped eyes of uniform size healthy tubers initially grown in acid washed quartz sand was under taken. Plantlets of uniform size were selected at 20 days of age and were transferred in perforated plastic pots floating in well aerated nutrient solution tubs with uniform level of all nutrients except N. Nitrogen level in different tubs were supplied in the form of NO_3 at three concentration level i. e. 0.05, 0.50 and 5.00 mM. Perusal of data indicated that three varieties responded differently to decreasing NO_3 levels. Root parameter such as fresh root weight and root volume in general decreased with decreasing NO_3- level. The cultivar Kufri Gaurav had highest value followed by Kufri Pukhraj and Kufri Jyoti. When root fresh weight tend to decrease linearly with decreasing NO_3 concentration efficient varieties tried to maintain their surface area by decreasing their root diameter and increasing root length **(Figs. 10 and 11).**

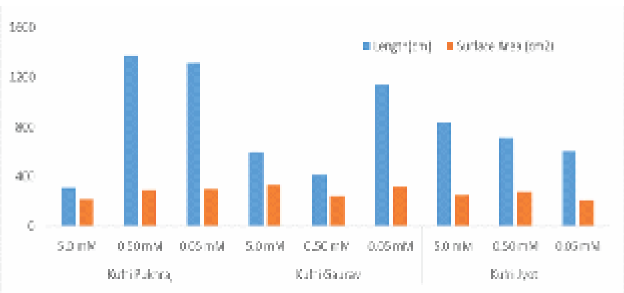


Fig. 10. Root length and surface area in solution culture

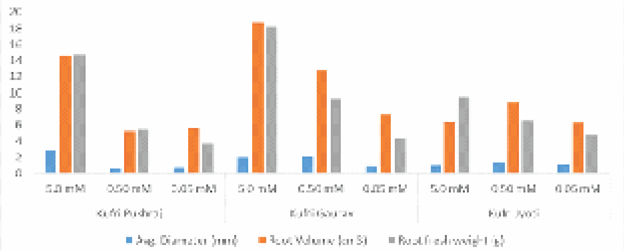


Fig. 11. Root average dia, volume and fresh weight in solution culture

Variety specific water and nutrient management schedule under limited water availability.

Field experiment was conducted at CPRI Campus, Modipuram, Meerut (UP) during rabi season of 2015-16 with five potato varieties at three moisture regimes (viz. irrigations applied at 2.5 IW:CPE ratio, 2.0 IW:CPE ratio and irrigation at critical stages of crop i.e. PE (plant emergence), SF (stolon formation), TIS (tuber initiation stage), ETES (early tuber enlargement stage) and LTES (Late tuber enlargement stage), and three levels of fertility (i.e. 150, 180 and 210 kg N/ha) levels.

The potato yields were in the order of Kufri Garima = Kufri Khyati> Kufri Sadabahar> Kufri Pukhraj> Kufri Bahar **(Figs. 12 and 13).** The productivity of all potato varieties were maximum at higher moisture regime when irrigations given at IW:CPE ratio of 2.5 in comparison to low and medium irrigation levels tried (Fig. 12). However, yield of all potato varieties were low with irrigations applied at critical stages of crop growth (PE, SF, TIS, ETES and LTES). The productivity of all varieties was maximum at N applied at the rate of 210 kg /ha in comparison to lower nitrogen doses tried (150 and 180 kg N/ha, respectively), however, it was found statistically at par with the 180 kg N/ha **(Fig. 13).** The potato yields increased with the increases moisture regime and nitrogen levels from 150 to 210 kg N/ha. When crop was irrigated at critical crop growth stages **(Fig. 14)** only the yield of all the potato varieties were lowest at 150 kg N/ha.

The soil moisture content was higher in the root zone before irrigation applied in the treatment where irrigation was applied at 2.5 IW:CPE ratio in comparison to other irrigation regimes tried i.e. irrigations at 2.0 IW:CPE ratio and at the critical stages of crop growth . The water use efficiency (WUE) was also higher when irrigations applied at 2.5 IW:CPE ratio with application of 210 kg N/ha against other treatments tried **(Fig. 15).**

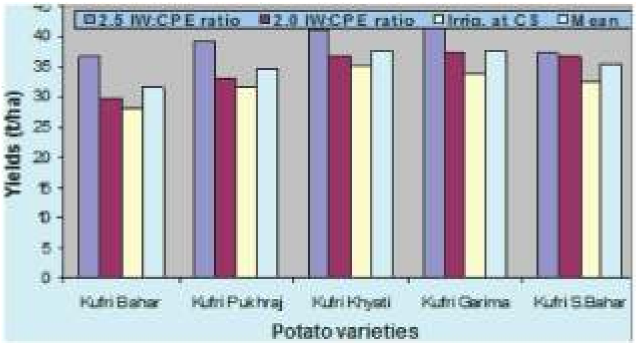


Fig. 12. Potato yield as influenced by irrigation regimes

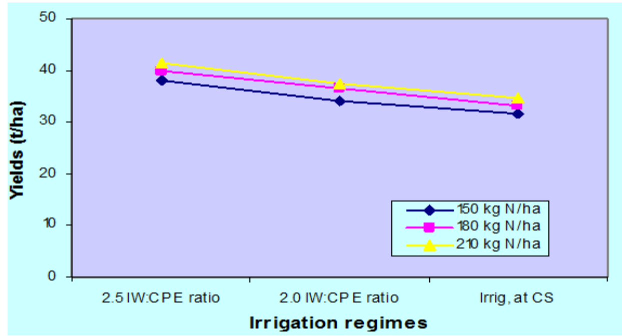


Fig.14. Effect of irrigation regimes and N applications on yield

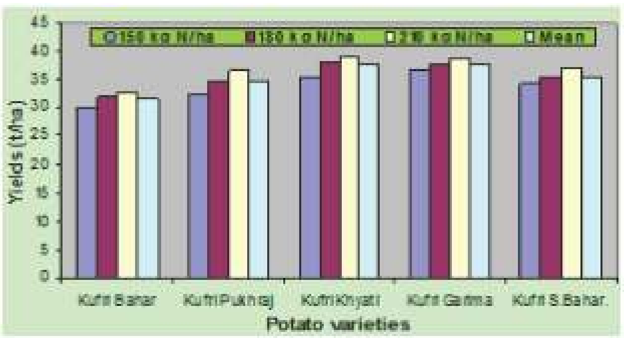


Fig. 13. Potato yield as influenced by N applications

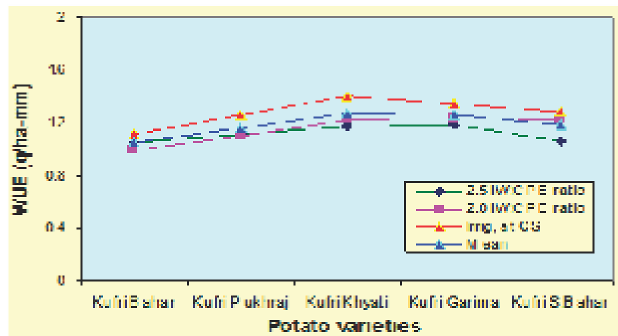


Fig. 15. Response of varieties to N use efficiency

Breeding for enhanced micronutrient content in potato

Knowledge regarding varietal variations in contents of essential metals in foods is important to design the strategies for biofortification and breeding nutrient rich varieties. This study examined concentrations Fe and Zn in 46 Indian potato varieties grown under uniform management practices and non-nutrient limited conditions at CPRIC Modipuram. The iron content in tuber flesh on dry weight basis ranged between 17.75 to 40.74 mg/kg while zinc content ranged from 9.54 to 21.00 mg/kg (Fig.16). The associations between two elements was significantly ($r=0.33$, $p < 0.05$) suggesting feasibility of simultaneous improvement of both traits.

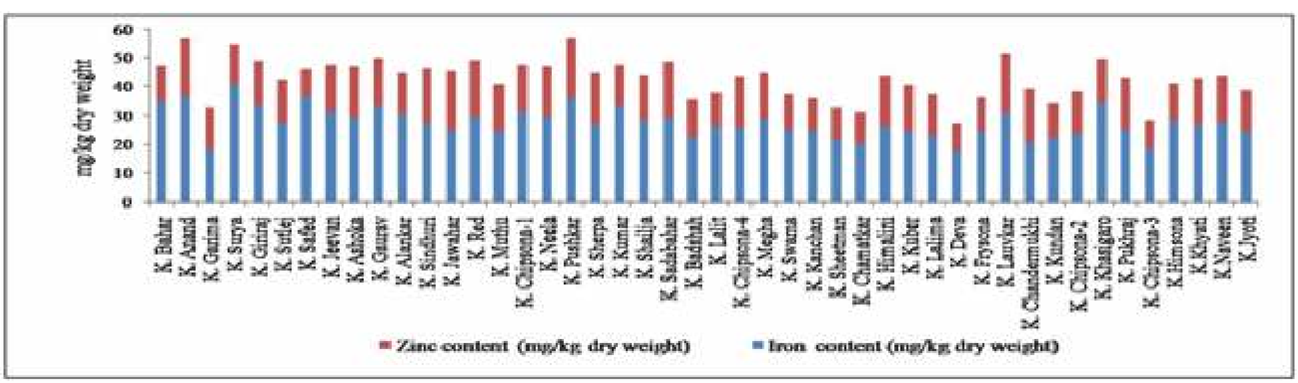


Fig. 16. Micronutrient (zinc and iron) content in potato varieties

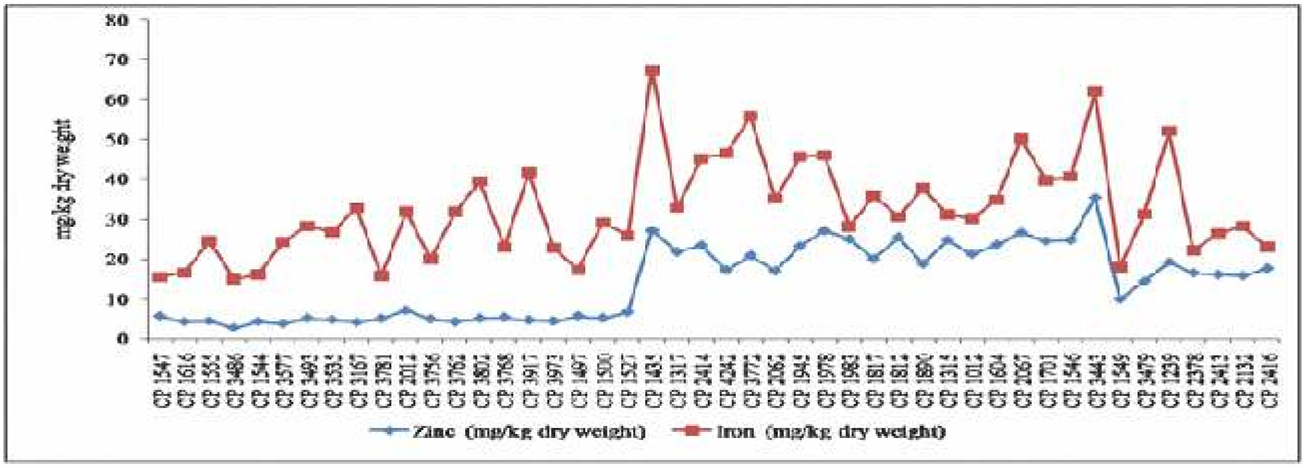


Fig. 17. Micronutrient (zinc and iron) content in tuberosum germplasm

Besides, zinc and iron content in flesh of forty-six potato tuberosum germplasm grown under uniform management practices was also studied with varying degree of flesh colour ranging from white to yellow. Iron content ranged 14.90-67.13mg/ kg and zinc between 2.78-35.40 mg/kg dry weight basis in peeled tubers (Fig. 17). The promising accessions identified will be utilized as parental line for breeding nutrient rich potato varieties.

Resource optimization in potato based cropping system

The target of 2050 for producing 122 mt of potatoes for catering the demand of seed, table, processing, and export sector is huge under increasing constraints of land, water, non-renewable farm resources, labour, and above all changing weather in crop season due to shift of climate. Institute foresees to increase potato acreage from current level of 1.8 mha to 3.62 mha, which seems very difficult. However, improvement in productivity of potato crop is vital and it can be improved further than ever thought target of 34.5 t/ha by improving in components of seed and crop management. Alike, handling of potatoes at harvest and afterwards, is another major issue to save upon the produce from spoilage due to mishandling at various level till it reaches either to consumers and processors or stored for off season. Keeping whole scenario of potato production in view, nine major activities have been started during 2015-16 for addressing the issues of raising farm yields, and safer handling of potato crop. This include improving seed potato production through aeroponics, augmenting micro-propagation potential of potato cultivars, yield gap analysis for prioritizing reasons and suitable strategy for tackling the problem, development of Indian good agricultural practices (GAP) for eco-friendly production of potatoes, organic potato production and potato based cropping system technology development for efficient use of resources, long term plant nutrition studies for sustaining soil health, development of agro techniques and popularization of new potato cultivars for *kharif* season in non-traditional area of Hassan (Karnataka), and mechanical technologies for précised potato cultivation. Salient findings are as follows:

Seed potato production through aeroponics and augmenting micro-propagation potential of potato cultivars in hills

Potato varietal sensitivity to nutrient solution under aeroponics: An attempt was made to observe varietal sensitivity for nutrient solutions at Shimla in cultivars viz., Kufri Jyoti, Kufri Chipsona-1, Kufri Khyati, Kufri Chipsona-3, Kufri Pukhraj, Kufri Lauvkar, Kufri Surya, Kufri Badshah, Kufri Bahar, Kufri Frysona, Kufri Chipsona-4 and Kufri Himalini. Kufri Pukhraj was the most sensitive variety to nutrient solution followed by Kufri Lauvkar and Kufri Chipsona-4 as it exhibited initial leaf burning covering whole plant in later phase terminating into drying off. These symptoms might be due to some kind of elemental toxicity, which appeared after every 4-5 days of solution uptake and required periodical dilution for recovery. **(Fig. 1)**

Kufri Pukhraj Kufri Lauvkar Kufri Chipsona-4

Fig. 1: Varieties showing toxicity symptoms

Exceptional behaviour of variety Kufri Chipsona-4 under aeroponics in hills: Exceptional behaviour of cv. Kufri Chipsona-4 was observed in relation to photo-periodism. In experiments carried out with several varieties in different planting dates, 2012-2015, Kufri Chipsona-4 planted during January- mid February 2014 showed maximum survival (84.2%) in comparison to other test varieties. Maximum minitubers per plant (36) were also obtained with average weight of 3.45 g. Remaining varieties did not perform well and developed long, thick succulent stolon with leaf primordia **(Fig. 2).** Likewise, there was 100% microplant establishment in Kufri Chipsona-4 with 45 minitubers per plant with 2.14 g mean tuber weight, when planted during February 2015. Mid- March planting resulted in negligible tuberization in Kufri Jyoti, Kufri Chipsona-3 and Kufri Girdhari. Tall indeterminate vegetative growth and long thick stolon were observed in these cultivars except cv. Kufri Chipsona-4 and September planting of this variety also exhibited better yield performance (33 minitubers). Average number of minituber production in Kufri Chipsona-4 was significantly higher in all planting dates as compared to remaining test varieties. Kufri Chipsona-4 may be considered as a day neutral and photo-insensitive variety for hill aeroponics due to its rooting behaviour, vegetative growth, crop canopy and yield performance during summer season under long day conditions.

Kufri Chipsona-3 Kufri Chipsona-4 Kufri Jyoti

Fig. 2: Varietal behaviour under aeroponics

Effect of photo-periodism on different clones of Kufri Bahar: Two different clones of Kufri Bahar along with conventionally produced (DUS) tubers were shifted in vitro under aseptic conditions. Various morphological characters of micro plants were recorded. After 2-3 cycles of sub-culturing, these micro plants were shifted to pots to see the effect of light on tuber shape. No significant differences were seen on tuber shape. Plant height was significantly more in DUS clone multiplied under long days (16 hrs. light), which perhaps showed its acclimatization to long days conditions, whereas, other two clones were at par for all the morphological characters **(Fig. 3).**

Fig. 3: Effect of photoperiods on Kufri Bahar

Screening of antibiotics for contamination free vigorous potato micro propagation

Eight different concentrations (25, 50, 75, 100, 125, 150, 175 and 200 mg/l) of 2 antibiotics *(Kanamycin* and tetra hydrochloride) were used to improve the micro-plant growth and vigour of potato varieties (Kufri Chandarmukhi, Kufri Chipsona-1 and Kufri Himalini). It was observed that lower concentration of Kanamycin (25 and 75 mg/l) could be incorporated in micropropagation medium of potato to minimize microbial contaminants as well as for improving the micro-plantlet vigour, whereas all concentrations of tetracycline hydrochloride had negative effect and showed phytotoxic symptoms on all morphological character **(Figs. 4 and 5)**. However, all the cultural contamination was completely checked.

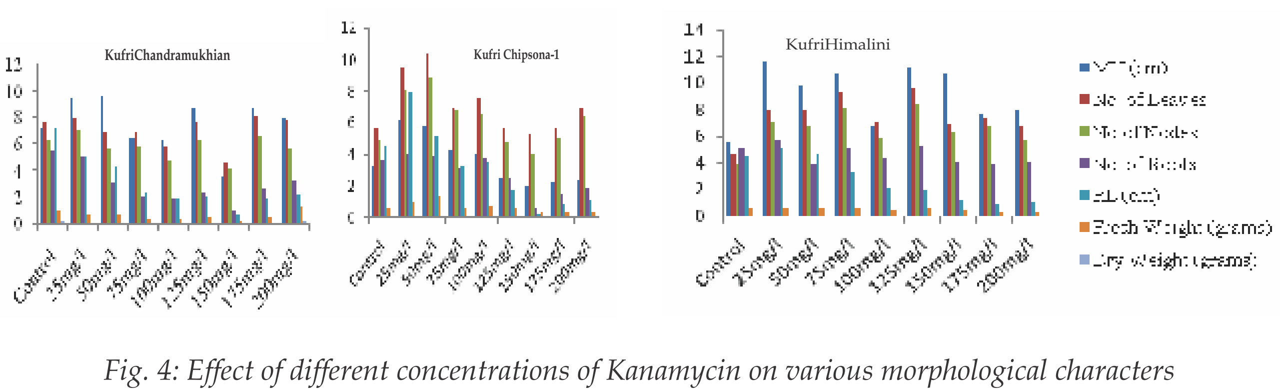


Fig. 4: Effect of different concentrations of Kanamycin on various morphological characters

Fig. 5: Phytotoxic effect of Tetracycline hydrochloride suppressing plant growth

Evaluation of different nutrient solutions in aeroponic small boxes for tuberization of problematic variety Kufri Jyoti

Tall indeterminate vegetative growth and long thick stolon are the problems of cv. Kufri Jyoti under aeroponics. Preliminary attempt has been made to solve this problem by evaluating 3 different nutrient solutions viz., Hoagland solution (solution 1), calcium nitrate solution (solution 2) and standard solution (solution 3) in small sized aeroponic boxes. Survival percentage was significantly higher in solution 1. Maximum plant height (26.7 cm) was found in solution 3 followed by solution 1 (24.5 cm). No marked difference was observed in root length. Number of harvests (11), minituber (30 per plant) and mean tuber weight (5.23g/tuber) were statistically superior in solution 2 and stolon growth was also less.

Studies on production behaviour of small size aeroponic tubers under protected conditions: An experiment was conducted to know the production behaviour of small size tubers (<1g, 1-2g and 2-3g) under poly-house during *Kharif* season at Fagu **(Fig. 6).** Per cent final emergence was not affected among all grades of tubers. Plant height and shoots per plant were better with increase in tuber size. Tuber number and yield (kg/ m^2) were significantly improved by increase in tuber size. Proportion of large size (>20g) tubers also enhanced and maximum (>51%) of it was with 2-3g seed tubers. Recycling of small sized aeroponic tubers under aphid proof protected conditions can be practiced successfully to improve the size of progeny tubers for making them worth multiplying in field.

Fig. 6: Variety KufriJyoti in aeroponic small boxes

Augmenting production of mini-tubers in aeroponics, and breeder seed in plains

Improved commercial scale aeroponic system:

A new design of commercial scale aeroponic system was fabricated to augment minituber production at Modipuram. System consists of new design of grow boxes made of bricks and concrete instead of styrofoam sheets to provide more stability, durability and comparatively easier maintenance. This system also has an improved control panel having displays of pH, EC, temperature and RH. A mechanical system for lifting the plants for tuber picking has been made to avoid injury to plants during picking and it also makes pickings more convenient. System for preventing lodging of plants has also been taken care off. The unit is equipped with automatic dosing pump to maintain pH of solution.

Performance of potato cultivars in aeroponic system: Seven potato cultivars viz. Kufri Khyati, Kufri Pukhraj, Kufri Surya, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4 and Kufri Frysona were evaluated at Modipuram. Days (d) taken for first harvest were minimum in Kufri Khyati and Kufri Surya (42 d), whereas Kufri Chipsona-3 and Kufri Frysona took 55 days to attain desired size of minitubers for first harvest. Maximum tuber number/plant were obtained from Kufri Frysona (54.7) and minimum from Kufri Khyati. Tuber weight/plant was highest in Kufri Pukhraj (111g), whereas minimum was in Kufri Chipsona-4 (68.9g).

Performance of aeroponic minituber in net house: Aeroponically produced minitubers of nine potato cultivars were evaluated in net house at Modipuram. Emergence of minituber was very good for all cultivars (> 94%), except for Kufri Surya (80%) and Kufri Badshah (90%). Highest tuber yield (2636g/m^2) was recorded in cv. Kufri Girdhari followed by Kufri Bahar and Kufri Khyati, while lowest was in Kufri Surya (979g/m^2). Highest tuber number was recorded in cv. Kufri Himalini (151.7/m^2) followed by Kufri Pukhraj (127.5/m^2) and Kufri Khyati (126.7/m^2), while lowest were produced by cvs. Kufri Surya, Kufri Badshah, Kufri Chipsona-4 and Kufri Bahar. Biggest size (36.3g/tuber) progeny tubers were achieved from cv. Kufri Bahar followed by Kufri Girdhari (29.8g) and Kufri Badshah (24.7g). Over all field performance of aeroponically produced minituber was very good.

Use of soluble fertilizers in aeroponics: At Jalandhar, a feasibility experiment was conducted in aeroponics system using water soluble fertilizers (2 solutions) to reduce nutrient solution cost and avoid the hassle of mixing several salts. Performance of fertilizer solutions was found satisfactory and comparable with the existing composition of nutrient solution being used at commercial scale. Variation of pH with time in conventional solution was upwards while in new solutions it was downwards.

Fig. 7: Hardening of in vitro plants in liquid media

Performance of Kufri Jyoti in aeroponics: In order to understand the performance of cv. Kufri Jyoti for time of planting in Punjab conditions, in vitro plants hardened in liquid media were shifted to grow boxes at different dates and their performance for final yield was compared. Highest tuber weight per plant was achieved in crop transplanted in third week of November.

Performance of different cultivars at commercial scale in Punjab: Performance of some potato cultivars for minituber number produced per plant was studied in commercial units recently installed in Punjab. Highest mean tuber number per plant was recorded in cv. Kufri Chipsona-3 followed by Kufri Chipsona-1, K Badshah and Kufri Pukhraj.

Evaluating two potato crops in Aeroponics:

Available time for cultivation under aeroponics in N-W India is only about 6 months and it is not possible to take 2 potato crops in traditional way. Efforts are on for the last 2 years with HD technique for completing crop cycle in relatively shorter duration so that 2 crops are feasible. Experiment was carried out on 3 varieties Kufri Khyati, Kufri Surya and Kufri Himalini. Study indicated positive response for taking 2 crops in a season, and optimized hardening along with modified transplanting methodology seems crucial as these will ensure faster tuberization **(Fig. 8)**

Fig.8:Aeroponics planting and production of aeroponic tubers

Evaluating two potato crops in Net House:

Currently, one potato crop is taken under net house in a year. Planting of two potato crops in a crop season in plains of N-W India under net house conditions can favourably boost the seed production potential from available net area **(Fig. 9).** An experiment was conducted with six cultivars and dual dates of planting at CPRS Jalandhar for multiplying early generation potato seed fast and simultaneous efficient use of net house area (**Fig. 10).** Significant yield and tuber number advantage were witnessed, also a decrease in average tuber weight was observed. A comparative production advantage as well as economics for seed potato production under two planting systems was worked out. Based on the economics it was observed that shift from single planting to dual planting resulted in increase of 1.71 times production cost, and 3.01 times tuber production and profit, with overall decrease in cost of production from Rs. 3.29 to Rs. 1.88 per tuber.

*Net house area assumed 500 sq. mt. No. of mini tubers required @ 20 X 15 crop geometry and 10% space for doors, walkways etc 10000 for single cropping and 20000 for dual cropping

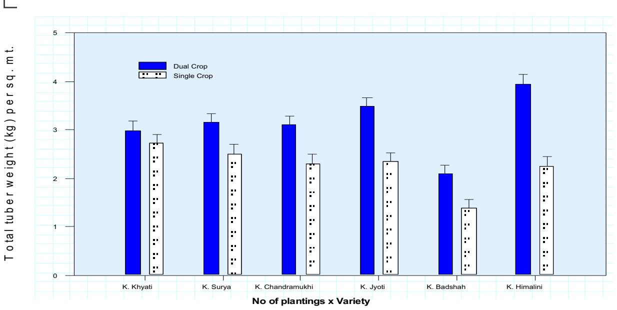


Fig.9. Total tuber weight (kg) per unit area for different varieties under single and dual crop plantings/season

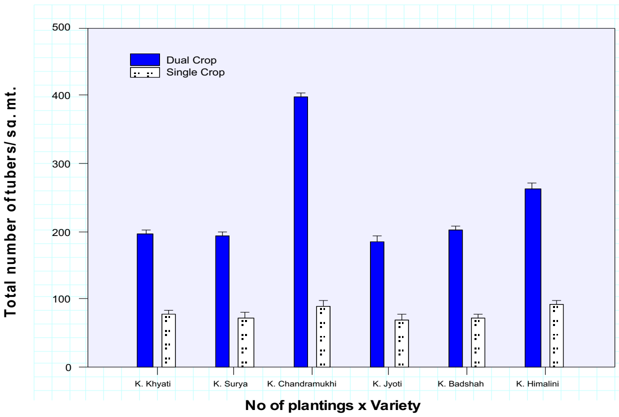


Fig.10. Total number of tubers per unit area for different varieties under single and dual crop plantings/season

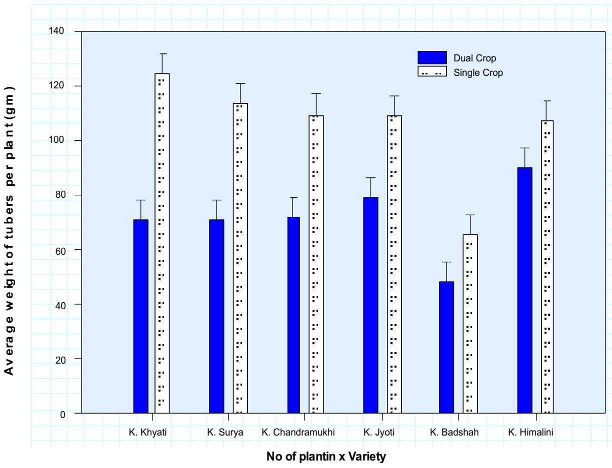


Fig.11. Average tuber weight (kg) per plant for different varieties under single and dual crop plantings/season

Maintenance and multiplication of potato microplants at Patna: Potato microplants of varieties like Kufri Surya, Kufri Himalini, Kufri Lauvkar, Kufri Chandramukhi, Kufri Pukhraj and Kufri Khyati were multiplied. Multiplied microplants were transferred to pro-trays for hardening under proper care. Fifteen days old plants were finally used for planting in the aeroponics.

Planting in the aeroponics: Microplants were finally transferred to new aeroponics from 20-21st November 2015.Variety wise yield performance varied between 88.1-117.6g per plant **(Fig. 13)**. A total yield of 33 kg of all varieties was harvested this year from aeroponics system.

Standardization of planting date for breeder seed production in Gwalior region: Three varieties Kufri Sindhuri, Kufri Chandramukhi and Kufri Chipsona-1 were taken up for optimizing their planting date. Increasing trend was recorded with increasing in date of planting both in total number and weight of tubers and highest tuber number was recorded in 31st October planting (667000/ha) and highest weight in 7th November planting (26.3 t/ha). Total tuber number were at par in Kufri Chandramukhi and Kufri Sindhuri (515000/ha). Total tuber yield was higher in Kufri Sindhuri (21.6 t/ha) over two varieties.

Phenotypic changes in seed tubers in different date of planting:

Experiment was conducted to find out deshaped tubers in different planting dates in cv. Kufri Bahar. 10th, 24th and 31st October planting recorded 45.3% of emergence, while 17th October recorded 37.5% of emergence. 24th and 31st October planting recorded higher growth charecters than earlier plantings. 24th October planting recorded highest tuber number (88) and weight (1194 g) per plot (Figs. 12 and 13). 17th and 31st October planting recorded higher deshaped tuber number (22.2 and 25.2%) over 10th and 24th October planting (17%) (Fig. 14). 10th and 31st October planting recorded 41.2 and 42.2% deshaped tuber weight over 17th (25.2%) and 24th (24.6%) October planting **(Fig. 15).**

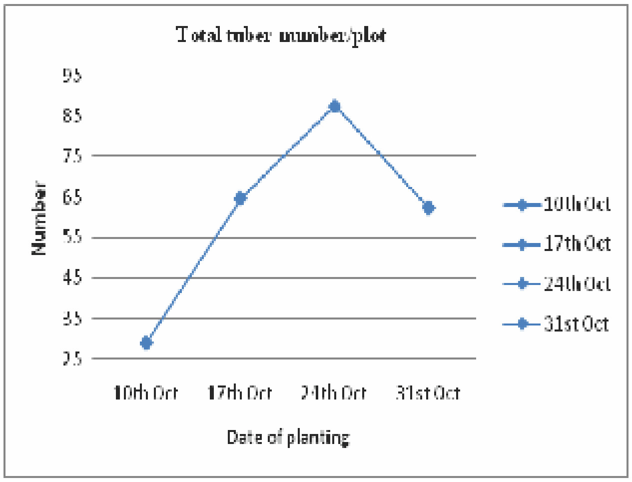


Fig. 12: Tuber number per plot

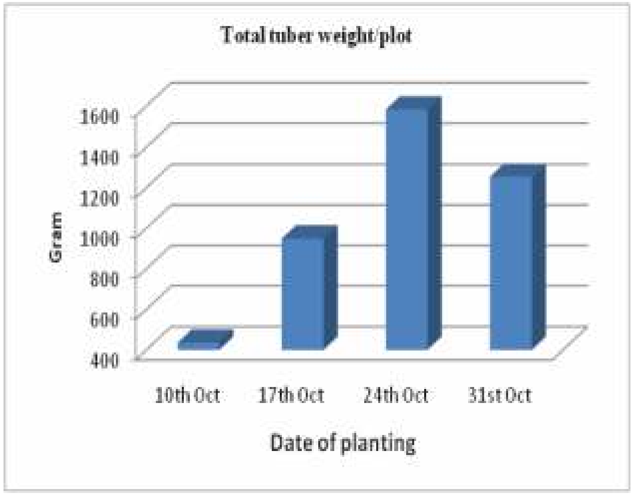


Fig. 13: Tuber weight per plot (g)

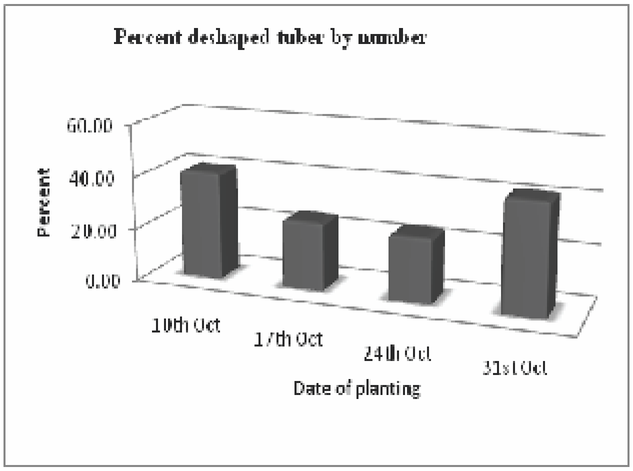


Fig. 14: Percent deshaped tuber by number per plot

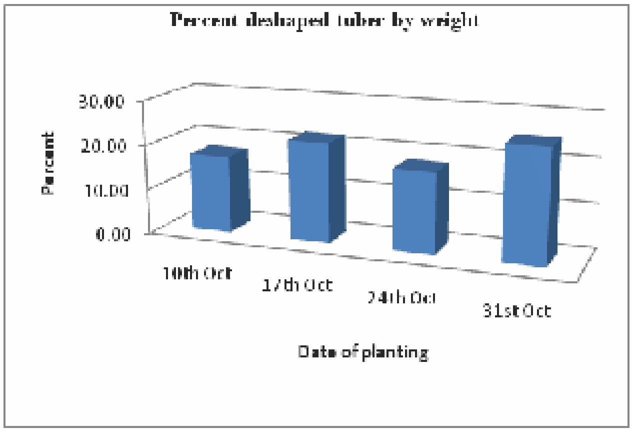


Fig. 15: Percent deshaped tuber by weight per plot

Refining Nitrogen requirement of recent potato varieties:

An experiment was conducted at Shimla to work out the N application rate for four potato cultivars under rainfed mid hill conditions. Soil of experimental field was high in available N. Results revealed that Kufri Shailja required 150 kg N/ha for optimum yield, whereas Kufri Jyoti and Kufri Himalini required 187.5 kg N/ha and Kufri Himsona produced optimum yield with 112.5 kg N/ha.

Boric acid application to control tubers cracking in cv. Kufri Chipsona-3:

Two sources of boric acid, Borex Decahydrate (10.5% boron) and disodium octaborate tetrahydrate (20% boron) were applied in various combinations in potato crop of cv. Kufri chipsona-3 to control tubers cracking. Both chemicals in all combination were found unable to control tubers cracking. Results were observed same in control plot as well as plots where chemicals were applied in various combinations.

Efficient use of Metribuzin herbicide in rainfed potato:

A field experiment was conducted at Shillong for efficient use of metribuzin in rainfed conditions of Meghalaya hills. There were three doses of metribuzin and six schedule of spray. Data revealed that potato yield was not differing significantly due to different dose of metribuzin while spray schedule of metribuzin brought out significantly the highest improvement in potato productivity when applied after 14 days of crop emergence.

Refinement of potato agro-technologies for pest management:

In two systems of groundnut-potato-maize + moongbean and cowpea-potato-okra + frenchbean observations were recorded on pest population and their management with eco-friendly methods at Modipuram. In Maize, shoot borer was major insect after emergence of the plant and it destroyed top center part of plant. In lady's finger immediately after emergence of plant, leafhopper *A. b. bigutula* was the major problem and at fruiting time in fruits, fruit borer was recorded 1.16/plant. In green gram and groundnut whitefly (*Bemisia tabaci*) was recorded. For bio-safe management of insect-pests 12 yellow sticky traps of the size 1.0'x1.5' were placed in field to capture the whitefly and aphid population. Light traps were placed to capture moths at night and 348, 232 and 148 moths of insects were captured in month of April, May and June 2015, respectively. Water traps were also placed on ground to capture soil insects and no soil insects were found in trap. It was recorded that more numbers of nymphs and adults of leafhopper were recorded on middle leaves of lady's finger compared to lower and upper leaf. Sprays (0.5% summer oil) were given at interval of 8-10 days to control leafhopper as soon as the adults (1-2/plant) were recorded on lady's finger plant. This resulted in good control of leafhopper. Dried neem leaves were used in organic treatments to see whether they could reduce the insect population by their decomposition and repellant action which resulted in the least number (6-8/plant) of leaf hoppers/plant in combination with foliar sprays of summer oil @0.5%.

Organic potato production technology development

Promising genotypes: For ware crop, Kufri Khyati, Kufri Mohan, Kufri Sadabahar, Kufri Pushkar, MS/0-3808 and MS-0/3740 were found better genotypes under organic farming as they had better marketable tuber yield and yield maintenance over popular varieties Kufri Bahar and Kufri Pukhraj. In chipping varieties, Kufri Himsona, Kufri Chipsona-1 and Kufri Chipsona-3 are good genotypes. French fry hybrid MP-04/578 also attained fair productivity.

Drip irrigation (cowpea- potato- okra): Distinct improvement in yield under organic farming was visible in potato crop (cv. Kufri Garima) in second year as organic system (CRR) achieved 75.4% of marketable and 77.5% of total tuber yield of inorganic source. Organic system (IA) could maintain 68.6% of marketable and 72.3% of total tuber yield in comparison to first year crop, where this treatment had 62.4% of marketable and 64.9% of total tuber productivity of inorganic nutrition.

Flood irrigation (cowpea- potato- okra): Yield improved significantly with organic nutrition in potato crop (cv. Kufri Garima) in second year as it could achieve 76.6% of marketable and 77.1% of total tuber yield of inorganic nutrition in organic system (IA). In first crop season, cv. Kufri Garima could achieve 62.4% of marketable and 64.9% of total tuber productivity of inorganic treatment.

Sprinkler irrigation (groundnut- potato- maize+ green gram): Yield maintenance under organic farming was distinct in potato crop (cv. Kufri Himsona) in second year as it could attain 83.7% of process grade and 88.3% of total tuber yield of inorganic treatment in organic system (IA). This retention was 43.4 and 28.3% higher over first year as during this cv. Kufri Himsona could maintain only 40.3% of process grade and 60.0% of total tuber yield.

Flood irrigation (groundnut- potato- maize+ green gram): Improvement in yield maintenance under organic farming was distinctly visible in potato crop (cv. Kufri Garima) in second year as it could attain 61.9% of marketable and 63.6% of total tuber yield of inorganic source in organic system (IA). This was 9.3 and 6.9% higher, respectively, over previous crop season, as Kufri Garima could retain 52.6% of marketable and 56.7% of total tuber yield.

Potato production technology for disease management: Disease incidence were recorded ingroundnut- potato- maize+ green gram and cowpea- potato- okra cropping systems followed in organic farming activity at Modipuram. Banded sheath blight (*Rhizoctonia solani*) of maize, *Sclerotium rolfsi* of lady's finger and green gram were observed. Besides, on lady's finger yellow vein mosaic was also recorded. Both yellow mosaic like symptoms and Cercospora leaf spot were observed on cowpea. Stem rot of groundnut (*Sclerotium rolfsi*) was observed on ground nut. Botanical pesticide was evaluated against late blight of potato and results were better against the control. Disease dynamics was recorded on 14 varieties including three hybrids in organic based potato cultivation. It was observed that on cv. Kufri Bahar (75% DS), Kufri Pukharaj (45% DS) and remaining varieties having 2-10% disease severity (DS). Disease dynamics was recorded in another organic based potato cultivation on cv. Kufri Himsona and amongst seven treatment moderate level of infection (< 4.0%) was recorded on organic (Homeopathic), organic (crop residue) and organic(bio-fertilizers and microbes).

Biochemical analysis of tuber: Tuber samples were analysed for dry matter content (%) to estimate the effect of inorganic versus organic nutrition. Dry matter content was marginally higher in inorganic treatments as compared to organic one. Among cultivars, Kufri Chipsona-1(24.9%) recorded maximum of this parameter followed by Kufri Chipsona-3 (24.2%), while lowest was in Kufri Khyati (16.8%). Mean reducing sugars in cv. Kufri Chipsona-3 were lower in inorganic treatments over organic source. Potato fertilized with 75% inorganic +25%vermicompost retained minimum of reducing sugars (53.8 mg/100g FW) followed by another treatment of 25% organic and 75% inorganic (53.8 mg/100g FW). Values registered for vitamin C content in all the treatments were observed to be more or less similar. 100% organic indicated maximum of ascorbic acid content (21.4mg/100g FW) in cv. Kufri Chipsona-3 followed by 75%inorganic+25% vermicompost (21.4 mg/100g FW) and 100% inorganic (21.3mg/100g FW).

Evaluation of potato based cropping systems: A field experiment was conducted at Gwalior to evaluate two planting methods (raised bed planting and normal planting) and 5 cropping systems (pearl millet, maize and cowpea sole crop treatments and two pearl millet + cowpea and maize + cowpea intercropping treatment combinations). Data revealed that sowing during kharif in two methods of planting did not showed any significant effect on grain yield. Intercropping cowpea + pearl millet increased grain yield of pearl millet significantly over its sole cropping. Intercropping cowpea + maize increased grain yield of maize significantly over its sole cropping. Growing of *kharif* crop in raised bed followed by potato in ridge-furrow system produced significantly higher tuber yield than growing *kharif* crop in normal bed followed by potato in ridge-furrow system. Among sole crop sequences highest tuber yield was recorded in maize-potato sequence followed by cowpea – potato sequence. Lowest tuber yield was recorded in pearl millet- potato sequence.

Long term plant nutrition studies in potato based cropping systems

System Productivity: Among 7 treatments (Table 1,2 and 3) tuber yield with application of vermi-compost on an average was higher than absolute control. Tuber number followed same trend as the tuber yield. Yield of wheat, potato, onion and Maize crops were higher in treatments receiving 100% recommended NPK through inorganic fertilizer over 100% organic treatments. Yield of rice, maize, groundnut and green gram was at par in both organic and inorganic nutrition. Application of secondary nutrients along with 100% NPK slightly increased productivity of all systems as productivity was higher than 100% NPK. Average system productivity (SP) was highest in maize-potato-onion cropping systems (47.6 t/ha) followed by groundnut- potato-green gram (40.0 t/ha). Lowest SP was recorded in rice-potato-wheat (38.9t/ha). Among cropping systems under organic treatments, tuber size remained smaller than treatment receiving NPK through inorganic fertilizer. Leaf area index was higher in inorganics as compared to organics. Highest dry matter content was recorded in green gram-potato- groundnut system. However, it was at par with other cropping system. Other quality parameters were better under organic treatment. Tuber dry matter content was highest in 100% organic nutrition through vermicompost remaining comparable to 50% organic+ 50% inorganic and 100% NPK+ secondary nutrient. Application of 100%NPK+ secondary nutrients and residue of previous crop has increased the potato yield in all three cropping system.

Soil Health: Soil analysis revealed that incorporation of crop residue as well as use of organic manure, with or without fertilizers improved organic carbon content as well as microbial biomass carbon, dehydrogenase activity and carbon sequestration rate as compared to inorganic treatment alone. rice-potato-wheat and maize-potato-onion showed higher C stocks in soil than groundnut-potato-green gram cropping system. Integrated application of organic amendments (vermi-compost, crop residue etc.) along with chemical fertilizer could be the best management practices for enhancing C sequestration in soil and sustainable crop production.

Disease Incidence: In potato-onion-maize (C2) and potato- green gram- groundnut (C3) cropping system observation were recorded on foliar diseases of potato especially on Phoma and leaf spot complexes. Results revealed that in absolute control, 100% NPK through organics and 100% organic + crop residue showed high disease incidence in both systems over other inorganic sources. Observation on soil and tuber borne diseases were recorded in potato-wheat-paddy (C1), C2 and C3. In C1 system only trace amount of common scab were observed. In C2 and C3 system black scurf of potato were recorded and results revealed that in absolute control, 100% NPK through organics and 100% organic+ crop residue showed high disease incidence in both C2 and C3 system. In C2 system, it was noticed that incidence of apical leaf curl virus (APCLV) were less in organic sources than inorganic sources. In C2 system, it was found that incidence of banded sheath blight of maize were less in inorganic sources than organic treatments. In C1 system, it was observed that incidence of powdery mildew of wheat was more in inorganic treatments than the organic sources. In C1 sequence, it was recorded that incidence of bakane disease of rice was more in inorganic treatments than the organic one. In C1 system, it was found that incidence of sheath blight disease of rice was more in treatment consisted organic sources than the inorganic sources.

Pest Incidence: Whitefly incidence and % apical leaf curl (1.67/5 plants and 2.35%), (2.33/5 plants and 2.7%) and (1.67/5 plants and 1.95%) was recorded on potato in the T3 treatment of C1, C2 and C3 cropping systems, respectively. Whitefly and % incidence of APCLV on potato crop did not show significant differences among different treatments of C1, C2 and C3 systems, however treatment consisting of 100% organic or part of organic manure recorded low incidence of whitefly and corresponding development of disease as compared to 100% inorganic nutrition along with control treatments, respectively. Population trend of thrips on groundnut, % stem borer damage in maize and % leaf folder and stem borer damage in rice did not show any significant differences among various treatments. However, thrips population (1.62-1.69/ 5 plant) was recorded on groundnut in 100% organic treatment as compared to 100% inorganic (2.71-3.33/ 5 plant). Similarly, leaf folder incidence was varied from 0.45-0.48 % and 0.93-1.13% in the 100% organic and inorganic treatments of rice, respectively. The incidence of stem borer in maize was 3% in 100% organic, 8.33% in 100% NPK and 9.0% in control. Low incidence of whitefly and thrips was observed on green gram and onion crops, respectively.

Table 1: Yield of Rice –Potato-Wheat cropping system and potato equivalent yield (PEY) as influenced by different management options

S. No.		Yields of Crops (t/ha)					
	Treatment	Wheat		Rice		Potato	PEY
		Grain	Straw	Grain	Straw		
1.	Absolute control	1.46	3.94	3.04	9.04	6.35	18.97
2.	100% NPK through inorganic	3.33	9.00	4.70	14.48	17.46	43.79
3.	100% NPK through organic	2.26	6.52	4.78	12.67	12.63	31.95
4.	50% inorganic + 50% organic	3.26	8.11	5.74	17.31	17.28	43.73
5.	100% inorganic + secondary nutrient	3.30	9.31	5.98	18.76	20.33	48.47
6.	100% inorganic + crop residue	3.41	9.39	6.00	19.80	19.91	48.97
7.	100% organic + crop residue	2.83	7.35	5.54	17.37	11.96	36.13
	CD (0.05)	**0.42**	**0.26**	**0.13**	**0.56**	**0.36**	**1.82**

Table 2: Yield of Maize-Potato-Onion and potato equivalent yield (PEY) as influenced by different management options

S. No.	Treatment	Yields of Crops (t/ha)				
		Onion	Maize		Potato	PEY
			Grain	Stalk		
1.	Absolute control	4.91	1.70	4.54	7.41	27.20
2.	100% NPK through inorganic	6.65	3.11	8.46	24.89	56.53
3.	100% NPK through organic	7.72	1.57	4.83	11.67	37.01
4.	50% inorganic + 50% organic	7.09	2.74	6.31	18.61	48.08
5.	100% inorganic + secondary nutrient	8.39	4.35	9.74	26.69	67.41
6.	100% inorganic + crop residue	7.56	4.63	7.13	26.22	64.19
7.	100% organic + crop residue	5.74	1.54	5.30	11.33	32.91
	CD (0.05)	**0.82**	**0.57**	**0.68**	**1.62**	**3.27**

Table 3: Yield of Moong-Ground nut-Potato and potato equivalent yield (PEY) as influenced by different management options

S. No.	Treatment	Yield of Crops (t/ha)					
		Moong		Ground nut			
		Grain yield*	Straw Yield	Pods(dry) yield	Straw yield	Potato yield	PEY
1.	Absolute control	0.34	3.78	0.78	2.07	11.72	24.14
2.	100% NPK through inorganic	0.46	6.07	0.81	2.17	35.19	50.25
3.	100% NPK through organic	0.33	3.24	0.66	2.57	19.09	30.44
4.	50% inorganic + 50% organic	0.35	4.54	1.01	2.31	29.30	44.28
5.	100% inorganic + secondary nutrient	0.74	4.83	0.74	2.48	32.85	49.13
6.	100% inorganic + crop residue	0.50	4.70	0.78	2.48	37.46	52.02
7.	100% organic + crop residue	0.36	2.74	0.64	2.24	18.50	29.44
	CD (0.05)	0.07	0.24	0.22	0.42	1.82	2.84

Development of agro techniques for potato crop and popularization of new potato cultivars suitable for *kharif* season

Identification of suitable potato hybrid (combined resistance to late blight and viruses) for kharif crop in plateau region: SM/92-338 (21.2 t/ha) performed best among all hybrids/ varieties evaluated at Hassan and recorded 13.4 % more tuber yield over second best hybrid LBY-15 (18.6 t/ha). Among the hybrids/ varieties evaluated, hybrid LBY-15 showed notable resistance against late blight and it had recorded 6.25 % disease spread at 75 days after planting followed by SM/92-338 (8.5 %) **(Fig. 16)** cultivars suitable for kharif season.

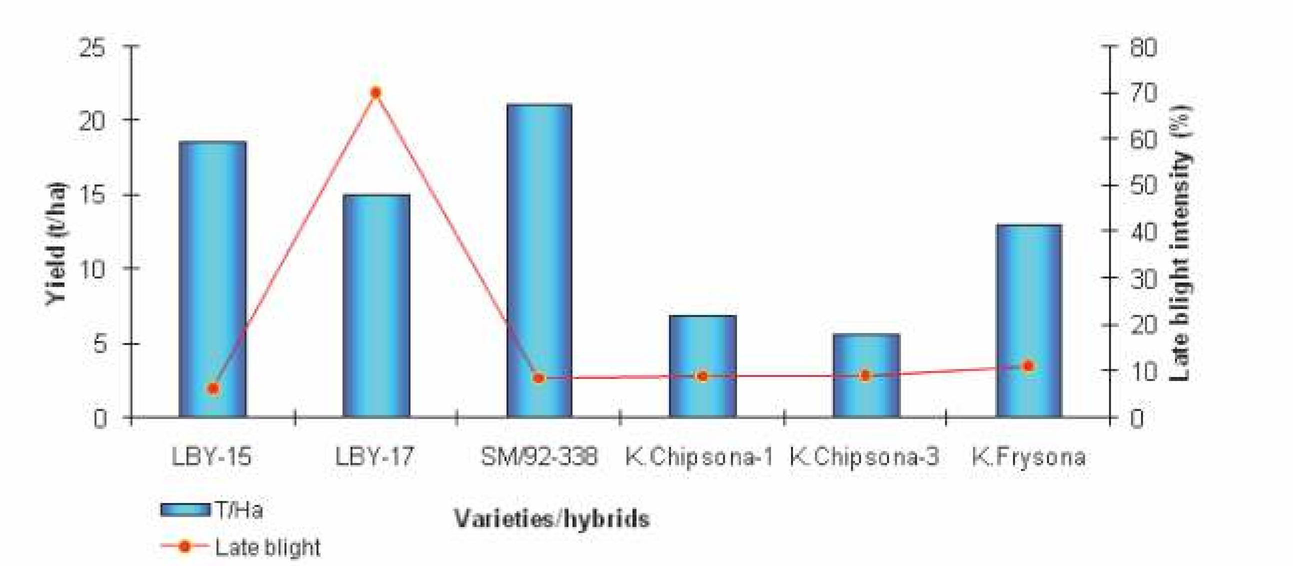


Fig. 16. Performance of late blight resistant hybrids at Hassan

Trial with Hill and Kharif potato hybrids: Among the hybrids/varieties evaluated at Hassan, AICRP-P-16 recorded higher yield of 12.9 t/ha which was on par with AICRP-P-17 (12.6 t/ha). Lowest late blight intensity of 1.47% was observed in AICRP-P-18 followed by AICRP-P-17 (2%) and AICRP-P-18 (2.12%) **(Fig. 17)**.

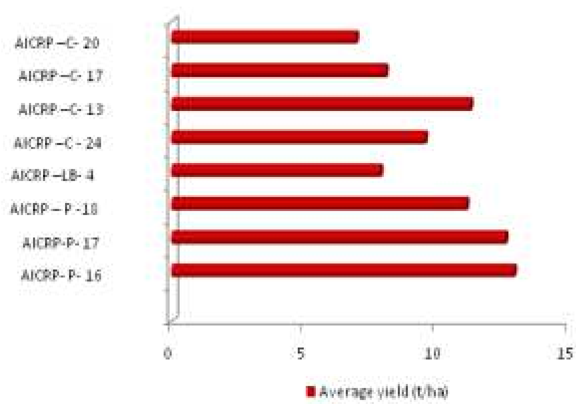


Fig. 17: Performance of Kharif potato hybrids at Hassan

Optimizing nitrogen requirement for different potato cultivars suitable for kharif season: Kufri Himalini (8.7 t/ha) and Kufri Jyoti (8.6 t/ha) recorded highest yield at 150:100:125 kg/ha of N, P and K, while Kufri Surya (7.9 t/ha) had maximum productivity at 100:100:125 kg/ha of N, P and K **(Fig.18)**.

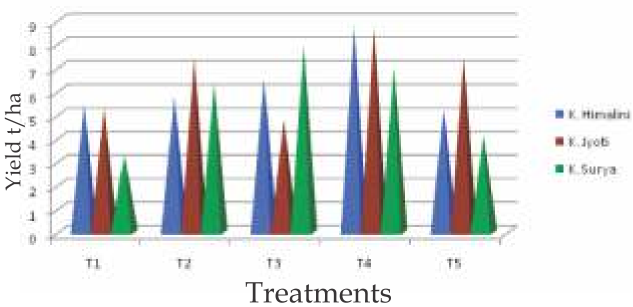


Fig. 18: Response of three potato varieties to different nitrogen levels at Hassan

Front line demonstrations, Hassan (Karnataka): Ten front line demonstrations were conducted during kharif season of 2015-16 at Hassan (Karnataka) to evaluate the performance of potato varieties. Recommended package of practices of the region were followed for crop cultivation. Cultivar Kufri Jyoti, Kufri Surya and Kufri Himalini were planted on ridges (60 x 20 cm) during first week of June, 2015 and crop was harvested at full maturity in second week of September, 2015. Observations viz. marketable and non-marketable tuber number and yield were recorded at each location from six different places selected randomly from the planted crop area for the varieties. Variety Kufri Himalini performed better than other two varieties namely Kufri Surya and Kufri Jyoti. In all the locations, Kufri Himalini recorded maximum yield and it gave highest yield of 28.6 t/ha in Annenahalli (Chandrayapatna). Average yield of Kufri Himalini (21.6 t/ha) was 42% higher than Kufri Jyoti (15.2 t/ha) and 55% higher than Kufri Surya (14.0 t/ha). Similar trend was also noticed in case of marketable tuber yield and numbers. In four locations, Kufri Surya performed better than Kufri Jyoti **(Table 4)**.

Table 4: Performance of Kufri Himalini, Kufri Surya and Kufri Jyoti in District Hassan (Karnataka) during kharif season 2015-16

S. No.	Locations	Potato yield (t/ha)				
		Kufri Surya	Kufri Jyoti	Kufri Himalini	Percent increase/ decrease over Kufri Surya	Percent increase/ decrease over KufriJyoti
1.	Bageshapura	19.17	18.70	26.4	37.71	41.18
2.	Shanthigrama	6.90	14.6	19.7	185.51	34.93
3.	Sopnahalli	11.25	8.00	23.9	112.44	198.75
4.	Hullangane	20.83	25.83	25.83	24.00	0
5.	Somnahallikaval	7.097	4.25	7.70	8.50	81.22
6.	Hulikallu	15.00	14.41	19.16	27.73	32.96
7.	Annenahalli	17.49	20.67	28.62	63.64	38.47
8.	Kalnayaganahalli	-	-	-	-	-
9.	Honnenahalli	-	-	-	-	-
10.	Umadeverahalli	-	-	-	-	-
	Mean	13.96	15.21	21.61	54.81	42.13

Mechanical technologies for potato cultivation

Assessment of potato damage during mechanical harvesting, grading and handling and its remedial measures

Harvest: Mechanical damage is a major concern for potato industry. A tractor operated two row potato elevator digger was tested at 3 different forward speeds and at the same harvest depth, for assessment of damage index on harvested potato. Depth of digger blade, speed of forward travel, and speed of moving parts of digger influence greatly amount of damage done during harvest. Samples were collected and after washing, sample tubers were then inspected and divided into categories- Undamaged, Scuffed, Slight, Severe. Severe type of damage index with tractor operated potato elevator digger was observed minimum (28) at forward speed of 2.6 km/hr, whereas scuffed and slight damage indices (2 and 1.5 respectively) were noted minimum at forward of 3.2 km/hr. Total damage indices were found as 48.5, 43 and 33.25 at tractor's forward speeds of 2.0 km/hr, 2.6 km/hr and at 3.2 km/hr. Respectively (Fig. 19). Damage index should be as low as possible (<100). Lower is the damage index, the less damage is being caused. Total damage percentage of tubers at tractor's forward speed of operation of 2.0, 2.6 and at 3.2 km/hr was observed as 12.5, 14 and 6.75 % respectively.

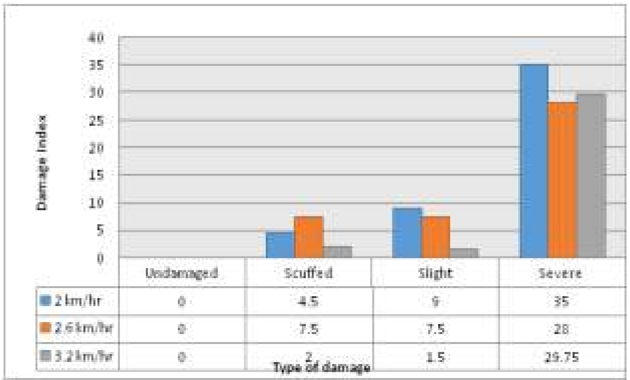


Fig.19: Effect of forward speed of tractor on potato damage Index

Grading: During grading with a square wire mesh type of grader with Kufri Jyoti variety, the scuffed, slight and severe type of damage indices were observed as 2.42, 0.75 and 8.17 respectively. Total damage percentage of tubers with grader was found as 3.67%. Bruising assessment of potato tubers after digging with an elevator digger and grading with a grader was also carried out. This assessment was categorized as nil, slight and severe. Bruising percentage with potato elevator digger was measured 9.32% and 1.36% for slight and severe type of bruising respectively. Slight and severe types of the bruising percentages with potato grader, were measured as 14.64 and 1.36 percent respectively. Various design improvements in square wire mesh type of potato grader having output capacity of 5-6 t/hr for pre-cold storage of potatoes, were also carried out in order to reduce the damage caused to the potatoes during grading. Rotational speed of the grading belts (having 52 mm, 32 mm and 20mm size square openings) were optimized by adjusting the size of the sprockets in the power transmission system. All inclined chutes, made out of GI sheet (20 gauge) provided to receive different grades of potatoes, were also covered with rubber sheet for this purpose. Grader has been designed to grade the potatoes in four size grades e.g. < 20 mm, 20-32 mm, 32 -52 mm and > 52mm.

Development, improvement and evaluation of tractor operated potato combine harvester: Two-row tractor operated trailed type potato combine harvester with provision to split ridge, lift loose material, separate soil and clods and collection of tubers in to bags simultaneously, was improved and field tested **(Fig. 20).**

Fig.20: Prototype of potato combine harvester during field operation

To develop advanced soilless production system for increasing potato mini-tuber production and reducing input cost

Testing of new aeroponic system:

A new design of commercial scale aeroponic system was developed and tested at Jalandhar. Important features of this soilless cultivation system include an improved electrical control panel having displays of pH, EC, temperatures, RH; new design of grow boxes made form bricks and concrete; system for preventing lodging of plants; a mechanical system for lifting of plants for tuber picking and root trimming; chilling system for cooling nutrient solution to desired level. System was tested on long term basis and consistency of various sub systems was observed for interruption, collapse and other operational problems. During testing it was observed that electrical control panel needs additional separate control for cooling pad pump for individual control in special circumstances. Temperature rise across new grow boxes lagged behind by three hours when compared to existing styro foam boxes. Plant lodging prevention system enhanced production by 25-30% and lifting mechanism reduces manpower requirement by 25-30%.

Improvements in portable aeroponic system:

Portable aeroponic system developed for conducting experiments on potato had problem of unusual temperature rise inside the grow box during last two season. Because of this, crop duration reduced by 20-30 days and there are problems associated with no or delayed tuberization, reduced yield and sometimes crop failure. To resolve these problems two units were modified and compared with the existing one. Control (Unit I) was the original unit in which grow box in itself hold nutrient solution and worked as combined grow box- cum-nutrient solution reservoir. In first modification (Unit II) additional nutrient solution tank was provide below the grow box inside the unit body. In unit III this additional solution tank was placed outside the unit casing. For testing the performance of modified units an experiment was conducted by planting hardened in vitro plantlets of cultivar Kufri Jyoti. Modified unit III, showed least temperature rise. There was normal plant and root growth in unit III while in unmodified unit there was crop failure due to high temperature inside the grow box **(Fig. 21).** Performance unit II was inferior to unit III in terms of crop stand and temperature rise.

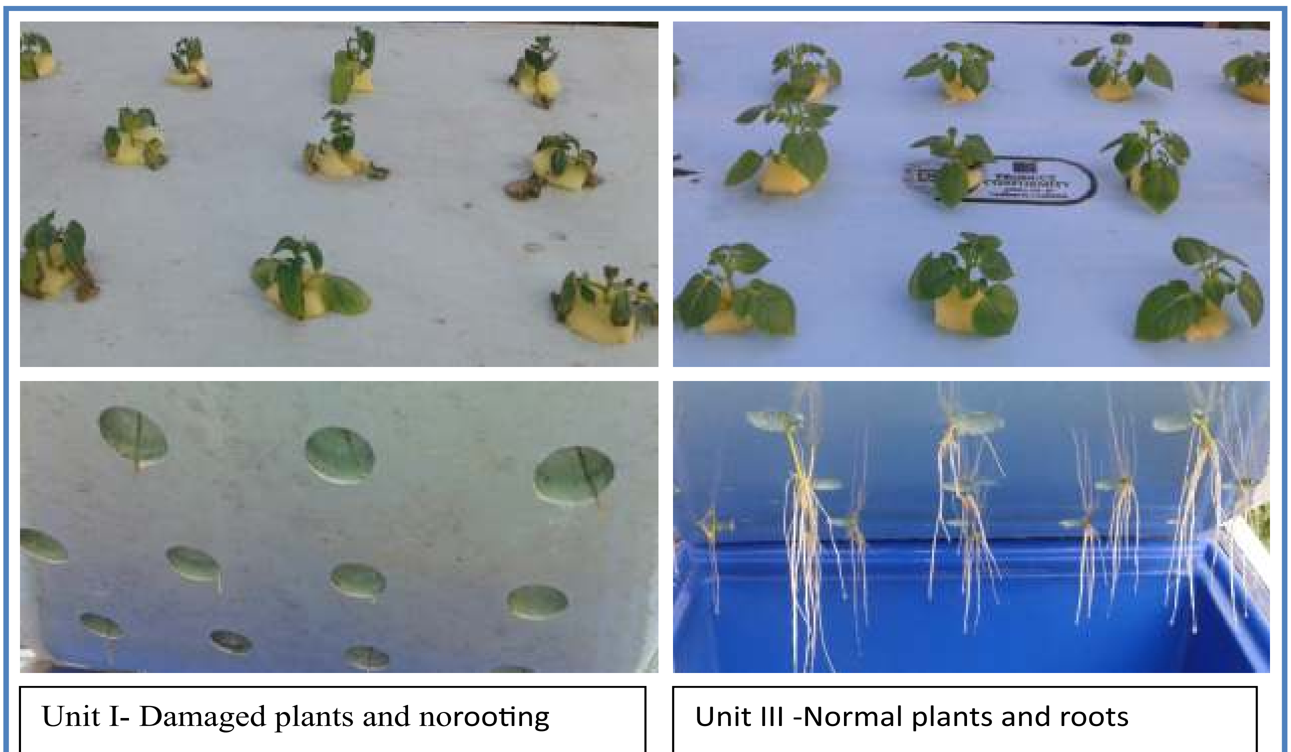


Fig. 21: High root zone affected crop in original (unit I) and healthy crop in modified (unit III) portable aeroponic unit

Designing of feeder unit for aeroponics: In N-W plains of India, considering temperature profile, available time for raising potato (in aeroponics) is only about 180 days. (15th October to 15th April.) In present system of crop rising under aeroponics two complete crop cycles could not be taken in available 160 days. For two crops 240 days are required, therefore, design of a feeder unit had been prepared. In this automated feeder unit, in vitro plants would be provided with suitable environmental (light, temperature, RH) conditions to make them ready for shifting to aeroponics systems when plants reach stolon initiation stage. In this way it is expected that a crop cycle will be completed in 90-100 days instead of 120-125 days and two crop cycles would be possible in available 180 days. Feeder unit consists of sub systems to feed the young plants and give them cosy environment for proper growth and root development.

Division of Plant Protection

Re-defining epidemiological parameters and management approaches for potato pathogens

Disease Monitoring and Profiling of Pathogens

Late blight appeared on 8th July, 2015 on cv. Kufri Jyoti in Shimla. Overall, the severity of potato late blight in Himachal Pradesh ranged from 25-90% depending upon the cultivar raised and plant protection measures adopted. In western Uttar Pradesh the disease appeared in Modipuram on 28th November, 2015 but could not spread fast.Late blight was severe in Mainpuri, Kanpur, Kannauj and Farrukhabad districts of central Uttar Pradesh where its severity ranged from 0-100%. The highest late blight severity was recorded in Kannauj (up to 100%) where about 25-35% area was severely affected and yield loss was predicted to be up to 50-60% followed by Kanpur (80%) where about 50-60% area was moderately affected and 20-30% loss was predicted. In western Uttar Pradesh, Muzaffarnagar and Bijnour districts were severely affected where about 50% severity was recorded whereas JP Nagar and Sambhal had moderate infection (up to 10%). Since late blight infection was observed in early crop, up to 10 % crop loss was predicted.

Survey for occurrence of virus diseases in Mawana, Bagpat, Muzaffarnagar, and Sambhal areas of western Uttar Pradesh was conducted during the crop season and samples were collected and analysed by ELISA. Results revealed the presence of PVX, PVS, PVM, PLRV, PVY, PVY^N and PVY^{O+C} in the samples collected from Mawana **(Fig. 1).** In this particular field besides other common potato viruses, PVY strains like PVY^N, PVY^{O+C} were detected which indicated that the seed material might have been procured from unreliable sources. In the same farm, severe necrosis on tubers was also observed on the local variety VSN **(Fig. 2).** Samples collected from Sambhal were infected with PVX, PVS and *ToLCNDV*-Potato. Apical leaf curl disease was also reported from Muzaffarnagar and Baghpat. Similarly, samples collected from Jalandhar (Punjab), Gwalior (Madhya Pradesh), Pantnagar (Uttarakhand) and Deesa (Gujarat) were tested by RT-PCR and results revealed that samples from Jalandhar were carrying mainly PVY, $PVY^O$and PVY^N, samples from Pantnagar were carrying PVS and PVM, samples from Gwalior were carrying PVY, PVY^O and $PVY^N$and samples from Deesa were carrying PVM and PVS.

Fig.1 Healthy and virus infected plants of variety VSN and K. Chipsona-1

Fig. 2 Severe necrosis on tubers

Comparative Genomics of Potato Pathogens

Characterization of Phytophthora infestans

Due to climate change, global trade and increasing cropping intensity, pathogens are evolving at a faster rate and quickly adapting to the new weather conditions and hosts. To devise suitable management strategies, it is essential to understand the pathogen variability. With the objective, the population of *P. infestans* was characterized using both biological and molecular markers. Both the mating types of *P. infestans* have been reported from India but A2 mating type is dominating in the hills and A1 mating type in sub-tropical plains. This trend of mating type distribution is being observed for several consecutive years implying that the mating types have established in the respective regions. Comparison of *P. infestans* population for metalaxyl sensitivity in different parts of the country revealed that none of the isolate developed tolerance to 400 ppm while 15 % isolates from HP hills and 60% from West Bengal exhibited tolerance at 300 ppm. With the introduction of new molecules for the management of late blight, it is the need of the hour to monitor the population of *P. infestans* for development of resistance to those molecules. In this direction, isolates of *P. infestans* were tested for their sensitivity to cymoxanil, dimethomorph and fenamidone and all the tested isolates showed sensitivity to those new fungicides. *Phytophthora infestans* population (130 isolates) collected from Himachal Pradesh, Meghalaya, Tamil Nadu, Punjab, Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal and Karnataka were characterized for ploidy status using Feulgen cytophotometry method. Results revealed that *P. infestans* population in the country are polyploid consisting of diploids, triploids and tetraploids. However, frequency of different polyploids varied from region to region. In north-western hills, the frequency of diploids was highest (90.48%) followed by triploids and tetraploids (4.76%). Whereas in north-eastern and southern hills, frequency of diploids was highest (80%) followed by triploids (20%). Tetraploids were altogether missing in north-eastern and southern hills. In Indo-Gangetic plains, the frequency of diploids was highest (87.88%) followed by triploids (9.09%) and tetraploids (3.03%). In plateau only diploids were recorded **(Fig. 3).**

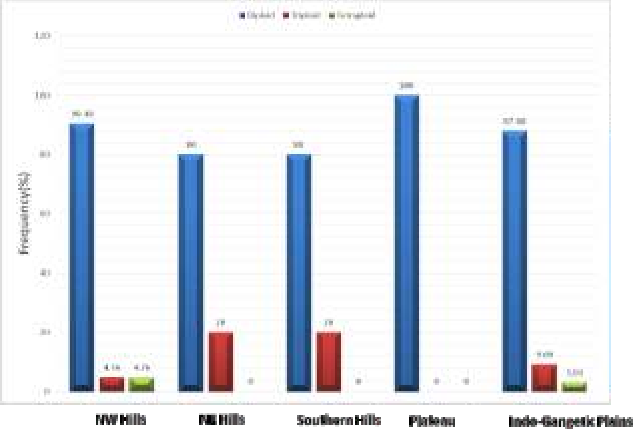


Fig. 3: Distribution of polyploids of P. infestans in India

Migration has played a major role in spread of new genotypes of *P. infestans* across the globe during last three decades. Mitochondrial haplotyping technique enabled to track specific lineage, providing a robust marker tool. Mitochondrial haplotyping of 100 isolates collected from Himachal Pradesh, Meghalaya, Punjab, Uttar Pradesh and West Bengal was done with primer F2-R2 (digested with *Msp*I) and F4-R4 (cut with *EcoR1*, **Fig. 4**) to determine the lineage. Results revealed that all the isolates belonged to the Ia haplotype, which confirms the previous years' results and tends to suggest that the new population has displaced the old population (Ib) in most of the regions

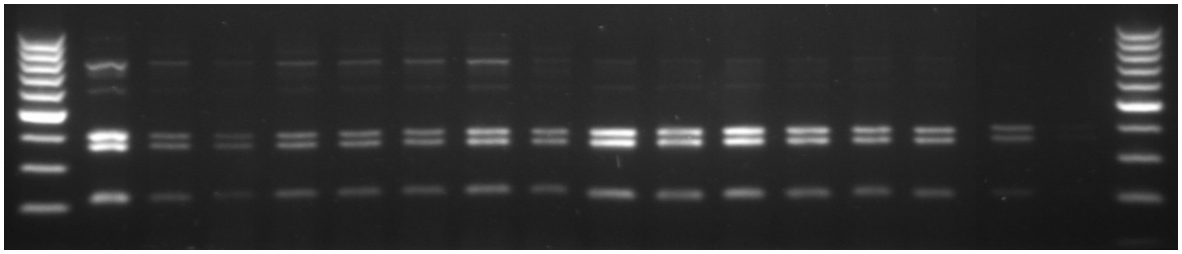


Fig. 4:Mt DNAhaplotyping with primer F4-R4 digested with EcoR1

Simple sequence repeats are very useful markers for diversity analysis. SSR markers being co-dominant can distinguish between dominant and recessive alleles. A sub-set of core collection of *P. infestans* isolates were selected for genotyping of Indian population using four polymorphic SSR primers (Pinf SSR1, SSR2, Pi4B & Pi04). Most of isolates having two alleles (228 and 243bp, Fig. 5) were observed with primer Pinf SSR1 in 100 isolates of *P. infestans*. Whereas, two alleles (198 and 204 bp) were observed with primer Pi4B (Fig. 6) and three alleles with primer Pi04 (164, 172, and 186 bp). Mostly two alleles (170 and 184 bp) were observed with primer Pinf SSR2 but in some of isolates more than two alleles were also observed.

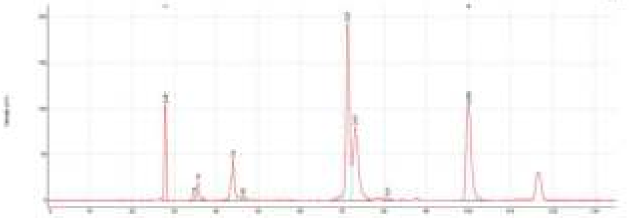


Fig. 5: Electropherogram of P. infestans isolate with Pinf SSR1 primer showing two alleles

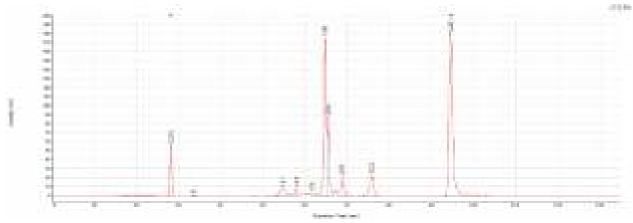


Fig. 6. Electropherogram of P. infestans isolate with Pi4B primer showing two alleles

Comparative genome analysis of Phytophthora infestans

Management of late blight pathogen is challenged by its remarkable speed of adaptation to chemical control strategies and quick break down of resistance. Keeping this in view, re-sequencing of *P. infestans* whole genome of Indian A2 (S15) mating type was done. Genome size of this pathogen is about 240 Mb and we have generated ~20X coverage of whole genome sequence using Ion Torrent (Next Generation Sequencing) technology. Total of 501,913 raw reads were generated having average read length of 150 bases. The assembly of these reads yielded 218 Mb data having largest contig length of 80,989 bp and average contig size of 431. Using fastaq format of 20X genome data and using Varscan, we have generated SNP data at genome level. Data revealed 7,342 SNPs at 20X coverage, whereas at 10X genome coverage 133,255 SNPs have been identified. INDELs data showed 743 at 20X coverage and 4,504 at 10 X coverage that confirmed existence of variation between Indian and European isolate **(Fig.7).** This information is being used for isolation of effector genes. Targeted re-annotation of novel genes especially effector genes is in progress using comparative genomics approach where the *P. infestans* S15 novel genes are compared with sequence of *P. infestans* strain T30-4, which has been sequenced by Broad Institute, USA.

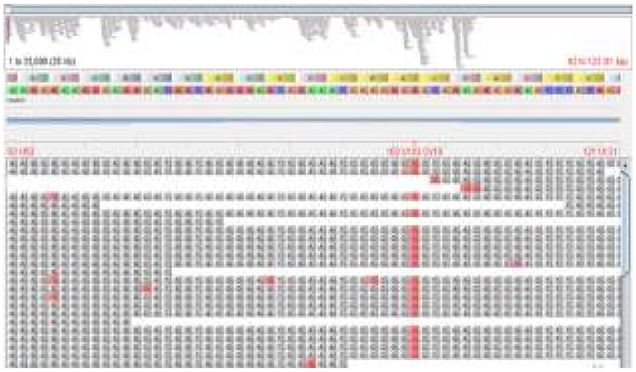


Fig.7: SNP variation between P. infestans and reference genome

Whole genome sequencing and comparative analysis of strains of PVY (PVY^O and PVY^N)

Potato virus Y (PVY) is a serious problem and the emergence of new genetically recombinant and serologically different strains has made it more difficult to manage and to diagnose. Hence, to resolve the issue we need to understand its genetic makeup and its serological relationships. We have already sequenced the complete genome of ordinary strain of PVY (PVY^O) with five different fragments by using the overlapping primers for sequencing. The entire fragments of the genome were assembled and annotated. This year we targeted PVY^N strain for whole genome sequencing with five different fragments **(Fig. 8)**, eluted and processed directly for sequencing with the help of overlapping primers. Out of five fragments we could sequence nearly four fragments and the other fragment is in the process of sequencing. The entire genome of both the strain of PVY will be compared for its variability analysis so that a proper diagnostic and management strategy can be designed.

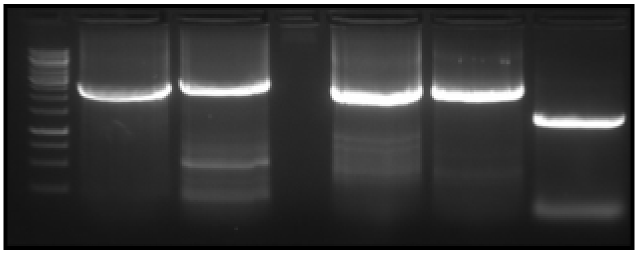


Fig. 8: PVY^N Whole Genome: Lane1:1Kb ladder, Lane2:1F 26R, Lane3: 6F 30R, Lane 4: empty, Lane5:10F 34R, Lane6: 14F 38R, Lane 7: 18F 40R.

Molecular Diagnostics and Detection of Potato Pathogens

Development of RT-PCR protocols for post entry quarantine pathogens

RT-PCR protocols were developed for quarantine pathogens viz., *Potato yellow dwarf virus, Arracacha B virus, Potato mop top virus,* and Potato latent virus. CP gene sequences of these viruses were retrieved from NCBI database and primers were designed from the conserved regions manually and properties were checked through online software oligonucleotide properties calculator. RNA was extracted from positive control samples supplied with the ELISA kits and RT-PCR protocols were standardized for further use in post entry quarantine testing.

Duplex RT-qPCR assay detection of ToLCNDV-potato along with PVX and PLRV

SYBR green based RT-qPCR assay coupled with melting curve analysis was developed for the detection of ToLCNDV-potato along with PVX and PLRV. Reproducibility and repeatability of the developed assays were determined using three different dilution series. The duplex RT-qPCR assays were validated to detect mixed infections of these viruses in field samples **(Fig.9).** Among the 118 field samples tested, 43 samples were infected with both ToLCNDV-potato and PVX, while 16 and 59 samples were infected with ToLCNDV-potato and PVX, respectively. Out of 59 samples, only 3 samples were infected with both ToLCNDV-potato and PLRV, while 30 and 23 samples were infected with ToLCNDV-potato and PLRV, respectively. Absence of melting peaks in remaining samples confirmed that these samples were free from infection with these viruses.

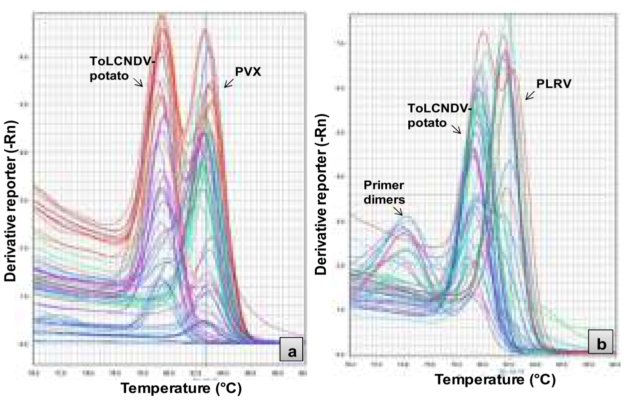


Fig.9: Duplex RT-qPCR detection of ToLCNDV-potato & PVX (a) and ToLCNDV-potato & PLRV (b) in field samples

LAMP assay for ToLCNDV-potato detection

Loop mediated isothermal amplification (LAMP) assay was standardized for detection of ToLCNDV-potato. This assay uses four specially designed primer sets matching the target DNA fragment; the DNA is amplified under isothermal conditions within a short period of time. The reactions can be easily monitored by detecting the turbidity caused by the formation of magnesium pyrophosphate. LAMP primers were designed from the coat protein gene region of ToLCNDV-potato using Primer Explorer V4. Different temperatures (60-65°C), concentration of Betaine hydrochloride, $MgSO_4$, primer (F3/B3, FIP/BIP, LF/LB) and Bst DNA polymerase were tried to optimize the assay and the assay was validated with samples from potato fields. The assay could successfully detect the virus from infected samples.

Standardization of a multiplex RT-PCR protocol

A multiplex RT-PCR protocol was standardized for the simultaneous detection of PVV, PMTV, TMV and TRV. All the primers were designed based on specificity and compatibility. Four pairs of specific primer were designed for single and multiplex RT-PCR amplification of conserved region within the coat protein gene. The nucleotide sequences of coat protein genes of each virus were obtained from NCBI (http://www.ncbi.nlm.nih.gov/blast). All the primers were designed with similar annealing temperatures to facilitate multiplex RT-PCR amplification. The specific primer sets produced amplicon of 219, 283, 380 and 460bp representing PVV, PMTV, TMV and TRV, respectively in multiplex RT-PCR **(Fig.10)** and the results were confirmed by DNA sequencing analysis. This multiplex protocol will be useful for indexing of these viruses in seed chain.

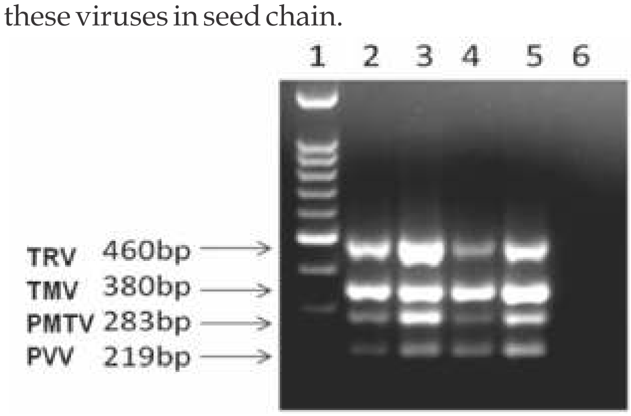


Fig.10: Standardization of multiplex RT-PCR for detection of multiple potato viruses. Lane 1-100 bp DNA ladder, Lane 2-5, different concentration of positive controls, Lane 6-water control

Quantum dots for detection and localization of potato viruses

Quantum dots are being used for biological imaging and tracking of a given antigen. Using the same concept, the commercially available quantum dots were used to conjugate the antibodies of *Potato virus X*. The conjugated quantum dots were incubated with the known pure culture of PVX and rest of the protocol was followed as used in TEM. The image of TEM indicated that the conjugated quantum dots antibodies of PVX were able to detect PVX in given sample (**Fig. 11**).

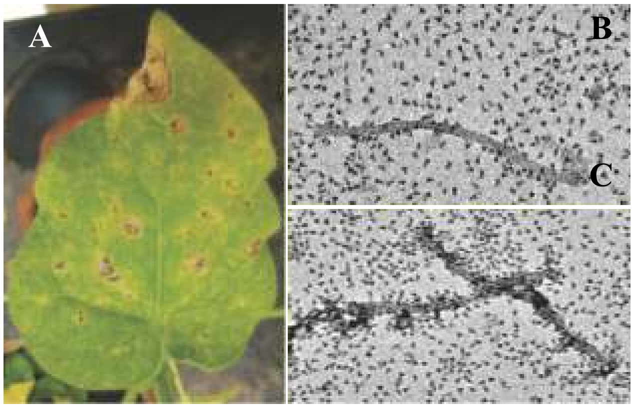


Fig. 11: Host plant showing the symptoms (infection) of PVX (A). TEM images showing the specificity of Quantum dots conjugated with the antibodies of Potato virus X which are capable to detecting PVX (B and C).

Similarly, to detect *Potato virus X* (PVX) in infected potato leaves by immuno-gold electron microscopy; purified IgG of PVX was conjugated with Gold nanoparticles for electron microscopic detection of PVX. The IgG conjugated with gold nanoparticles were incubated with the suspected potato leaf samples and processed for electron microscopic examination which showed a good concentration of filamentous flexuous long particle coupled with several colloidal gold (CG) nanoparticles revealing the presence of PVX (**Fig. 12**). More than one IgG-CG complex was associated with each PVX particle indicating its successful conjugation with gold particles. Since only the homologous virus is decorated with IgG-CG complex, it can be used for specific detection and diagnose of targeted viruses even in mixed infection of viruses with similar morphology. Thus, this technique can be used successfully for detection or screening of PVX in potato plant samples. Similarly, the technique was extended for detection of PVY and it successfully detected the PVY which is evident from the TEM image (**Fig. 13**).

Fig. 12: Host plant infected with PVX (A). Transmission electron microscopic images PVX conjugated with gold nanoparticles. Detection of PVX in potato sprouts (B) and in leaves (C).

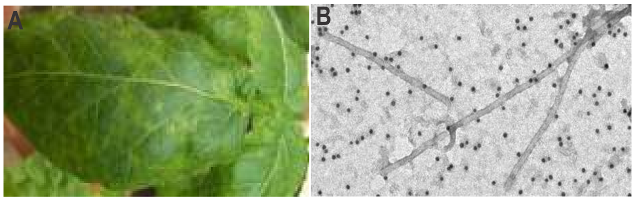


*Fig. 13: Host plant infected with **PVY** (A). Transmission electron microscopic images **PVY** conjugated with gold nanoparticles. Detection of **PVY** in potato leaves (B).*

Production of polyclonal antibodies

Use of *E.coli* expression system for the production of coat protein (CP) of plant viruses as immunogen has become a common practice nowadays. This approach has several advantages over conventional methods of immunogen preparation by avoiding the complex virus propagation and purification/procedures. ToLCNDV-potato is a difficult virus and could not be purified by conventional methods. Hence, attempts were made to develop polyclonal antibodies by expressing CP gene in *E.coli* system. Primers were designed for re-amplification of ToLCNDV-potato gene and PCR amplicon of 771 bp was obtained. The PCR products were digested, ligated and cloned in cloning vector pUC29 at *Hind III and Xho I* restriction sites. Positive clones were sequenced confirmed and processed further for sub cloning in expression vector (pET-G). The positive pET-G clone was then transformed in BL21.pLysis expression host. A 57 KDa protein was identified, purified and injected to rabbit for production of polyclonal antibodies. Rabbit was immunized with 0.50 mg of antigen with equal volume of Complete Freund's Adjuvant followed by 1st booster and 2nd booster of 0.25 mg of antigen at 14th and 28th day, respectively. Serum was collected after 35 days and used in ELISA test. 3rd booster was administered on 49th day with 0.25 mg of antigen.

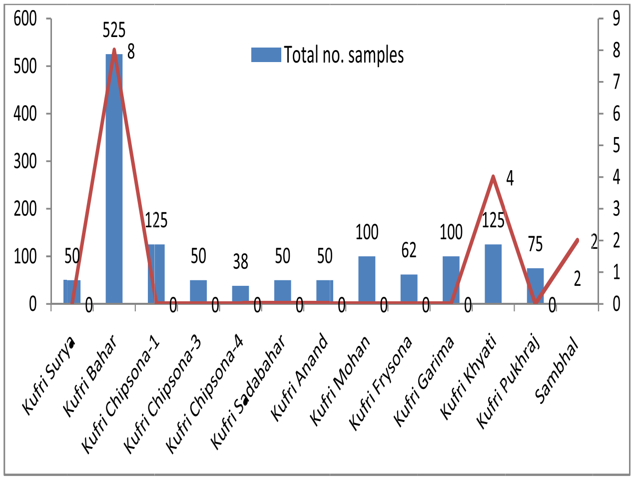


Fig. 14: Validation of polyclonal antibody (RP-2016) for the detection of ToLCNDV-potato through DAC-ELISA.

The polyclonal antibodies (Pab) developed against ToLCNDV-potato was validated by using field samples in DAC-ELISA test. Out of 5,000 samples tested, 8 samples of Kufri Bahar, 4 samples of Kufri Khyati and 2 samples of Kufri Bahar collected from Sambhal (U.P.) were positive **(Fig. 14).**

Epidemiology and Forecasting of Potato Pathogens

Effect of temperature on polyploids of *P. infestans*

Mycelial growth of polyploids was observed under 15-28^{o}C with the optimum temperatures being 15-20^{o}C. At 25^{o}C, all ploids grew slowly with average growth rate of 0.60-0.96 cm day^{-1} whereas at 28^{o}C, only triploids and tetraploids could grow. In general tetraploids exhibited more mycelia growth at all tested temperatures followed by triploids and diploids. Mycelial growth was not observed for any of the ploid at 30^{o}C. There was a significant differential effect of temperature on sporangia germination for the polyploids. Indirect germination was highest at 4 and 8^{o}C, with germination decreasing drastically as temperature increased to 22^{o}C. Direct germination was observed at ≥15^{O}C and up to 22^{O}C, direct germination was good in all polyploids, though differed significantly, thereafter it declined drastically **(Fig. 15).** Averaged over all temperatures, total germination percentage was same for diploids and tetraploids (62.38%) as compared to 56.38% in triploids.

Maximum relative rate of sporangial germination (indirect) in diploid was recorded at 8^{O}C (0.063 per hour) followed by 4, 15, 18 and 20^{O}C in descending order, whereas rate of direct germination increased with increase in temperature up to 22^{O}C. In triploids, maximum relative rate of indirect germination was recorded at 8^{O}C (0.025) whereas in direct germination it was recorded at 15^{O}C (0.044) and then decreased with increase in

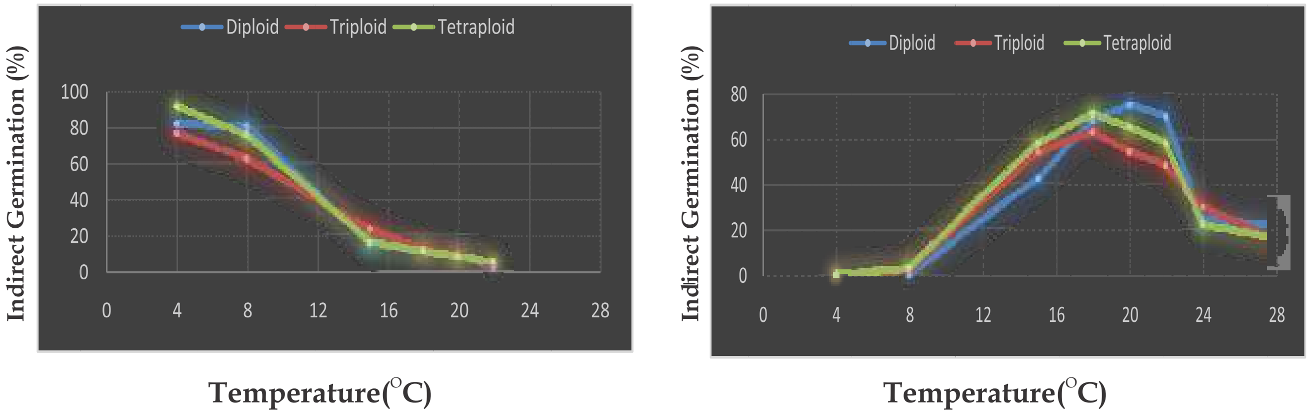


Fig. 15: Effect of temperature on germination of sporangia of polyploids of P. infestans a) Indirect germination, b) Direct germination

temperature. In tetraploids, relative rate of indirect germination increased with increase in temperature up to 15°C and then declined with further increase in temperature. On the other hand, highest rate of direct germination was recorded at 20°C (0.028) followed by 18 and 15°C temperature **(Fig. 16).**

Shortest incubation period (IP) was recorded in tetraploids (84 h) at 10°C followed by triploids (108 hr) and diploids (120 h). At 15°C, triploids and tetraploids had shortest IP i.e. 84 h while in diploids it was higher (96 h). At 18°C, again tetraploids had shortest IP (72 h) followed by triploids and diploids. All polyploids had same IP (72 h) at 20°C while at 24°C, IP of tetraploids further reduced to 60 h. At 28°C, diploids and triploids could not establish infection while tetraploids could do after 72 h. In general, IP decreased with increase in temperature and shortest IP for all polyploids occurred at 24°C. The IP was shortest for tetraploids with a mean of 74 h compared to 84 h for triploids and 91.2 h for diploids. In general, at higher temperature more lesion areas were induced by tetraploids followed by diploids and triploids. At 10°C, all polyploids induced lesser lesion size (0.25 cm^2) whereas at 28°C, diploids and triploids induced no lesions while tetraploids produced least lesion size (0.25 cm^2). Lesion area increased with

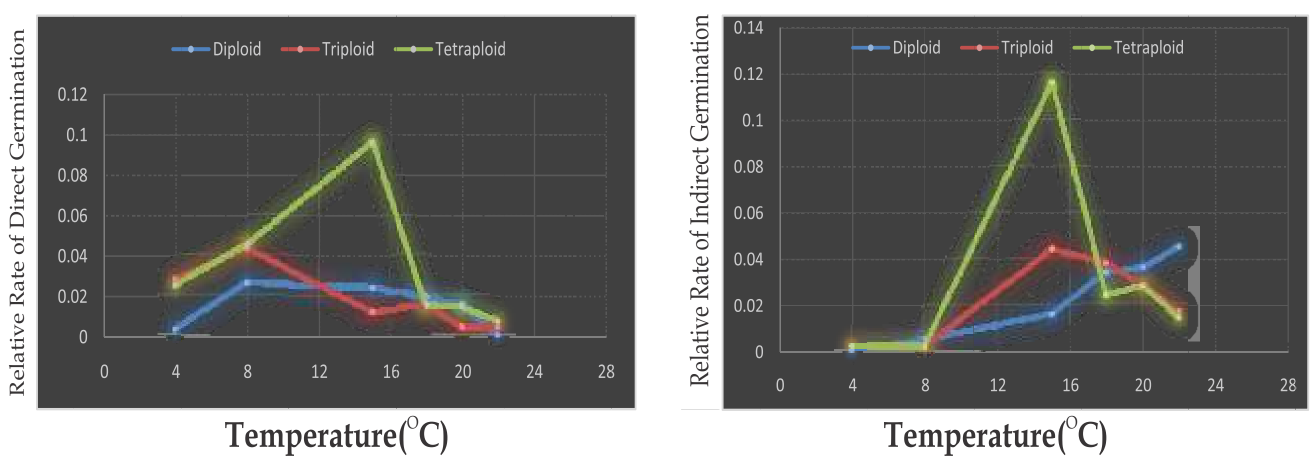


Fig. 16: Relative rate of germination of polyploids of P. infestans at different temperatures a) Direct germination, b) Indirect germination

increase in temperature in all polyploids up to 20°C and thereafter it decreased. Averaged over all temperatures, isolates from tetraploids had larger lesion areas than diploids but did not differ significantly, whereas LA differed significantly from triploids. Temperature differentially affected sporulation of all polyploids, and the highest sporulation was recorded at 15 and 18°C. Polyploids did not sporulate at 10°C and 28°C. Diploids and triploids also did not sporulate at 24°C. In general diploids had highest sporulation followed by tetraploids. Averaged over all temperatures, diploids had a significantly higher sporulation than triploids and tetraploids.

Role of weeds in the epidemiology of potato viruses

Different weed hosts commonly found in and around potato fields at Modipuram which play an important role in harbouring white fly populations during off season of the crop were collected and tested for ToLCNDV-potato. PCR results revealed that weed hosts viz., *Abutilon*, Bitter gourd, Kundru (*Coccinia grandis*), Brinjal, Golden duranta, *Acalypha sp.*, Dahlia, *Commelina benghalensis, Solanum nigrum* and Chilli showed virus specific band of 491 bp there by indicating the presence of the ToLCNDV-potato **(Fig. 17).** It indicated that these host plants are the reservoir of the virus during off season and play an important role in the epidemiology of the virus. Similarly, non-hosts namely chilli, brinjal, *Solanum nigrum,* mentha, cow pea, *Lantana camera,Phaseolus sp,* parthenium, jatropa, torai (*Dolicus labalb*), latjira, wild bean, sponge gourd, chench weed, ladies finger, bottle gourd and cucumber were collected from Gwalior region of Madhya Pradesh and tested for presence of Indian potato viruses *i.e.,* PVY and its strains (PVY^{O}, PVY^{N} and PVY^{C}), PVX, PVA, PVM and PVS through RT-PCR. The results indicated that these plants were not carrying any of the potato viruses.

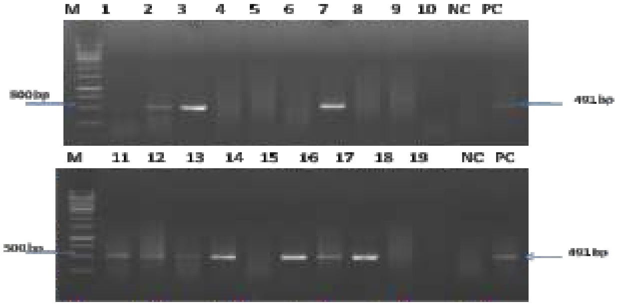


Fig. : 17. PCR results of weed samples showing ToLCNDV-pot. specific bands of 491 bp m=1 Kb lader, 1. Abutilon 2. bitter gourd 3. Coccinia grandis 4. Cassia occidentalis 5. Papaya 6. Brinjal 7. Luffacylindrica 8. Phyllanthus niruri 9. Trifolium 10. Golden duranta 11. Cassia sp. 12. Acalypha, 13. Dahlia 14. Trifolium Sp. 15. Commelina benghalensis 16. Solanum nigrum 17. Brinjal 18. Luffa sp. 19. Chilli, NC=negative control, PC = positive control

Validation of Indo-blightcast

The model was validated across the agro-ecologies in India through AICRP (P) centres and IMD during *kharif* and *rabi* seasons of 2015-16. The model predicted late blight accurately and it appeared within stipulated time (15 days) at each location **(Table 1).** Accordingly the advisories were issued to respective regions to protect the crop from late blight attack.

Table 1: Validation of Indoblightcast across agroecologies

Location	Prediction date of late blight	Actual date of late blight appearance
Shimla (HP)	25.06.2015	07.07.2015
Ludhiana (Punjab)	06.12.2015	12.12.2015
Modipuram (UP)	15.11.2015	27.11.2015
Kalyani (WB)	26.01.2016	30.01.2016
Pantnagar (Uttarakhand)	05.12.2015	08.12.2015
Jorhat (Assam)	18.01.2016	22.01.2016

Host-pathogen Interaction

Gene expression profiling of ToLCNDV-potato inoculated plants

Microarray analysis was performed to identify differentially regulated genes during ToLCNDV-potato infection in a resistant (Kufri Bahar) and a susceptible (Kufri Pukhraj) cultivar. The responses of the two potato cultivars were quite different and transcripts involved in stress responses, signal transduction pathways, protein binding, defence related proteins/R genes and other biological and metabolic processes were altered. RT-qPCR assay was performed for twenty genes that were up/down regulated at >2 fold to >10 fold in susceptible/resistant cultivar after virus inoculation. Out of 680 genes which were up-regulated in Kufri Bahar, 299 genes (43.97 % genes) were completely GO annotated, whereas 381 genes (56.03 %) had no GO annotation or unknown function type. Among 1934 genes up regulated in Kufri Pukhraj, 947 genes (48.97 %) were completely annotated, while remaining genes (51.03 %) had no GO annotation or unknown functions. Pathway maps were constructed using mapman software and the most representative genes were involved in signalling (MAPK), proteolysis and cell wall associated genes. The hormone related genes, i.e. auxin, ethylene, SA, ABA, brassinosteriod showed up-regulation in both the cultivars. Several transcription factors i.e. ERF, bZIP, WRKY, MYB and DOF related to biotic and abiotic stresses were altered after infection in both resistant and susceptible cultivars.

Deep sequencing of small RNAs involved in ToLCNDV - Potato infection

Small RNAs expressed during ToLCNDV-potato infection in susceptible cultivar, Kufri Pukhraj along with Kufri Bahar was studied using deep sequencing approach. These cultivars were artificially inoculated with ToLCNDV-potato and samples were collected at different time intervals. Small RNA libraries were prepared for a total of eight samples (inoculated and un-inoculated) collected at 15 & 20 DAI and sequenced using the Ion ProtonIM System. Mapping of small RNAs was carried out after trimming and filtering of reads. About 93-98 % of reads mapped on the reference genome. The small RNAs were compared with the currently known mature plant miRNAs in miRBase. Differential expression analysis was carried out for the 349 miRNAs and RT-qPCR assay was performed for the ten selected miRNAs.

Symptom expression studies using infectious clones of ToLCNDV-potato

Infectious clones were developed by cloning of partial dimers of DNA A and DNA B components of the isolate MOD-21 in plant transformation vector and mobilized into *Agrobacterium.* These cultures were artificially inoculated to *Nicotiana benthamiana* leaves through infiltration. Agroinoculation of DNA A (pRI101-A1.8 mer) alone resulted in downward leaf curling in *N. benthamiana* plants; however, symptoms were milder when compared to those plants co-inoculated with the DNA B (pRI101-B1.6 mer) component **(Fig. 18)**. This indicates DNA A can maintain itself and cause infection. Severe symptoms were observed in *N. benthamiana* plants inoculated with DNA A and DNA B with typical downward curling, stunted growth and yellow mottling.

Fig. 18: N. benthamiana plants agroinfiltrated with a) pRI101 vector, b) pRI101-A1.8 mer, c) pRI101-B 1.6-mer and d) pRI101-A1.8 mer and pRI101-B 1.6-mer

Flanking sequence analysis of ToLCNDV transgenic events KPLC2-53 and GTLC2-127

The AC1 gene of ToLCNDV-Potato has been exploited for pathogen derived resistance in Kufri Pukhraj and Kufri Badshah. Transgenic integration loci in two of the ToLCNDV-Potato transgenic events, KPLC2-53 and GTLC2-127, were identified using affinity-based genome walking method. PCR reactions were carried out by using gene specific and genome walker primers and the final PCR products were cloned and sequenced. Analyses of the sequenced products were confirmed by NCBI BLASTn to authenticate the site of integration in the respective event. An attempt was made to identify the DNA sequences flanking right border of T-DNA integration site in two events (KPLC2-53 and GTLC2-127) that were considered for genomic Southern analysis. An affinity-based genome walking method, named Locus-Finding (LF) PCR was adopted to determine the potato genome flanking the T-DNA. The Right border flanking sequence of the event KPLC2-53 **(Fig. 19 a)** showed 99 % homology with the ''*Solanum lycopersicum* chromosome 7'' and that of event GTLC2-127 **(Fig. 19 b)** showed 98 % similarity with ''*Solanum tuberosum* group chromosome 11''. Results revealed that no conserved domain has been detected from the potato genome indicating that inserted site has no implications on functional protein of the potato genome.

A

TAAAATTAATGTGAAAATACACAACACGTACTCTTAATTAA
GTGATAATTGCAAGTATGATCGGCAAGTGTTTAACGTTAT
TAGTTTCCTGTAAATATTAAGTCTGTATAAATGTTTGCCTC
AATTTTAATTACTTATTCACATCAATATTTATATCAAATCTAA
TAATTCAACTTTAGTAACTAAAAATTAAAAGTAAAATACAT
ACTCCCACTTAACCATAATGTACTTGCAAGTATAAATTATG
CAATTTCGAAAACAACCTTTCTATCTCTACGAGATAATGAT
AATTAAAGTTCGCACACATTCTGATAGTTTAAACTGAAGG
CGGGAAACGACAATCTGATCATGAGCGGAGAATTAAGG
GAGTCACGTTATGACCCCCGCCGATGACGCGGGACAAG
CCGTTTTACGTTTGGAACTGACAGAACCGCAACGTTGAA
GGAGCCACTCAGCCGCGGGTTTCTGGAGTTTAATGAGCT
AAGCACATACGTCAGAAACCATTATTGCGCGTTCAAAAG
TCGCCTAAGGTCACTATCAGCTA

B

CGACACCCTCGGGATGGCTCGAGTTTTTCAGCAAGATAGCTGATAGTGACCTT
AGGCGACTTTTGAACGCGCAATAATGGTTTCTGACGTATGTGCTTAGCTCATTA
AACTCCAGAAACCCGCGGCTGAGTGGCTCCTTCAACGTTGCGGTTCTGTCAG
TTCCAAACGTAAAACGGCTTGTCCCGCGTCATCGGCGGGGGTCATAACGTGA
CTCCCTTAATTCTCCGCTCATGATCAGATTGTCGTTTCCCGCCTTCAGTTTAAAC
TATCAGTGTTTGAGCATTAAACTAATCAATTCCAGCATAACTTGTATCTAAACTA
AATGACCCCGCTTAAAGGATCATTTGATTGATTTTATTGATCTCAACACATAATT
AACATAAGACAATGCCCCCCTGTATTTATTTTTCTGACACCTTTTGAATTTAGAG
ATTCAAACACGTGATATGGAGTGGGCTGGTTATCATGAGGTTCCCACCTTTTTA
CCCCAAGACATCTTGAACCGAGCTAGTCTTGTAAGTTGTAAGATGCATCAAAG
GGTGGCTCGAGCTCGAGTTGATAACATGGTGCTAACCAAGGTCAAGATTATTT
GTAGGGAGAAATAAATATGGGAACTAACAATATAAAAAAAAAAAAAAAAAACA
ATTTTTGGATTGAAAGGGCTTTATATAATTATATATACACTCTATGGTAACAAAA
TTTAGAGTTGATGATTTTGTACTCTTTTGAGTTTGTTTTAGTTGATGATATTTGA
AACTTTATTGGTAAACAAACCAAAGGAATGTGTTAAAG

Fig.19: Identified Right Border (RB) flanking sequence of event a) KPLC2-53 and b) GTLC2-127; the sequence highlighted in red colour font indicates the potato genome sequence and yellow colour highlighted the vector sequence

Management of Potato Pathogens

Chemical management

A combination of rhamnolipid + botanical was tested under field conditions at Modipuram and at Shimla against standard contact fungicides for the management of late blight. Results revealed that minimum terminal disease severity (61.7%) was observed in chlorothalonil treated plots followed by propineb (65.0%), botanical + rhamnolipid (68.3%), mancozeb (70.0%), rhamnolipid (71.7%) and botanical (75.0%) as against 99.0% in untreated plots **(Fig. 20)** at Modipuram at 100 days of crop age.

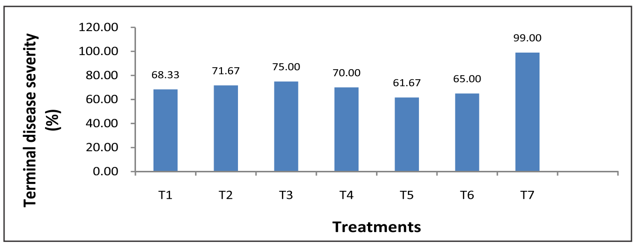


Fig. 20: Evaluation of bio- based formulation against late blight of potato at Modipuram. T1: Rhamnolipid (0.25%) + Botanical (3%), T2: Rhamnolipid (0.25%), T3: Botanical (3%), T4: Mancozeb (0.2%), T5: Chlorothalonil (0.2%), T6: Propineb (0.2%), T7: Control

Similarly, minimum disease severity (27.66%) at Shimla was recorded in chlorothalonil treated plots followed by mancozeb (28.32%) and propineb (36.25%). Rhamnolipid + botanical treatment was least effective ***(Fig. 21).***

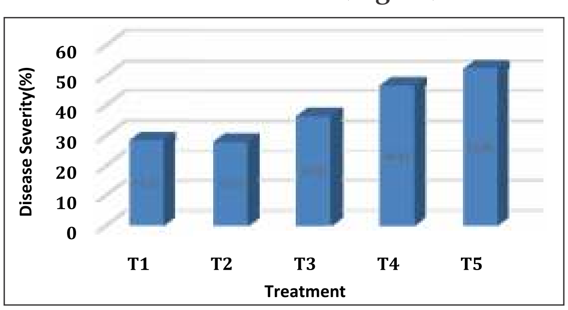


Fig.21: Evaluation of bio- based formulation against late blight of potato at Shimla. T1: Mancozeb (0.25%), T2: Chlorothalonil (0.25%), T3: Propineb (0.25%), T4: Rhamnolipid (0.25% + Botanical (3%), T5: Control

Phytophthora infestans is evolving at a faster rate and therefore it is essential to evaluate different molecules for their efficacy against the pathogen for its effective management. Among the treatments, prophylactic spray with mancozeb (0.2%) followed by azoxystrobin+tebuconazol (0.1%) at onset of the disease and one more spray with azoxystrobin+tebuconazol after 7 days recorded lowest disease severity (38.30 %) against control (85.00%). The next best treatments were prophylactic spray with mancozeb (0.2%) followed by dimethomorph+mancozeb (0.3%) and one more spray with dimethomorph+ mancozeb (0.3%) after 7 days and prophylactic spray with mancozeb (0.2%) followed by dimethomorph+mancozeb (0.3%) and one more spray with dimethomorph+mancozeb (0.3%) after 7 days and prophylactic spray with mancozeb (0.2%) followed by ametoctradin + dimethomorph (0.2%) and one more spray with ametoctradin+dimethomorph (0.2%) after 7 days where 40 and 41.7%, respectively disease severity was recorded.

In another experiment the efficacy of phosphorous acid and BABA was tested against contact fungicides for the management of late blight at Shimla. In total four sprays were given. Results revealed that minimum disease severity (37.29%) was recorded in phosphorous acid treated plots followed by chlorothalonil and rhamnolipid + botanical (40.75%). BABA was least effective **(Fig. 22).** Similarly, phosphorous acid was found effective at Modipuram.

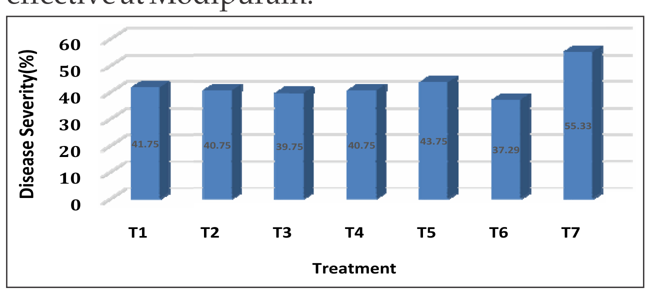


Fig. 22: Efficacy of phosphorous acid and BABA against late blight of potato at Shimla. T1: Mancozeb (0.25%), T2: Chlorothalonil (0.25%), T3: Propineb (0.25%), T4: Rhamnolipid (0.25% + Botanical (3%), T5: BABA (0.2%), T6: Phosphorous acid (0.2%), T7: Control

Similarly, experiment was conducted at ARS, Madenur, Hassan, Karnataka in *kharif* season. Among the treatments, prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% followed by azoxystrobin @ 0.1% + mancozeb @ 0.2% and one more spray with mancozeb recorded lower disease severity (43.75%). The next best treatments were prophylactic spray with mancozeb (0.2%) followed by cymoxanil + mancozeb (0.3%) and one more spray with mancozeb @ 0.2% (55%) followed by prophylactic spray with mancozeb @ 0.2% - dimethomorph + mancozeb @ 0.3%- one more spray with mancozeb @ 0.2% (56.25%).Similarly, when fungicides were evaluated at Ooty during *kharif* season, prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% followed by dimethomorph + mancozeb @ 0.3% and one more spray with mancozeb (17.50%) provided good control of late blight. This was followed by prophylactic spray (just at the time of canopy closure) with mancozeb @ 0.2% followed by azoxystrobin @ 0.1% + mancozeb @ 0.2% and one more spray with mancozeb (17.50%). Similar results were obtained when these fungicides were tested during autumn season.

Evaluation of alum as safer chemical against black scurf of potato

A pot experiment was conducted at ICAR-CPRS, Gwalior farm to evaluate the efficacy of aluminium sulphate (alum) as safer chemical against black scurf of potato using black scurf infested tubers of Kufri Pukhraj. The treatments comprised of alum dip (1, 2 and 3%), alum spray (1, 2 and 3%), standard recommended boric acid (3% dip and spray), carbendazim + mancozeb (0.2% dip) and check (untreated). The results revealed that alum dip (1, 2 and 3%) and alum spray (1, 2 and 3%) reduced the disease incidence significantly (7.4 to 12.7%) compared to control (25.9%) and were statistically at par with boric acid dip (7.3%) and spray (9.5%) treatments. The results indicate the promise of alum as alternate source of boric acid since the chemical is cheaper (Rs. 15-20 / Kg) as compared to commercial grade boric acid (Rs. 60 / Kg).

Biotechnological approaches

dsRNA based fungicide for management of potato late blight

An *in vivo* expression system in *E. coli* was used to produce large amounts of dsRNAs encoding *P. infestans* genes with a view to provide a practical control of late blight disease in potato. Gene specific primers tailed with T7 promoter sequence were designed to amplify the desired sequence and cloned into normal cloning vector pTZ57R/T. Positive clones were subsequently subjected to induce synthesis of dsRNA in T7 express cells by using IPTG. IPTG induced bacterial dsRNAs promoted specific interference with the *Phytophthora* infection in potatoes. Furthermore, we have demonstrated that it is easy to obtain crude extracts of bacterially expressed dsRNAs which are equally effective in protecting potato from *P. infestans* infections when sprayed onto plant surfaces along with emulsifying agents by a simple procedure. Late blight symptoms were significantly lower when plants were sprayed with bacterial lysate before pathogen inoculation **(Fig. 23).**

Fig.23: Screening of dsRNA against late blight

Multi siRNA vector for multiple gene knock-down applications for late blight resistance

The best approach to attenuate *Phytophthora* is to target multiple essential genes through siRNA approach All cluster of genes involved in the same pathway or life cycle of the *Phytophthora* or signalling process could be knocked down at once, especially in the study of complex signal transduction cascades. Based on this hypothesis, we targeted the various cellular processes of *Phytophthora infestans* including sporulation, signalling process and protein synthetic machinery of the cell to alter its pathogenicity. Using siRNA target finder software, selected the effective siRNA of the targeted gene of interest and stacked all siRNA in a single synthetic construct **(Fig. 24)** driven by T7 promoter on both 5' and 3' end. The efficacy of siRNA has been assayed/checked using *in-vitro* dsRNA technology through detached leaf assay against *P. infestans*. Results were highly encouraging that may provide effective management strategy.

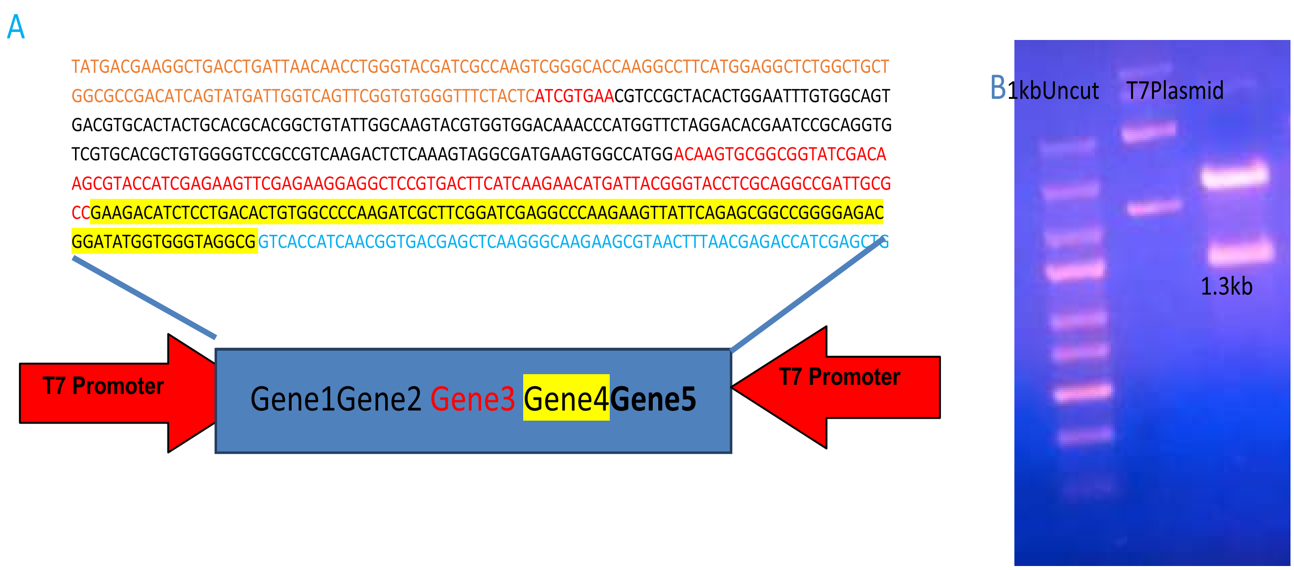


Fig.24: A. Multi siRNA vector driven T7 promoter harbouring Phytophthora infestans genes. B. Restriction digestion confirmed the 1.3kb of 5 stacked gene in single vector

RNAi strategy for management of bacterial wilt

Since none of the potato genotypes including wild species has resistance genes for bacterial wilt, identification and discovery of resistance gene(s) for successful breeding programme is the challenging task. Therefore, we attempted one strategy to isolate candidate genes required for susceptibility (plant disease susceptibility factors) and create knock-down plants resulting a disease-resistant phenotype. Based on VIGS principle, we carried out screening of genes related to disease susceptibility using potato variety "Kufri Jyoti" and the tobacco rattle virus vector system (pTRV2). The *Ralstonia solanacearum* responsive gene i.e. PAP2 gene was randomly cloned into the pTRV2 vector and transformed into *Agrobacterium tumefaciens*, and then inoculated into K. Jyoti to create VIGS plants. VIGS plants showed accelerated cell death and rapid accumulation of reactive oxygen species (ROS) **(Fig 25a and 25b)**. To authenticate the silencing and resistant nature of the VIGS plants, qRT-PCR was performed that showed reduced expression of PAP2 and increased expression of FGS2 (Flagellin Sensing receptor gene **(Fig. 26).** Based on this proof of concept, we developed RNAi construct for conferring resistance against bacterial wilt.

Fig. 25: Characteristic symptoms of bacterial wilt in VIGS and control plants (1a); Accumulation of H^2O^2 in VIGS and control plants (1b)

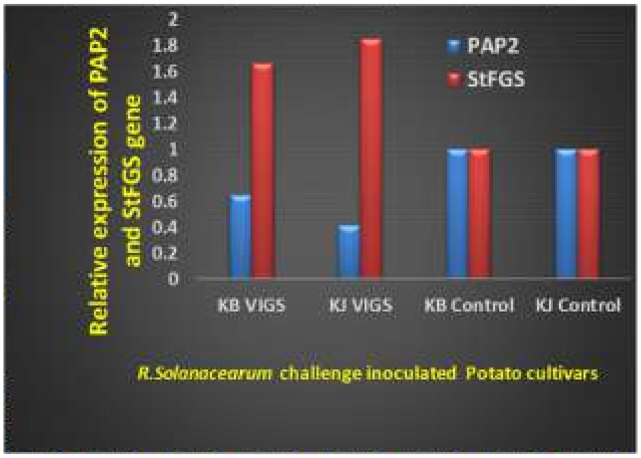


Fig. 26: RT-PCR showing reduced expression of PAP2 gene and up regulation of FGS2 gene in VIGS plants

Development of potato transgenics with resistance to major viruses

Coat protein gene of Potato Virus Y (PVY) was used for engineering pathogen derived resistance to PVY in the popular potato cultivar Kufri Pukhraj. Integration of coat protein gene in Kufri Pukhraj transgenic lines was carried out through Southern Hybridization. The results of southern blot analysis **(Fig. 27)** confirmed the integration of the gene in the selected transgenic lines (Line 1 to 4).

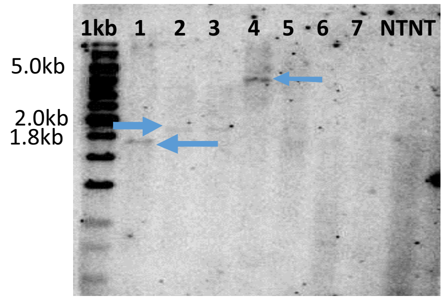


Fig. 27: Copy number analysis of nptIIgene in PVYCP transgenic lines. Lane 1. KPSY1, lane 2 – KPSY13, Lane 3 – KPSY18, Lane4 – KPSY20, Lane5 – KPSY21, Lane6-KPSY26, Lane7-KPYNT3, NT-Non transgenic.The probe used in Southern blot hybridization neomycin phosphotransferase II gene (NPTII) of the pBIN19 plasmid.

Host resistance

Twenty germplasms were screened for ToLCNDV-potato through grafting. Out of these, a single germplasm was found resistant and three germplasms were found moderately resistant to ToLCNDV-potato. Besides, germplasm was also screened for bacterial wilt resistance. Among tomato varieties, Arka Samrat, Arka Rakashak, Hawaii 7998 were found apparently resistant to *R. solanacearum* (Race 3) while Arka Abha, Arka Alok, Utkal Urvashi, Palam Pink, Pusa Ruby were susceptible **(Fig. 28).** Among brinjal varieties, Arka Anand was apparently resistant to *R. solanacearum* (Race 3) while CHBR-2, PR-5 and Pusa Purple Long were susceptible. All the potato germplasm lines viz., 1724-07, 2609-06, 2610-10 were susceptible to *R. solanacearum* (Race 3).

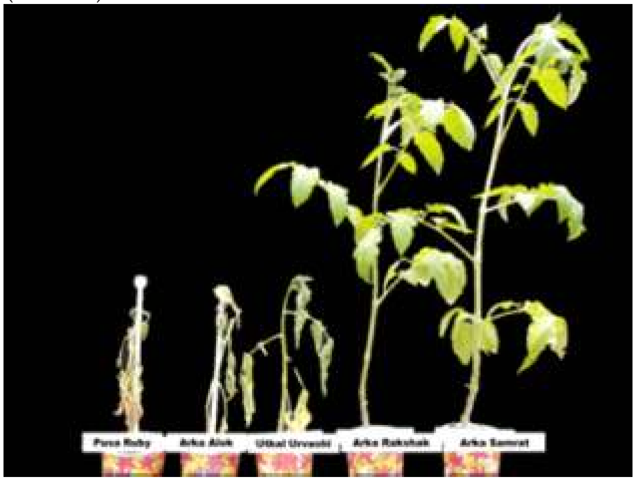


Fig. 28: Screening of tomato cultivars against R. solanacearum

Biological control

Endophytes (92) isolated from leaves, stems and roots of field grown potato plants were purified and screened against *Phytophthora infestans, Ralstonia solanacearum* and *Streptomyces scabies*. Out of 50 bacterial and 42 fungal endophytes; 7 bacterial and 2 fungal endophytes showed promising results against *P. infestans* under *in vitro* conditions **(Fig. 29).**

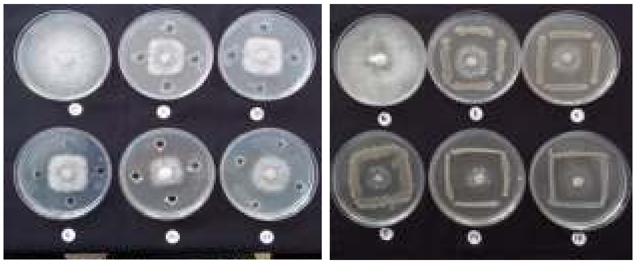


Fig. 29: Antagonistic effect of endophytic bacteria against P. infestans

Similarly, 75 endophytic bacteria were screened *in-vitro* through agar diffusion method for their antagonistic activity against *R. solanacearum* and *S. scabies*. Against *R. solanacearum*, one of the endophytic bacterial culture had excellent (average radius of inhibition zone ≥11mm) and four others had good inhibitory effect (average radius of inhibition zone 6-10 mm, **(Fig. 30);** while against *S. scabies* one culture showed excellent inhibitory effect (average radius of inhibition zone ≥11mm) and two had inhibitory effect that ranged from 4 to 5 mm radius of inhibition zone in agar diffusion test **(Fig. 31).**

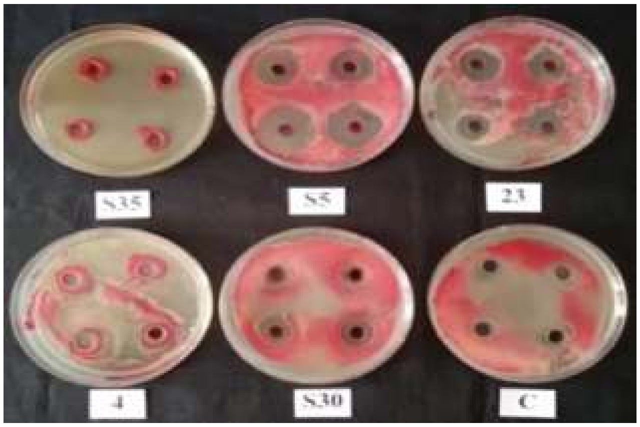


Fig. 30: Antagonistic effect of endophytic bacteria against R. solanacearum

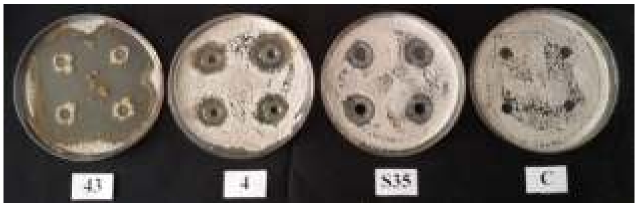


Fig. 31: Antagonistic effect of endophytic bacteria against Streptomyces scabies

Bio-fumigation of soil with brassicas for the management of soil and tuber borne diseases

Field trials were conducted at ICAR-CPRS, Jalandhar, ICAR-CPRIC, Modipuram and ICAR-CPRS, Patna to see the effect of bio-fumigation of soil with brassicas on management of soil and tuber borne diseases especially russet scab and black scurf. In the first year of experimentation, none of the five brassicas, i.e. Indian rape, rapeseed, taramira, Indian mustard and radish, proved effective against russet scab and black scurf diseases. The trial shall be repeated during the current year to see the cumulative effect of bio-fumigation on soil and tuber borne diseases over the years.

Post entry quarantine testing of imported germplasm

Sixty five *in vitro* cultures of potato including thirty eight (five from US Department of Agriculture and thirty three from CIP, Lima Peru) imported by Crop Improvement Division, CPRI, Shimla; eighteen imported by M/s TechnicoAgriSciences Pvt. Ltd; four imported by M/s SidhiVinayakAgri Processing Pvt. Ltd. and five imported by M/s Merino Industries Ltd were tested for post entry quarantined pathogens.

Testing of viruses under National Certification System for Tissue Culture Raised Plants (NCS-TCP) through DAS-ELISA/PCR

Nine hundred and ninety seven samples of M/s TechnicoAgri Sciences Pvt. Ltd. Baddi, Solan (HP), and M/s Pepsico India Holding, Hoshiarpur (Punjab) were tested for the presence of PVX, PVS, PVY, PVA, PVM, and PLRV by DAS- ELISA and GBNV and ToLCNDV-potato by PCR. Besides, three hundred and twenty samples from M/s Nishant Bioteck, Bilaspur, HP were also tested for apple viruses namely ACLSV, AMV, ASGV, ASPV, and PNRSV. Apart from this, nearly 1200 samples from M/s Pepsico India Holding, Hoshiarpur (Punjab), M/s TechnicoAgri Sciences Pvt. Ltd.,Baddi, Solan (HP), M/s Dayal Seed Pvt. Ltd., Partapur, Meerut, Deputy Director Horticulture, Karnal were also tested for different viruses through DAS-ELISA/ PCR under non-ATL.

Biology, modelling and management of insect pests, vectors, and cyst nematodes of potato

Monitoring and population dynamics of potato pests and their natural enemies

Potato attracts wide variety of insect pests and their natural enemies under field conditions. Insect pests that attack potato are grouped into sap sucking pests, soil pests, foliage feeders and storage pests. The sap sucking pests such as aphids and whiteflies are of utmost importance in seed potato as they cause indirect damage by transmitting viral diseases. Therefore, regular monitoring and population dynamics of aphids and whiteflies in seed and ware potato is essential to take timely management decisions for healthy potato production.

Himachal Pradesh

Aphids and whiteflies first appeared during fourth week of June on summer crop at Shimla but their population could not reach critical limit during the crop season Defoliators such as *Helicoverpa armigera* was recorded @ 0.1 larvae/ 10 plants. Cutworm damage was first recorded during 4th week of May and overall population was 0.2 larvae/10 plants during crop season. Severe flea beetle(*Psyllodes plana*) damage (20 beetles/10 plants) was recorded on potato which was favoured by dry weather due to low rainfall.

A severe damage (up to 55%) of *P. plana* on potato was observed at Bekhalty during July-August. *Myzus persicae* and whiteflies @26 and 10 per 100 compound leaves respectively was recorded at Gallu. Defoliators and soil pests were not recorded in these locations. Special attention was given for monitoring South American tomato pinworm, *Tuta absoluta,* a quarantine pest of international importance on its incidence in potato growing regions of Shimla. *T. absoluta* was not recorded on potato in Shimla. The natural enemies observed on potato plants were coccinellids (1-2 beetles / 20 plants) and spiders (5-6 per 20 plants) at Gallu and Talai regions while at Beakalty, natural enemy population was not observed. A parasitoid, *Binodoxys acalephe* was recorded from *Myzus persicae* samples collected from potato fields of Hisar region.

Punjab

Myzus persicae first appeared during first week of November on ware potato and crossed critical limit in first week of December and reached its peak in last week of December at Jalandhar **(Fig. 1).** On the other hand, aphid first appeared on seed crop in second week of November but ws never able to reach critical limits due to application of systemic insecticides as per schedule. *Bemisia tabaci* and leafhoppers (*Amrasca biguttula biguttula*) started appearing in third week of October and declined subsequently both in ware and seed potato and their population was well below threshold level during entire crop period **(Fig. 2 & 3)**.

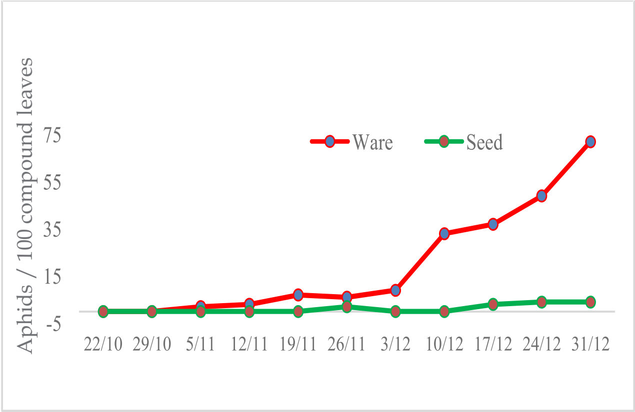


Fig.1. Population dynamics of Myzus persicae on potato crop at Jalandhar

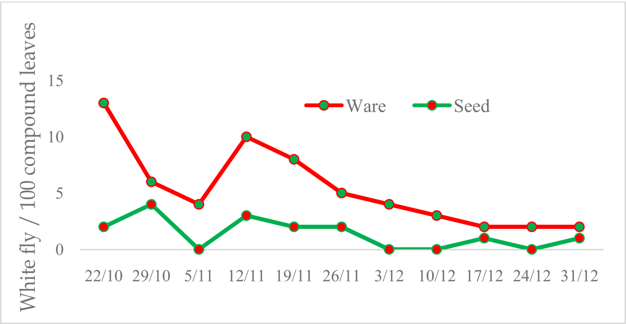


Fig.2. Population dynamics of Bemisia tabaci on potato crop at Jalandhar

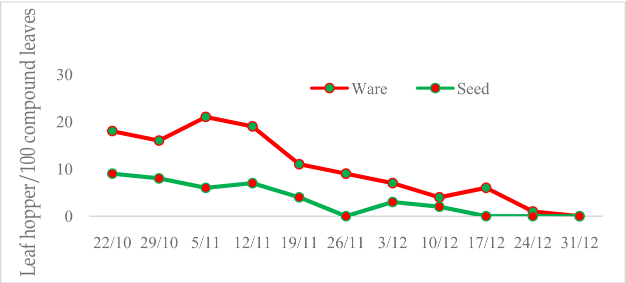


Fig.3. Population dynamics of leafhopper on potato crop at Jalandhar

Uttar Pradesh

Myzus persicae crossed the critical level after first week of December in unsprayed potato crop at Modipuram. However, seed crop was free from aphids, *M. persicae* and *A.gossypii* as the crop was timely sprayed after strict monitoring at weekly intervals. Whitefly population was very high (14/plant) in second week of October on early crop. Whitefly incidence was very high in early crop than main crop.

Field surveys were conducted to Rataul, Khekda and Badagaon of Baghpat and Kiratpur and Mandaur of Bijnore in the month of January and February 2016 for monitoring insect pests in potato. Potato was free from both aphids and whiteflies at Baghpat. On the contrary, a heavy population of aphids (400/ 100 compound leaves) was observed in Bijnore. Mustard crop which was adjoining to potato harboured huge numbers of *M. persicae* serving as a very good alternate host.

Mite population was high in both early and main crop (unsprayed) due to high temperatures in Modipuram and few fields were burnt in Baghpat and Bijnore area.

High population of cutworms (10-15/plant) and *Spodoptera litura* were witnessed on Diamonte and K. Bahar during December. Suitable control measures were suggested to farmers for control of cutworms.

As a part of exploring new areas suitable for seed production areas, potato fields (K. Pukhraj and K. Badshah) in Jodhpur was surveyed during first week of January. Whiteflies were recorded in very high numbers on two varieties but *M. persicae* and *A. gossypii* were not found. A mild tuber infestation of white grubs (1-2%) was recorded at harvest.

Madhya Pradesh

Very low populations of *Myzus persicae* and *Bemisia tabac*i were recorded on ware and seed potato at Gwalior **(Fig 4 & 5).** A maximum of 3 aphids and 1.6 whiteflies/ 100 compound leaves were recorded on ware crop. This year, vector pressure was very low when compared to previous seasons. Gwalior witnessed a very low vector pressure which would be ideal for healthy seed potato production.

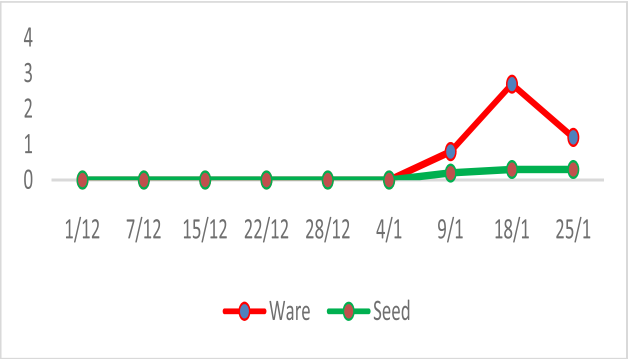


Fig.4. Population dynamics of Myzus persicae on potato crop at Gwalior

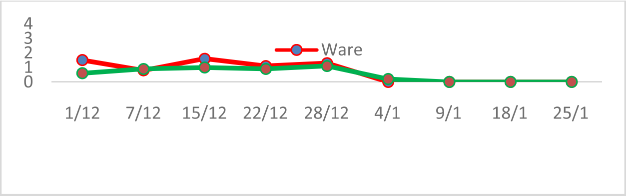


Fig.5. Population dynamics of Bemisia tabaci on potato crop at Gwalior

Bihar

The populations of *Myzus persicae, Aphis gossypii* and *Bemisia tabaci* were recorded on unsprayed potato crop at Patna. Aphids first appeared during first week of December and crossed critical limit during third week of December. Aphids reached their peak (1334 *M. persicae*/100 compound leaves) during third week of February **(Fig. 6)** .

Whiteflies population first appeared on potato during second week of December and its population was well below threshold during rest of season **(Fig. 7)**.

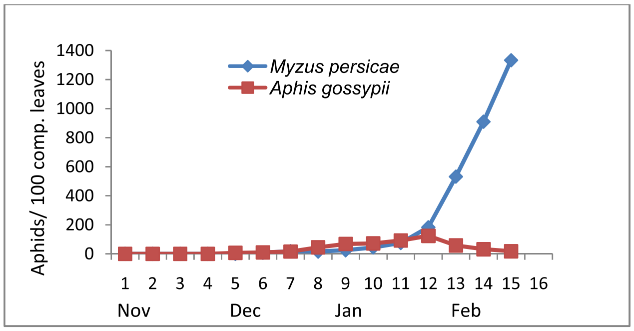


Fig.6. Population dynamics of Myzus persicae and Aphis gossypii on potato crop at Patna

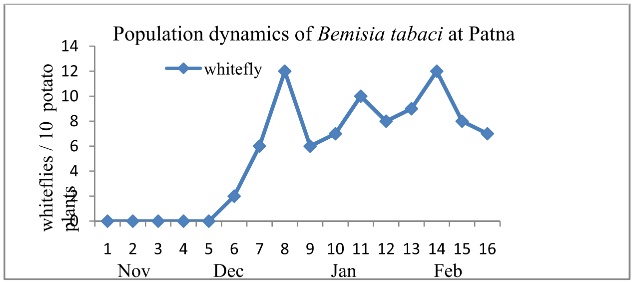


Fig.7. Population dynamics of Bemisia tabaci on potato crop at Patna

Monitoring the incidence of potato tuber moth (PTM)and South American tomato pinworm, *Tuta absoluta* on potato using pheromones

The incidence of PTM and *T. absoluta* were monitored on potato at Gwalior, Bhubaneswar, Raipur and Pune. PTM population was first recorded on potato during third week of December (1 nos) at Bhuvaneswar but were not recorded during rest of the season. At Gwalior, PTM incidence was first noticed during first week of January (4 nos) that continued till third week of January (7 nos), but declined subsequently. At Pune, PTM population appeared during first week of January and population increased subsequently during January and February beyond threshold. However, no PTM was reported at Raipur. These results indicate PTM occurrence was very high at Pune and slight incidence was reported from Gwalior and no incidence at Raipur and Bhuvaneswar **(Fig. 8)**. *T. absoluta* was not observed from these locations on potato .

Fig. 8a : Pheromone traps installed in potato field

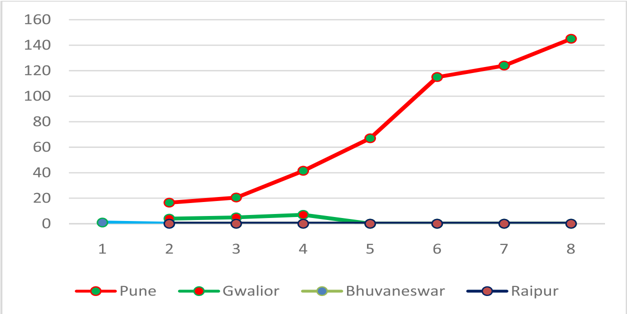


Fig. 8b : Pheromone trap catches of PTM at different locations in India

Identification of aphids, whiteflies and leafhoppers infesting potato

Aphids are the key vectors of potato viruses namely PVY, PLRV, PVA, PVM and PVS in India. Species diversity and density of aphids and whiteflies will have profound effect on seed and ware potato production in India as they horizontally spread viruses. Therefore, it is important to map the species diversity of vectors on potato. Aphids were sampled from potato growing areas of Hisar, Deesa, Modipuram, Patna, Jalandhar, Pune, Aligarh, Chindwara and Gwalior during October to January. Aphids were identified using universal primer (658bp) specific to CO I gene **(Fig. 9)** . A total of five species, *Myzus persicae, A. gossypii, Aulacorthum solanii, Rhopalosiphum rufiabdominalis* and *Rhopalosiphum padi* were recorded on potato. *R. padi* was recorded on potato from Hisar. Whiteflies sampled from Jalandhar, Modipuram and Pune were identified as *Bemisia tabaci*. Very low incidence of leafhoppers was observed on potato during crop season at Jalandhar and Pune. Leafhoppers studied in Jalandhar were *Amrasca biguttula biguttula*. In Pune, the leaf hoppers were *Amrasca biguttula biguttula* and *Empoasca* sp. **(Table 1).**

Table 1. Insect samples identified from potato during 2015-16

S.No.	*Location*	*Samples*	*Species*
1	Hisar, Deesa, JalandharModipuram, Patna, Pune, Gwalior, Aligarh and Chindwara	Aphids	1. *Myzus persicae* 2. *Aphis gossypii* 3. *Aulacorthum solanii* 4. *Rhopalosiphum rufiabdominalis* 5. *Rhopalosiphum padi*
2	Jalandhar, Modipuram, Pune	Whiteflies	1. *Bemisia tabaci*
3	Jalandhar and Pune	Leafhoppers	1. *Amrasca biguttula biguttula* 2. *Empoasca* sp.

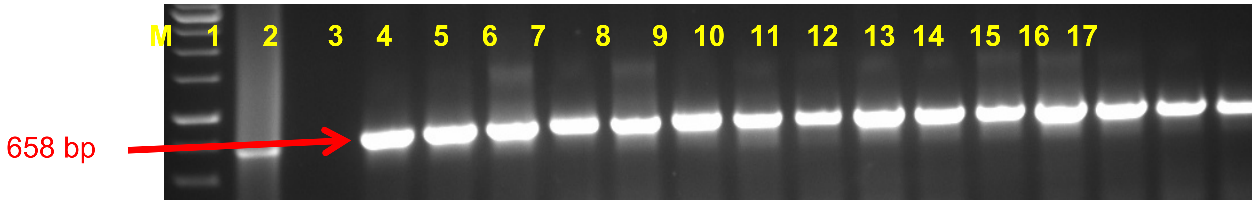


Fig. 9 : PCR amplification of Aphids collected from potato fields

Detection of potato viruses from insect vectors

Detection of viruses in field collected insect vectors would give useful information about the viruliferous nature of vector and also health status of the crop. Therefore, field collected aphids and whiteflies were tested for their viruliferous nature with respect to PLRV, PVY and ToLCNDV-potato. Results revealed that *M. persicae* from Jalandhar, Hisar and Shimla were carrying the PVY and *M. persicae* from Patna and Gwalior were free from PVY **(Fig. 10)**. These aphid samples were processed for PLRVand were found negative.

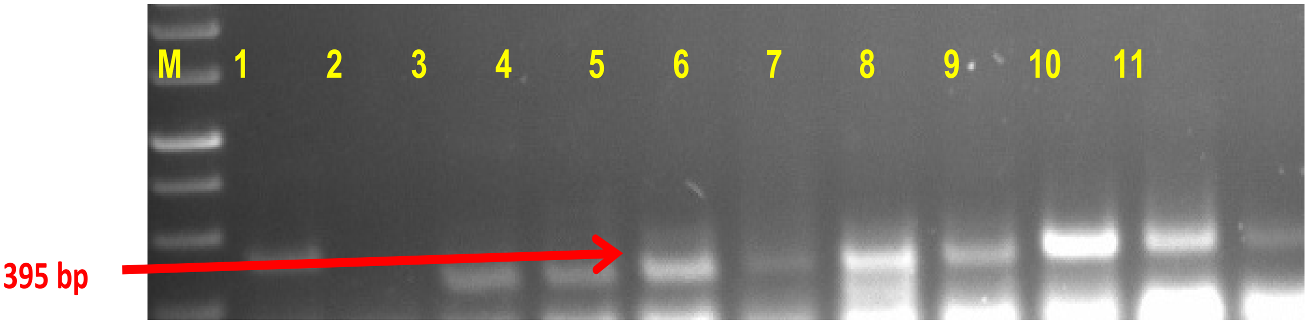


Fig.10 : Detection of PVY in Aphid samples of Jalandhar, Hissar and Deesa , M-1 kb ladder, Lane1 Positive control, 2-Water Control, 3-5 Jalandhar, 6-8 Hissar, 9-11 Deesa samples

PCR detection of ToLCNDV-potato in *B. tabaci* and *T. vaporariorum*

Whitefly transmitted Begomovirus, *Tomato leaf curl New Delhi virus*-potato is an emerging virus causing about 50% marketable yield loss of potato. The horizontal spread of virus in field is exclusively facilitated by the whitefly vectors. Therefore, an assay was performed to detect ToLCNDV-potato in *B. tabaci* and *T. vaporariorum* in a single reaction **(Fig. 11)**. This assay identifies a given whitefly specimen and also indicate wether it is carrying virus or not in a single reaction. Protocol was validated for their sensitivity and reproducibility using single whitefly collected from potato fields of Jalandhar and Modipuram. This is a useful protocol to understand the epidemiology of virus, virus vector relationship and more importantly it helps in taking timely vector management decisions to restrict the horizontal spread of the virus in field.

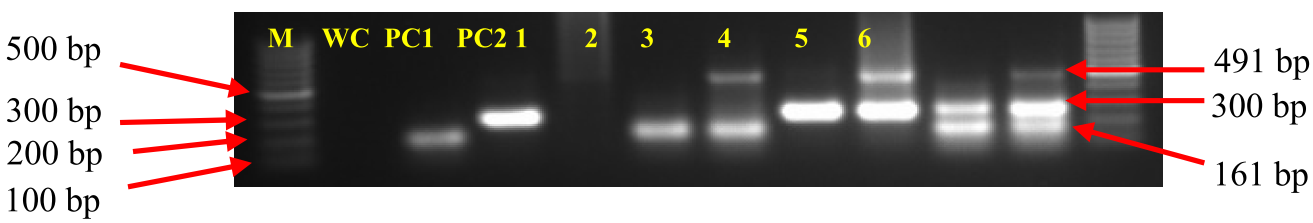


Fig.11 : Simultaneous detection of ToLCNDV-potato in B. tabaci and T. vaporariorum. M- 100 bp; WC- Water control; PC1- T. vaporariorum; PC2- B. tabaci; Lane 1- T. vaporariorum alone; 2- T. Vaporariorum& ToLCNDV-potato; L3- B. tabaci alone; L4- B. tabaci & ToLCNDV-potato; L5- T. vaporariorum & B. tabaci; L6- T. vaporariorum, B. tabaci & ToLCNDV-potato.

B. tabaci has been reported to be the principal vector of *Tomato leaf curl New Delhi virus*-potato (ToLCNDV-potato). Hence, whiteflies were collected from three potato growing locations to determine their viruliferous nature. Results revealed that populations of *B. tabaci* from Modipuram and Jalandhar were carrying ToLCNDV-potato while whiteflies from Pune were free from this virus.

Germplasm screening for aphid resistance

Eleven wild potato germplasm were evaluated for their resistance to green peach aphid, *Myzus persicae* under glasshouse conditions. Survival and multiplication of *M. persicae* was very low on germplasms *i.e.* TRF 37 and VER 59, but very high on germplasms, BER 96 and MCD 71 **(Fig. 12)**.

Fig.12 Wild germplasms of potato

Integrated management of potato pests

Efficacy of kaolin on sucking pests

Field experiment was conducted for the management of sucking pests including aphids and whiteflies in potato using kaolin spray at two different locations i.e. CPRS, Jalandhar and CPRS, Gwalior. Kaolin @1.0% and 1.5% significantly reduced (35%) aphid population as compared to untreated control at Jalandhar. However, standard check imidacloprid was the best in managing aphid population. There was no significant effect of kaolin treatments on whitefly population as whitefly population was very low.

Effect of mineral oils/non-edible seed oils on insect vectors and disease incidence

Mineral oils @3% was effective in reducing sucking pests including aphids and whiteflies in potato at Jalandhar. Besides, three oils i.e. summer oil, karanj oil and castor oil @2ml/lit were also tested for their effect on whiteflies and aphids and were found effective at low level of populations.

Efficacy of cyantraniliprole 10% OD on whiteflies and aphids in potato

Field experiment was conducted for the management of aphids and whiteflies in potato using different doses of cyantraniliprole at CPRS, Jalandhar and CPRIC, Modipuram during *rabi* season.Two sprays of cyantraniliprole (four diff. doses) along with recommended standard (imidacloprid) check was included as treatment. Cyantraniliprole @75 and 90g a.i./ha (3 and 7 days after second spray)recorded 45-58% reduction of aphid population in potato.

Large scale testing of flonicamid for management of insect vectors

A large scale trial was conducted at CPRIC, Modipuram using variety K. Bahar and K. Lalima to validate the efficacy of new insecticide, flonicamid (@4 gm/10 litres) against aphids and whiteflies. Flonicamid was highly effective in reducing aphids followed by whiteflies.

Effects of combination of insecticide and fungicide as seed treatment on sucking pests and on incidence of black scurf disease

The main objective of the experiment was to reduce the cost of plant protection by suppressing early appearing sucking pests and black scurf in main crop. Three insecticides (Imidacloprid, thimethoxam, spiromesifen) and fungicides (monocirin, penflufen, boric acid) in various combinations along with control were tested as seed treatment for the management of sucking pests and black scurf on potato cv. K. Bahar. Two recommended practices i.e. boric acid and imidacloprid as combined seed treatment recorded lowest incidence of *B. tabaci* and *M. persicae* **(Fig. 13 & 14).**

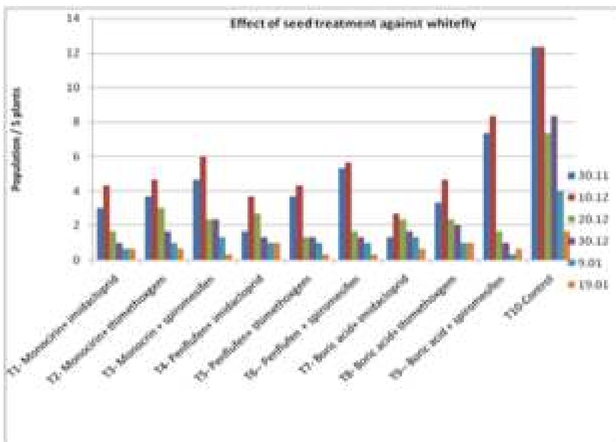


Fig.13 : Effect of seed treatment on whitefly population

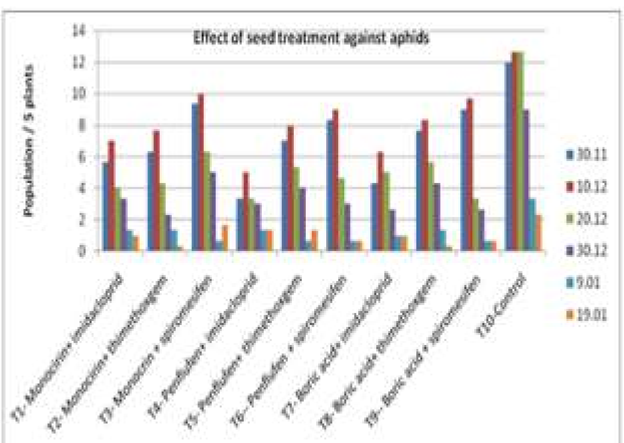


Fig.14 : Effect of seed treatment on aphid population

Incidence of whiteflies and ToLCNDV-potato on potato under sprayed and un-sprayed condition during early crop season

The effect of early and protective insecticidal treatment to seed and early planted potato at Modipuram was evaluated in varieties of potato on whitefly population. The data revealed that plant protection measures were required in early planted potato crop to reduce the incidence of insect vectors and potato apical leaf curl disease on potato cultivars for getting maximum yield **(Fig. 15).**

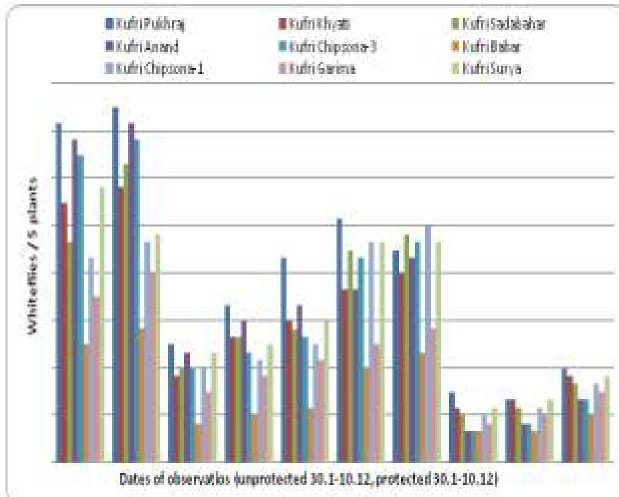


Fig.15 : Incidence of whitefly on different potato cultivars on early crop during 2015

Compatibility of insecticides and fungicides against population build up of sucking pests and late blight incidence on potato cv. K.Pukhraj

Compatibility studies with three insecticides (Imidacloprid, thiomethoxam, spiromesifen) and three fungicides (Mancozeb, Metalaxyl, Cymoxanil) in combinations along with control were applied on potato cv. K. Pukhraj during main crop season with an objective to reduce the cost of plant protection and to suppress the incidence of sucking pests and late blight damage. No phyto-toxicity was recorded in any treatments. All the combinations of imidacloprid with Mancozeb, Metalaxyl & Cymoxanil were effective as compared to other combinations in reducing the incidence of sucking pests and late blight (2-2.5%) without phyto-toxicity effect **(Fig. 16 & 17)** .

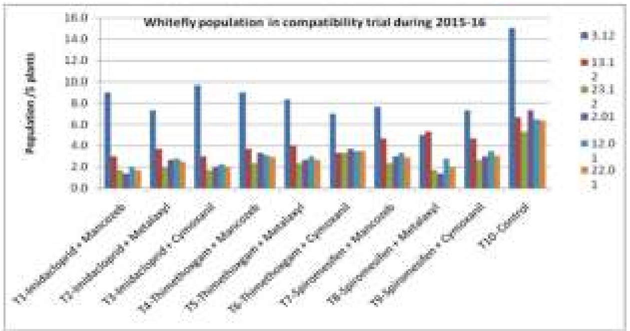


Fig.16 : Whitefly population in compatibility trial during 2015-16

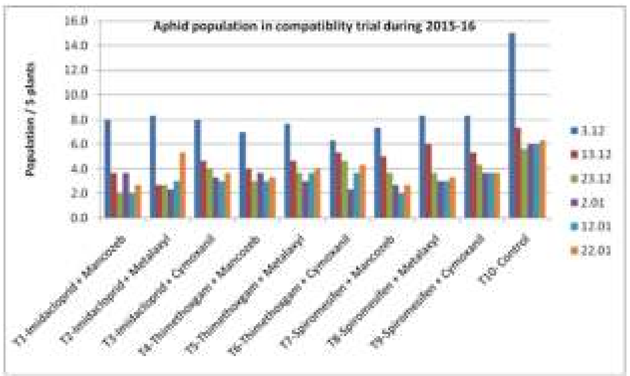


Fig.17 : Aphid population in compatibility trial during 2015-16

Pesticide residue analysis in potato tubers

The pesticide residue in tubers of K Bahar and K Badshah was analysed after harvesting. Pesticides that are being routinely used in controlling pest population in both seed and ware potato namely thimet (10G@10kg/ha), oxy-demeton methyl (0.2%), imidacloprid (0.04 %), flonicamid (0.02%, 0.03%, 0.04%), thiacloprid (0.04%) and spiromesifen (0.04%) were applied to potato crop at different stages. Potato tubers (1kg) were sampled at the time of harvest and sent to Institute of Pesticide Formulation Technology, Gurgaon (Haryana) for residue analysis to know MRLs.The results revealed that all the insecticides were below detectable levels (BDL) indicating that they are safe for consumption. However, spiromesifen (@0.04%) was measured as 0.033 ppm (Table 2).

Table.2. Insecticide residue analysis of different insecticides in potato tubers

Sr. No.	Name of the test Chemical	Potato tuber (variety)	Concentration (ppm)
1	Thimet 10g	Kufri Bahar , at earthing up dehaulmed at 75 days	BDL
2	Metasystox 25ec 0.20%	Kufri Bahar, seed crop, stage II, C block	BDL
3	Imidacloprid 0.04%	Kufri Bahar	BDL
4	Flonicamid 0.04%	Kufri Bahar	BDL
5	Thiacloprid 0.04%	Kufri Bahar	BDL
6	Flonicamid 0.03%	Kufri Bahar	BDL
7	Flonicamid 0.02%	Kufri Bahar	BDL
8	Flonicamid 0.04%	Kufri Badshah	BDL
9	Spiromesifen 0.04%	Kufri Badshah	0.033
10	Control		BDL

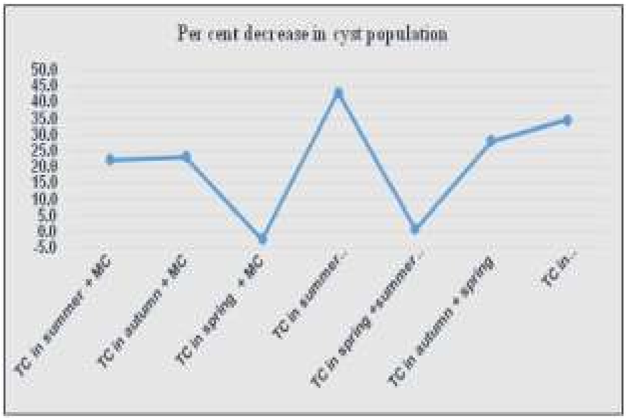


Fig. 18: Effect of trap crops on Cysts of PCN during three seasons at Ooty

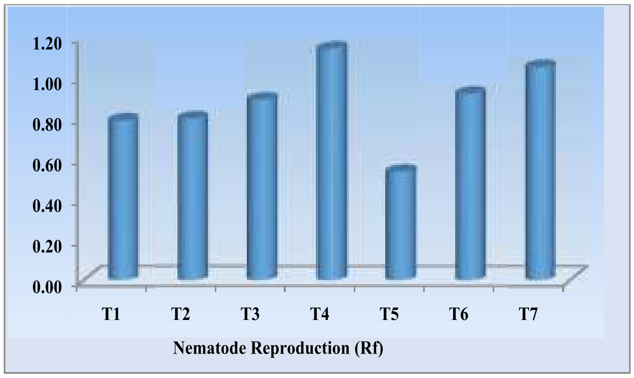


Fig.19: Effect of various management options on reproduction of PCN

Evaluation of trap crops against potato cyst nematod (PCN)

Solanum tuberosum cv. Kufri Jyoti was evaluated as trap crop for potato cyst nematode in all three seasons *viz.*, summer, autumn and spring in different combinations. Kufri Girdhari was sown after the trap crop after applying recommended dose of carbofuran. Maximum decrease in cyst populations was found in trap cropping for two seasons *viz.*, summer + autumn (43.10%) followed by three seasons *viz.*, summer, autumn and spring (35.0%) **(Fig. 18).**

Evaluation of various management options for eradication of PCN

An experiment was conducted to evaluate various management options for eradication of PCN in resistant variety Kufri Swarna. Among various treatments, T5 (trap crop +solarisation + furadon @ 2 kg a.i./ha + organic amendment i.e. neem cake @ 5t/ha) found to suppress PCN population (47.02%) with a lowest reproduction factor of 0.53 **(Fig. 19)**.

Evaluation of different doses of dazomet (Basamid 10 G) against potato cyst nematodes

An experiment was conducted to evaluate different doses of dazomet (Basamid 10 G) against potato cyst nematodes in susceptible variety Kufri Girdhari. Dazomet @ 50 g/m^2 reduced PCN population by 12.87% with a reproduction factor (Rf- 0.87) **(Fig.20)**. Carbofuran was not effective to manage PCN population.

T_1: Trap crop + Solarisation + Furadon @ 2 kg a.i./ha+ Biocontrol agent (*Pseudomonas fluorescens* + *Paecilomyces lilacinus* @ 10 kg/ha)+ Organic amendment (Neem cake @ 5t/ha); T_2: Solarisation + Furadon @ 2 kg a.i./ha+ Biocontrol agent (*Pseudomonas fluorescens* + *Paecilomyces lilacinus* @ 10 kg/ha)+ Organic amendment (Neem cake@ 5t/ha);T_3: Trap crop + Furadon @ 2 kg a.i./ha+ Biocontrol agent (*Pseudomonas fluorescens* + *Paecilomyces lilacinus* @ 10 kg/ha)+ Organic amendment (Neem cake @ 5t/ha); T_4: Trap crop + Solarisation + Biocontrol agent (*Pseudomonas fluorescens* + *Paecilomyces lilacinus* @ 10 kg/ha)+ Organic amendment (Neem cake @ 5t/ha);T_5:Trap crop + Solarisation + Furadon @ 2 kg a.i./ha+ + Organic amendment (Neem cake @ 5t/ha);T_6: Trap crop + Solarisation + Furadon @ 2 kg a.i./ha+ Biocontrol agent (*Pseudomonas fluorescens* + *Paecilomyces lilacinus* @ 10 kg/ha);T_7: Untreated control.

Trap crop = Kufri Jyoti uprooted after 45 days of planting; Solarisation = 4 weeks (20 µ LDPE)

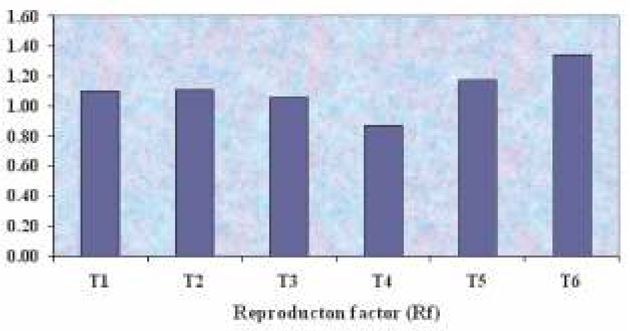


Fig. 20: Effect of different doses of dazomet (Basamid 10 G) on reproduction of PCN

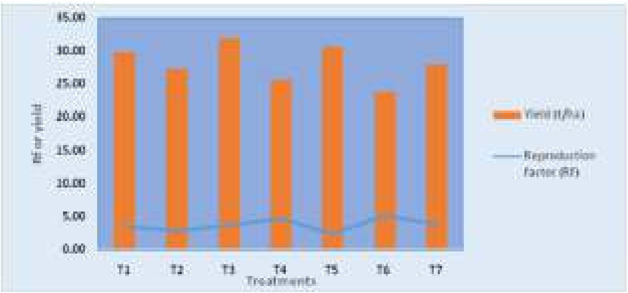


Fig. 21 : Effect of crucifers as biofumigants against potato cyst nematode

T_1: Dazomet @ 20g/m2 ; T_2: Dazomet @ 30 g/ m^2 ; T_3: Dazomet @ 40 g/m^2 ; T_4: Dazomet @ 50 g/m^2; T_5: Furadon @ 2 kg a.i./ha at the time of planting ; T_6: Untreated control

Effect of crucifers as biofumigants against potato cyst nematode

An experiment was conducted with crucifers as biofumigants against potato cyst nematode in fields planted with susceptible variety Kufri Jyoti. T5 recorded lowest reproduction factor of 2.38. **(Fig. 20).**

T1: Radish *(Raphanus sativus)* @12.5 t/ha + Black polythene sheet; T2: Cabbage *(Brassica oleracea)* @12.5 t/ha + Black polythene sheet; T3: Mustard *(Brassica juncea)* @12.5 t/ha + Black polythene sheet; T4: Cauliflower @12.5 t/ha + Black polythene sheet; T5: Dazomet (40g/m^2) + polythene sheet; T6: Carbofuran 3G@ 65kg/ha; T7: Untreated control

Survey for assessment of PCN dynamics in different crop seasons

A survey was conducted in six revenue villages, viz., Velpatty, Kookal, Kurungi Nagar, Poombarai, Poondi, Mannavanur of Kodaikanal taluk during summer (2015-16). Low level of PCN population were recorded in Velpatty (4 cyst/100 ml) while highest population (226 cyst/100 ml soil) from Kookal village.

Division of Crop Physiology, Biochemistry and Post-Harvest Technology

Post-Harvest Management and Nutritional Enhancement of Potatoes

Potatoes are semi-perishable in nature and a considerable proportion (about 16%) of the total production is lost due to improper post-harvest operations and low utilization; as a result there is considerable gap between gross production and the net availability. Post-harvest loss assessment and its reduction is essential to make available more food from the existing level of production. Losses can be minimized by refinement of post-harvest handling and storage techniques and the present programme deals with these issues.

Nutritionally, potatoes are considered as a wholesome food and are amongst the most important crops for human consumption, together with wheat, rice and maize. Presently, the global potato sector is undergoing major changes. Consumers are becoming increasingly aware of potential benefits from choosing a healthy diet and they are willing to pay more for food they believe will benefit their health. Since potatoes are consumed in large quantitites, they form an important source of antioxidants. The attempts are being made to make potatoes further rich in nutrition by development of potatoes having more antioxidants, higher resistant starch and higher nutrients and flavour. Also there is increased awareness about the higher oil content in fried processed products of potato. Therefore, there is a need to develop high quality processed potato products with low oil content, high nutritive value (fortification) and longer shelf life. This is also being addressed through this programme.

Post-Harvest Loss Assessment

For the estimation of post-harvest losses, the experiments were initiated from the beginning of harvesting. The assessment of physiological and pathological losses is being done in potatoes stored under different storage systems (2-4C, 10-12C and non-refrigerated storage). Besides, the assessment is also being done through surveys of farmers and marketing channels. The interview schedule was developed and a survey of 60 farmers was completed in Punjab during the year **(Fig. 1).** Further work shall continue during the storage season of 2016 at Jalandhar and Patna and based on the factors responsible for enhancing losses, the management practices shall be standardized.

Fig. 1: Controlled temperature storage facility at Jalandhar and survey during harvesting

Sprout suppression in potatoes with naturally occurring volatile compounds

Large scale studies were conducted in walk-in-chambers (25q of potatoes) to evaluate potential naturally occurring volatile compounds for sprout suppression in potatoes as a replacement for chemical suppressants. Treatment with salicylaldehyde suppressed sprouting in four potato cultivars (table and processing) *viz.* K. Chipsona-1, K. Jyoti, K. Surya and K. Chandramukhi with nil sprouting up to 7 months of storage at 12°C **(Fig. 2)**. Total mean weight loss in potatoes (6.30%) after 7 months of storage remained less than CIPC treated potatoes (8.34%). Whereas the control (untreated) potatoes recorded 100% sprouting after 30 DOS. Contents of reducing sugar and sucrose remained low in salicyldehyde treatment in all the four varieties as compared to CIPC treatment and chip colour in potatoes treated with salicylaldehyde was better than CIPC throughout storage up to 7 months at 12°C. There was no odd flavour/smell and change in skin colour of whole potato tubers after removal from chamber. Organoleptic evaluation at monthly interval up to 7 months of storage showed no adverse effect on taste and flavour of boiled potatoes in comparison to CIPC treated potatoes. The results show that tuber treatment with salicyladehyde is a possible replacement for CIPC and can effectively control sprouting at 12°C up to 7 months of storage without any adverse effect on processing quality, taste and flavour of tubers.

Fig. 2: Potatoes stored at 12°C with Salicylaldehyde treatment compared to Control

Development of good keeping quality potatoes

It is a well-known fact that weight loss in potatoes is caused due to evaporative and respiratory losses and sprouted potatoes loose more water than the dormant potatoes. Therefore, to develop good keeping quality potatoes, longer dormancy and thick periderm are the desired attributes. The programme aims to develop such varieties and for the purpose parent selection, hybridization and seedling raising were performed during the year. Parents were selected on the basis of previous germplasm evaluated and taking into consideration two parameters viz. good keeping quality and long dormancy, in selected 24 parents. Out of these parents, only 13 showed flowering and were used for crossing, resulting in 6 successful crosses. The TPS obtained from these crosses were planted in nursery beds for evaluation and a total of 100 selections were made, which have been stored for subsequent evaluation. Investigations into morphological markers related to identification of good keeping quality are under study. Different parameters including keeping quality characteristics (sprouting, weight loss, rottage and firmness), Periderm thickness using simple microscope, wounding occurrence under simulation, wound healing rates, phenols, sugars, ascorbic acid, dry matter, specific gravity, calcium estimation and respiration rates are being observed. Identification of morphological markers related to good keeping quality will augment selection of high yielding good keepers.

Characterization of biochemical and cellular processes related to dormancy and sprouting

Various complex biochemical pathways are suggested to be involved in regulating the post-harvest storage and shelf life characteristics of potato. Studies on one or a few enzymes/ genes at a time of these pathways have yielded some information regarding differential post-harvest behaviour of different varieties; however, gaps still exist in complete understanding of these complex pathways regulating the post-harvest characteristics of potato. Keeping this in view, the proteomics and functional genomics based studies were done. Two varieties with good keeping quality and two varieties having poor keeping quality of potatoes were stored at two different temperatures (one set at 4 ^{O}C and other set at 12 ^{O}C) for 60 days. Potato tubers were withdrawn at 15 days intervals from the storage and immediately used for sampling the tubers for proteomics and functional genomics studies. The proteins were extracted and separated using two-dimensional gel electrophoresis. In all the four varieties several proteins were found to be differentially expressing when stored at two different temperatures **(Fig. 3).** These proteins differed in their molecular weights and isoelectric points. Identification of these proteins is in progress. Also, comparative transcriptome profiling of the stored tubers of these varieties is in progress. Identification of the differentially expressed proteins and genes will help in defining and future manipulation of the key controlling points of various metabolic pathways regulating the post-harvest behaviour of potato tubers.

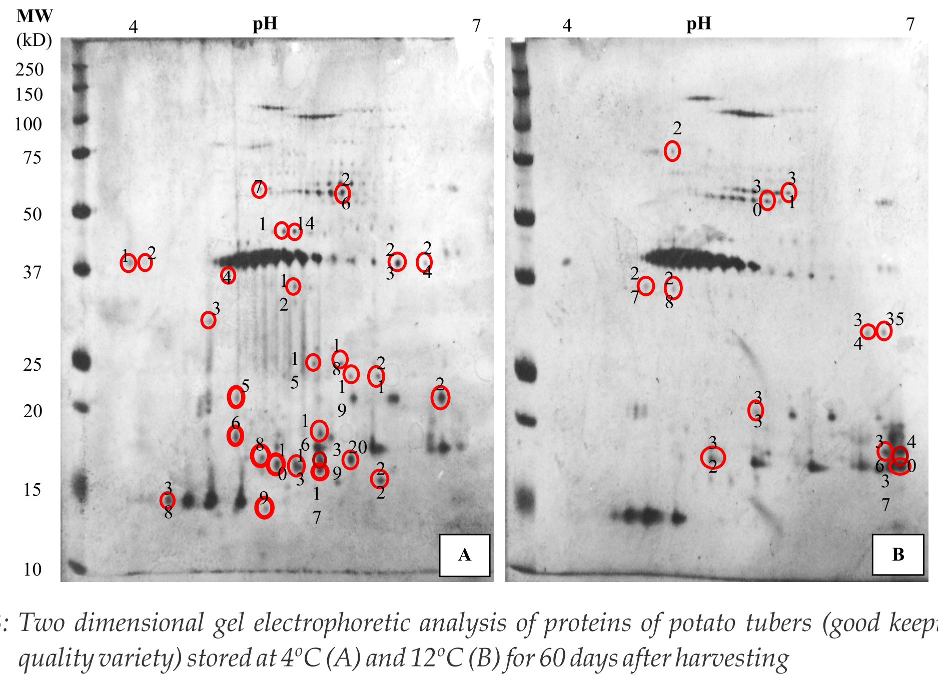


Fig. 3: Two dimensional gel electrophoretic analysis of proteins of potato tubers (good keeping quality variety) stored at 4^{o}C (A) and 12^{o}C (B) for 60 days after harvesting

Physio-biochemical studies for delayed dormancy/sprouting

The study was initiated to identify the key genes responsible for the delayed dormancy/sprouting during storage in potatoes. Four varieties namely, K. Dewa (Best keeper for table potato), K. Chipsona 1 (Best keeper for processing potato), K. Phukraj (Poor keeper), and K. Giriraj(Poor keeper) were stored at three different temperature, 18°C, 10-12°C+ CIPC and 4°C for six months. Morphological observations such as date of dormancy break; number of sprouts per tuber, length of longest sprout, weight loss of tuber were observed at monthly intervals. Sprouting initiated from the second month of storage in all varieties at 18°C except in K. Dewa. Only 28% sprouted tubers of K. Dewa were observed during third month of storage at 18°C, whereas rest of the varieties had more than 50% sprouted tubers **(Fig. 4)**. The results demonstrated better keeping quality of K. Dewa and poor keeping quality of K. Giriraj. The biochemical analysis for the estimation of enzymatic activity of Malondialdehyde (MDA), Catalase (CAT), and Superoxide dismutase (SOD), Ascorbate Peroxidase (POD) along with the ABA, GA and sugars are in progress. Same samples shall be used for the transcriptomics

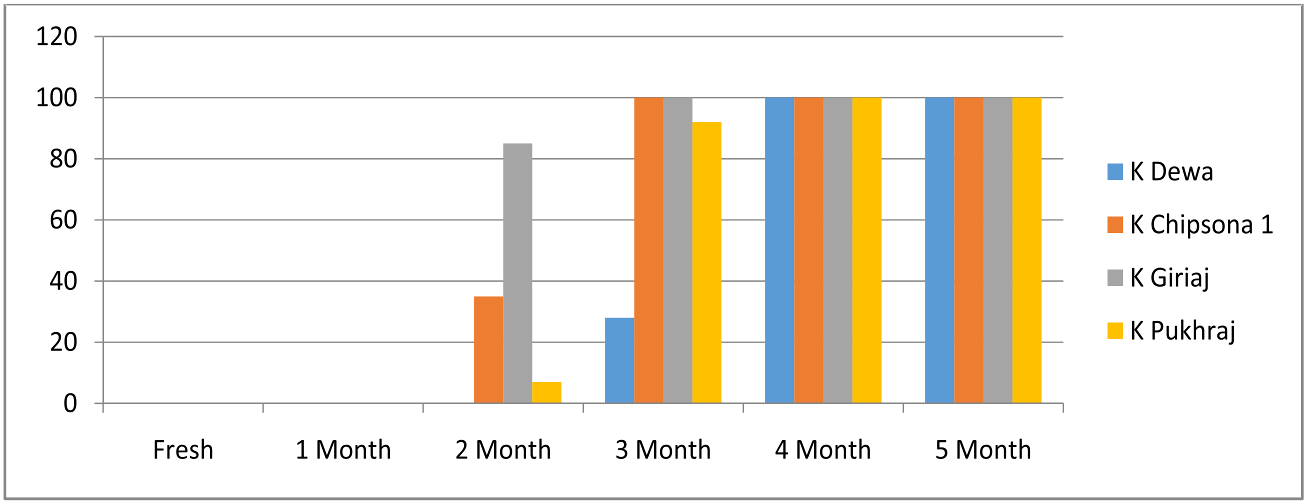


Fig. 4: Percentage of sprouted tubers at 18°C

Indirect estimation of glycaemic index of potato and potato products

Glycaemic index was estimated through estimation of resistant starch (RS), amylose, reducing sugars, sucrose and glucose. Glycaemic Index is inversely related to amylose and RS content whereas is directly proportional to free glucose. For analysis, five popular potato varieties viz. Kufri Jyoti, Kufri Bahar, Kufri Sindhuri, Kufri Chandramukhi and Kufri Chipsona-1 were cooked with conventional cooking method viz. boiling, boiling and cooling, roasting and fried as per standard procedures used for preparation of chips and French fries. It is well known that high concentration of free glucose in food leads to immediate glucose spike in blood. Therefore, foods with low free glucose are preferred as far as blood glucose levels are concerned. The tubers with higher glucose content can be considered as high glycaemic. Glucose content ranged from 0 to 643 mg/100g FW in the treatments. Boiled potatoes when tested hot, contained highest concentration of free glucose i.e 290 mg/100g FW ***(Fig. 5).*** Except for Kufri Bahar, boiled and then cooled tubers of Kufri Jyoti, Kufri Sindhuri, Kufri Chandramukhi and Kufri Chipsona-1 did not contain free glucose (tested through YSI analyser). Potato chips also contained negligible concentration of free glucose (2.9 mg/100g FW). Amylose content was the maximum in chips prepared from all the potato cultivars. Amylose was estimated in the range between 12 to 56%. Amylose content was the maximum in chips prepared from Kufri Bahar (56%). The least concentration of amylose was reported in the boiled and frozen potatoes and also in roasted potatoes, which may be due to conversion of retrograded amylose to resistant starch. The potato cultivars which are having high amount of RS or amylose or both can be considered as low glycemic. Resistant starch content in cooked Indian potato cultivars ranged from 0.78 to 7.63%. The highest value was exhibited by boiled and cooled tubers and content was high in Kufri Bahar (7.63 mg/100mg) followed by Kufri Chipsona-I (6.16 mg/100mg), Kufri Jyoti (6.06 mg/100mg), Kufri Sindhuri (5.20 mg/100mg) and Kufri Chandramukhi (4.96 mg/100mg). RS content was the lowest in boiled tubers of all the cultivars. The mean RS content was highest in boiled and frozen tubers followed by roasted tubers. Even popular potato products viz. chips and French fries contains considerable amount of RS. Reducing sugars and sucrose content in the cooked potatoes ranged from 58 to 698 (mg/100g FW) and 53 to 183 mg/100g FW, respectively. Reducing sugars were the least in microwaved potatoes and potato chips, whereas sucrose was the least in roasted potatoes. The results showed that boiled and frozen potatoes as well as roasted potatoes are healthier as they contain high content of RS along with low free glucose levels.

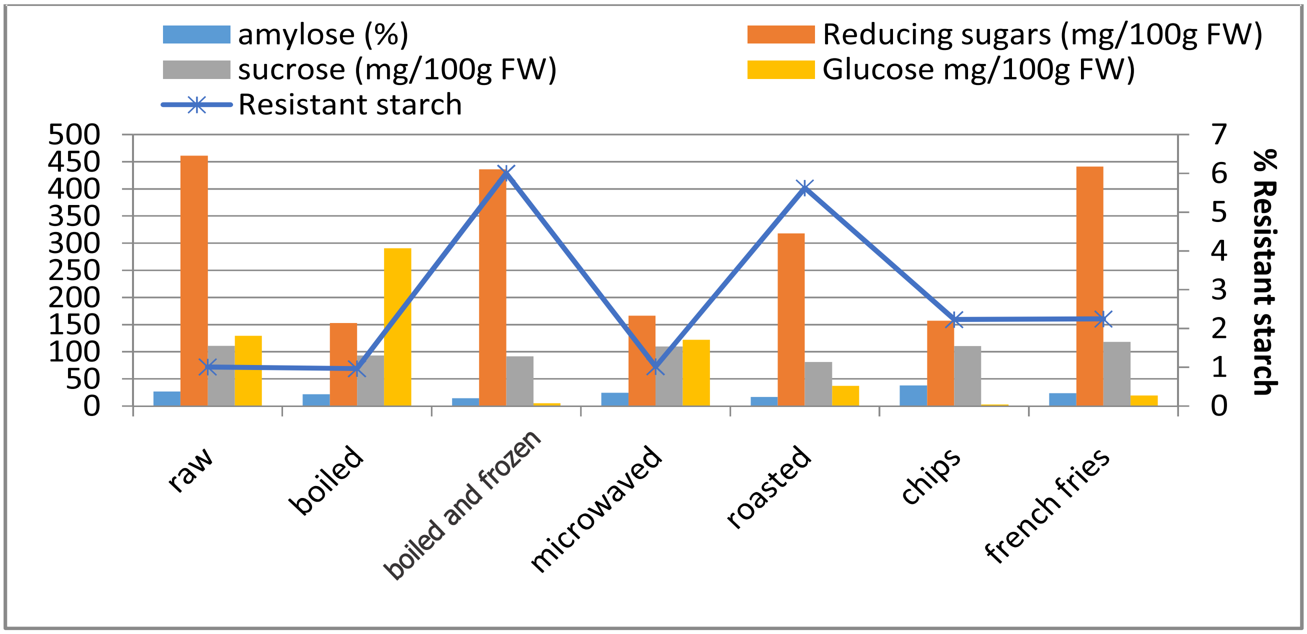


Fig. 5: Effect of cooking on amylose, reducing sugars, sucrose, glucose and resistant starch content(mean of five varieties)

Lysine content in potato protein

Potatoes are known to contain high lysine content and their protein content is considered of high biological value due to high lysine content. Lysine content in potato protein ranged from 1.7% (K. Chipsona-3) to 15.1% (K. Shailja). Protein of varieties viz. K. Shailja, followed by K. Megha, K. Naveen, K. Red, K. Kuber, K. Chandramukhi, K. Lalima and K. Jeevan contained significant concentrations of lysine that is ranging from 8 to 15% of total protein content **(Fig. 6).**

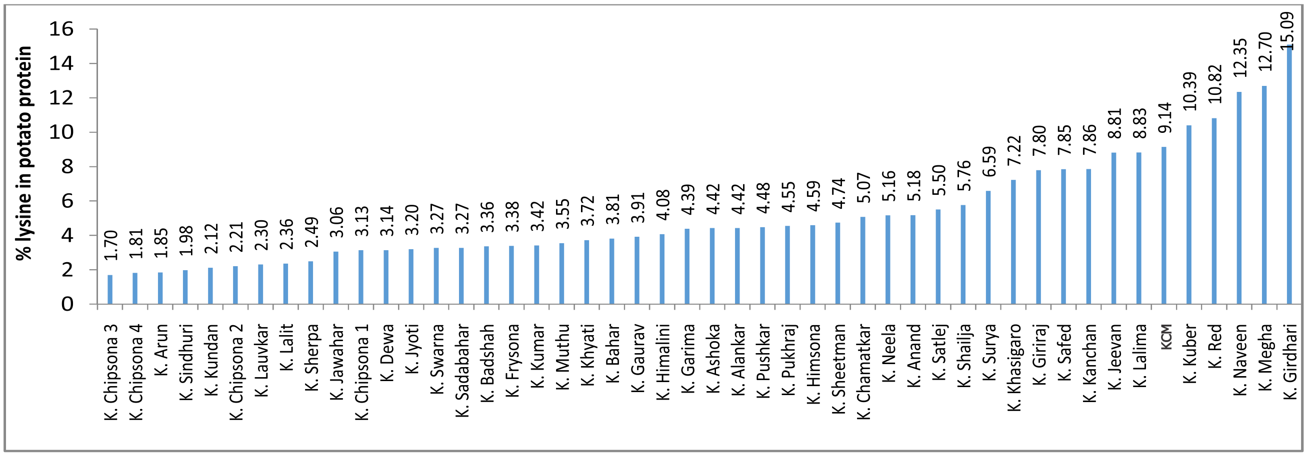


Fig. 6: Lysine content in potato protein

Potato prebiotics: Inulin

Prebiotics are group of carbohydrates resisting digestion and absorption in gastrointestinal tract and are fermented by the gut microbiota, selectively promote the growth and activity of a limited number of colonic bacteria, and alter the colonic microflora balance towards a healthier composition. In the past, work on resistant starch has been done in our laboratory. But resistant starch is not the only prebiotic in potato, inulin is also present in low concentration. Inulin content varied from 0.13% (Kufri Frysona) to 1.14% (Kufri Gaurav) in oven dried samples of Indian potatoes **(Fig. 7).** Being prebiotic and healthy component of food, development of inulin rich potatoes can be future line of work.

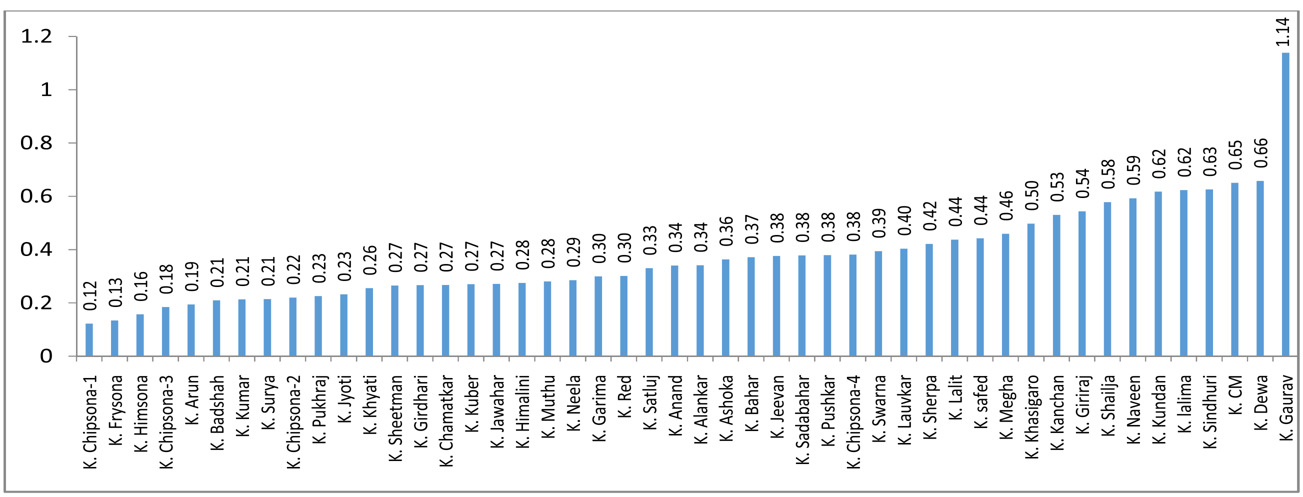
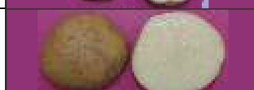


Fig. 7: Inulin content (%) in Indian potatoes

Colour evaluation of potato flesh by image analysis

Colour of potato flesh is very important quality attributes for processors and consumers. To eliminate the errors of subjective judgment, colour evaluation of potato flesh was done using RGB (Red Green Blue) colour cube. The basis of evaluation was that all the colours are secondry which are made up of three primary colours i.e. Red, Green and Blue in different ratio of intensity which ranges from 0 to 255. On this basis, flesh and peel colour of of all potato cultivars has been recorded by image analysis for elimination of subjective errors for the first time **(Table 1)**.

Table 1. Colour Attributes of Indian Potato cultivars (Four representative cultivars)

S. No.	Variety	Peel/Flesh	Peel			Flesh		
			R	G	B	R	G	B
1	Kufri Bahar		154	131	111	186	183	173
2	Kufri Chipsona-2		142	116	68	179	174	146
3	Kufri Kanchan		126	93	92	168	160	143
4	Kufri Lalit		135	107	97	177	172	122

Near-Infrared Spectroscopy: A non-destructive tool for processing quality evaluation of potatoes

Dry matter and moisture content are the most important quality parameters to judge the suitability of any potato cultivar for its ultimate utilization. Non-destructive and rapid method (application) for determination of drymatter (DM) and moisture content (MC) in potatoes was standardized using near infrared spectrophotometer (NIRSp) system. Dried potato powder using diffuse reflection mode was used for training, calibration, and validation purpose. Reproducibility of scanning curve ***(Fig. 8)*** is required for more accurate prediction. The predicted values for MC and DM content using NIRSp were in the range from 76.00 to 83.98 and 16.02 to 24.00% against 75.35 to 86.76 and 14.64 to 24.65%, of wet lab experimental values, respectively.This shows per cent error in MC and DM prediction to vary from 0.86 to 3.20% and 2.70 to 9.43%, respectively. Accuracy of prediction can be further enhanced by expanding the training/calibration sample sets. The developed application may be utilized for screening of large number of potato samples during industrial evaluation, germplasm evaluation, hybrid selection and varietal development etc.

Fig. 8: Powdered potato sample and Interferogram of potato powder

IVPD evaluation of potato cultivars

In-vitro Protein Digestibility of all potato cultivars was evaluated using modified method of Akeson and Stahman, 1964 by incubating the raw potato flour (prepared using hot air oven at 70^{O}C) with pepsin followed by the pancreatic enzymes after imitating the gut condition artificially (*In-vitro*) keeping the fact in view that all processing treatment used for potatoes are thermal treatment (having temperature more than 70^{0}C). The IVPD of potato flour from different cultivars ranged from 54.90 to 99.93% **(Fig. 9).** Almost 20 cultivars were having IVPD more than 90% which mainly consisted of table cultivars. High IVPD of potato protein in comparison to other plant foods may be due to extremely low level of anti-nutritional factors present in potato.

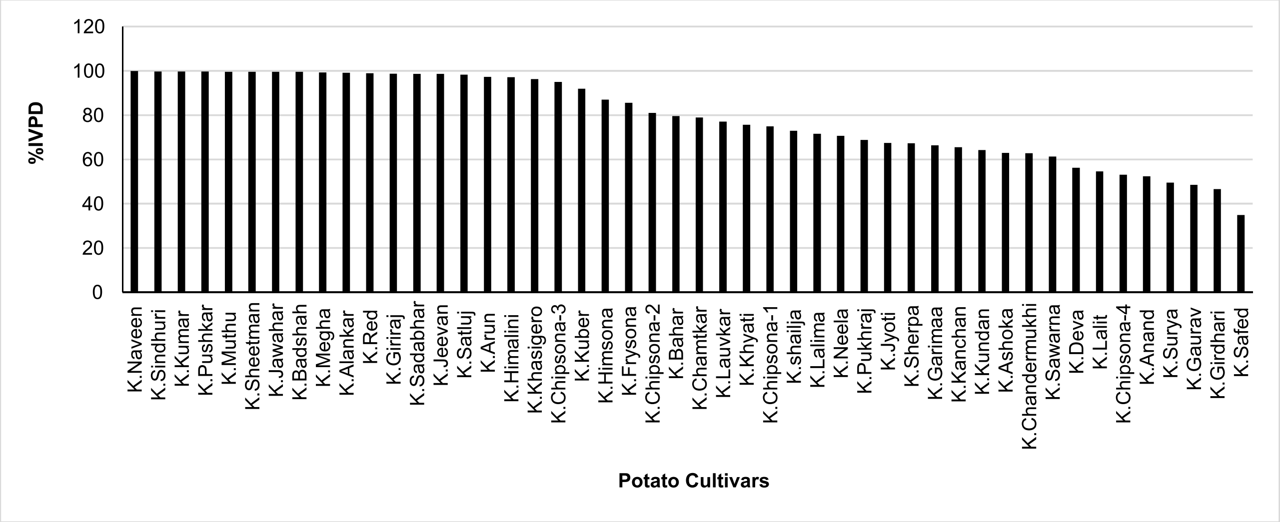


Fig. 9: In-vitro protein digestibility of Indian potato cultivars

Development of nutritionally superior varieties

In breeding for nutritional improvement of potatoes, 15 crosses were attempted involving 10 parental lines with high resistant starch, good potato flavor and high antioxidants. Out of these, 8 crosses were successful and a total of 13, 350 TPS were generated. The generation advancement of the population was carried out in the *rabi* season at CPRIC, Modipuram. The evaluation of hybrids for the desired traits shall continue.

Nutritive value of dehydrated potato shreds

Final patent application for "Dehydration of potatoes" was submitted to IPO in April 2015. It is registered as patent application No. 1273/DEL/2014. Dehydrated potato were got analysed for different parameters, nutrients and minerals at Punjab Biotechnology Incubator, Agriculture & Food Testing Laboratory, Notified under EPA-GOI, recognized as Class-A Lab-PPCB at Mohali (Punjab). Products were found to be rich in protein, vitamin C, vitamin B3, potassium, magnesium, calcium, phosphorus, zinc, copper, besides good source of fibre and carbohydrates. Dehydrated potato is thus a wholesome food with high nutritive value and its consumption in non-fried form will help to meet the recommended daily intake of various nutrient components.

MoU signed for two technologies

MoU for the technology entitled "Dehydration of potatoes" were signed during the year for commercialization on non-exclusive basis as per the guidelines of ICAR with two agencies. Main objective of the MoU is the value addition of potato on large scale, which will help to increase the potato utilization, solve the problem of storage and help the farmers by getting remunerative prices. MoU for another technology entitled "Processing of potatoes into chips, French fries and other products" has also been signed with an agency.

Patent on 'Dipstick for glucose estimation'

A patent entitled ' Dispstick for estimation of glucose in potato tubers and method thereof ' has been filed druing the year. These dipsticks shall help farmers and traders in evaluating the glucose content in the potato tubers before making the decision to supply these tubers for processing.

Fortification of potato products

For nutritional enhancement, fortification of products with desired nutrients in permissible quantities is aimed. New methodologies were developed for screening of varieties for phytate and ascorbate concentration through ELISA plate reader and based on the low phytate to ascorbate ratio, variety Kufri Chipsona-4 (0.431) was preferred followed by Kufri Frysona (0.627), Kufri Chipsona-3 (0.652), Kufri Himsona (0.691), Kufri Chipsona-1 (0.744) and Kufri Chipsona-2 (1.028).

Potato chips were fortified with three GRAS fortificants for zinc fortification using vacuum impregnation and one salt was selected for further studies due to its low cost and highest level of incorporation compared to other two salts **(Fig. 10).** Zinc concentration in control and fortified potato chips with 0.05, 0.25, 0.35, 0.50, 0.65, 0.75% concentration was 2.67, 11.32, 71.60, 79.80, 88.70, 115.6 and 140.7 mg/100g, respectively (confirmed through Atomic Absorption Spectroscopy).

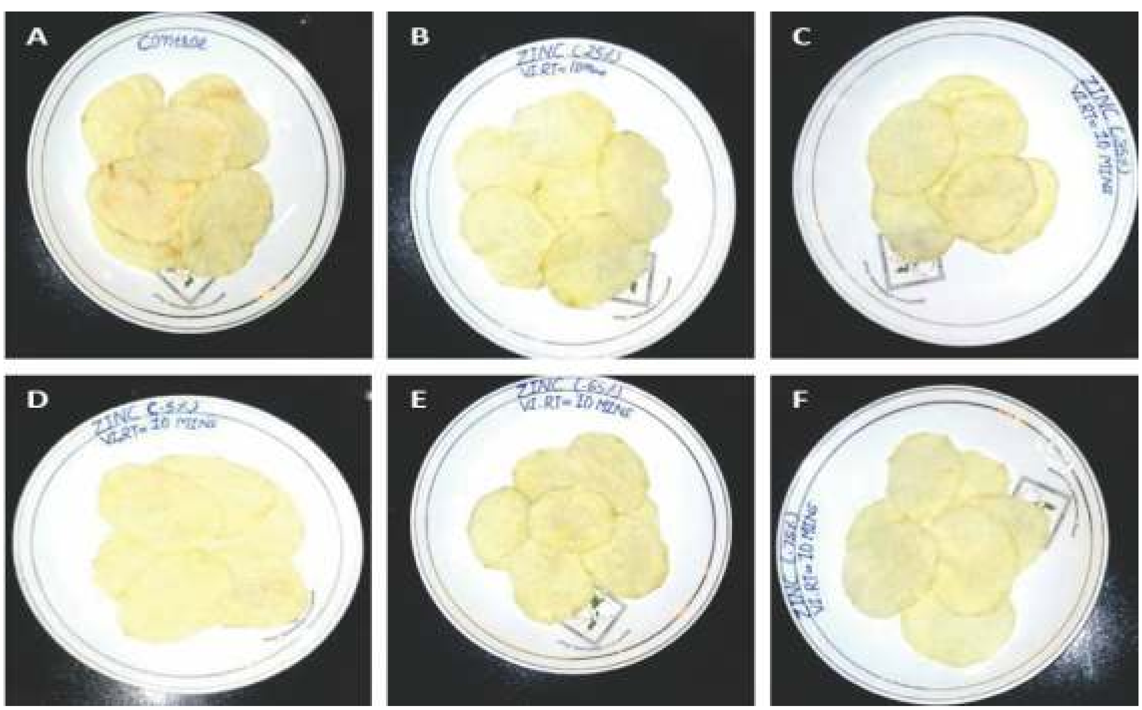


Fig. 10: Product Optimization through Zinc fortificant (A) Control (B) 0.25% (C) 0.35% (D) 0.5% (E) 0.65% (F) 0.75% of selected zinc salt concentration

Similarly, Iron fortified potato chips were prepared using six GRAS fortificants through vacuum impregnation. Discoloration was the major problem in iron fortification. Apart from maximum level of impregnation and cost of fortification; effect of fortificants on colour of the product was also taken into care. Therefore, one of the iron salt was found to be the best among all the fortificants and it was selected for further studies ***(Fig. 11).*** Iron concentration in control and fortified chips with 0.05, 0.15, 0.25, 0.35, 0.50, 0.65 and 0.75% concentration was 4.9, 12.02, 29.40, 39.90, 44.80, 58.5, 68.30 and 73.60 mg/ 100g, respectively (confirmed through Atomic Absorption Spectroscopy).

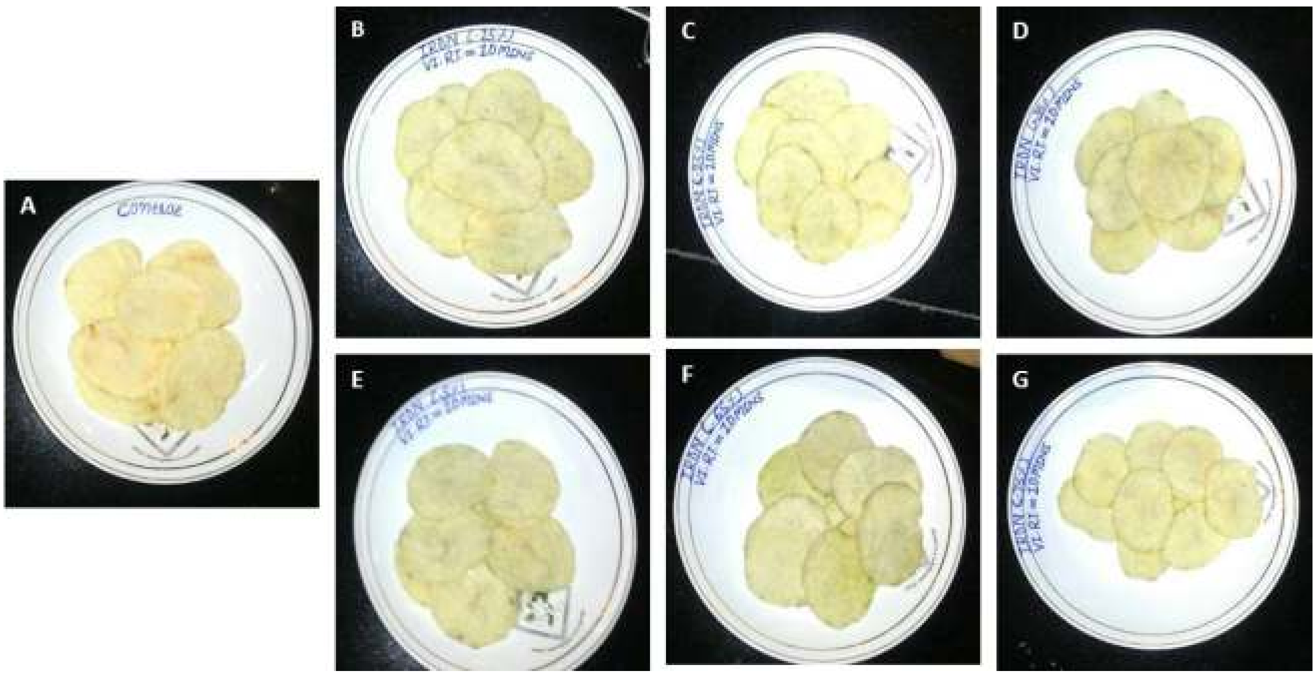


Fig. 11: Product Optimization through Iron fortificant (A) Control (B) 0.15% (C) 0.25% (D) 0.35% (E) 0.50% (F) 0.65% (G) 0.75% concentration of selected iron salt

Flavouring compounds (AMP+GMP) in iron and zinc fortified potato chips

Flavouring compounds viz. AMP and GMP were estimated from zinc and iron fortified potato chips prepared through vacuum impregnation. Flavouring compounds ranged from 3.65µg/g FW to 7.34µg/ g FW and were the highest in chips with 0.25% concentration of zinc salt ***(Fig. 12).*** A clear trend was obtained where flavouring compounds decreased with increasing concentration of zinc salt.

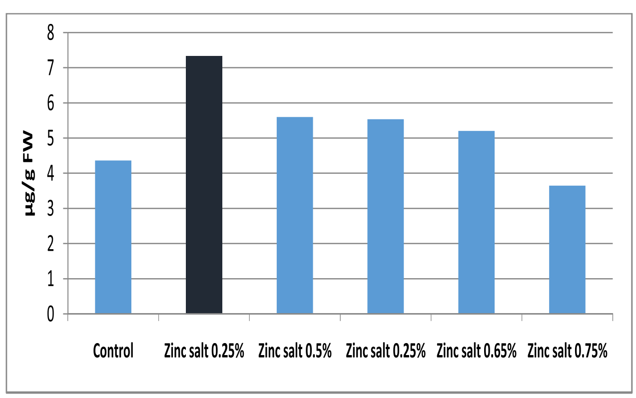


Fig. 12: Flavouring compounds (AMP+GMP) in zinc fortified potato chips

In iron fortified potato chips, flavouring compounds ranged from 4.34µg/g FW to 10.83µg/g FW ***(Fig. 13).*** The concentration of flavouring compounds was the least in control potato chips i.e without iron fortification. Flavouring compounds were the maximum in potato chips prepared with 0.35% concentration of iron salt. A clear trend in increase was obtained in concentration of flavouring compounds from control to 0.35% iron concentration, though from 0.35% to 1% iron concentration, results were not consistent.

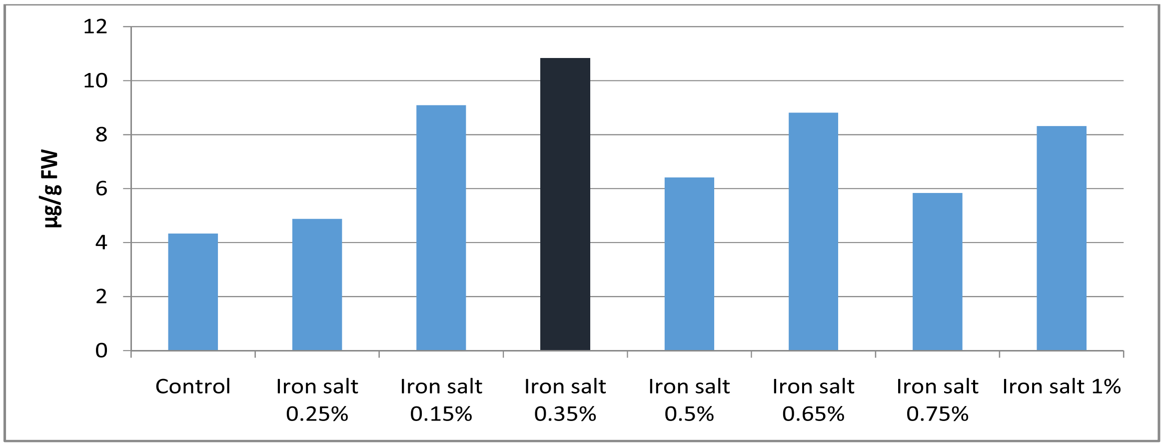


Fig. 13: Flavouring compounds (AMP+GMP) in iron fortified potato chips

Synthesis of starch nanocrystals

A method for synthesis of potato starch nanocrystals was optimized by using the 'Top Down' approach of nanotechnology. To convert potato starch granules ***(Fig 14: A)*** into starch nanocrystals, starch extracted from Kufri Chipsona-1 was used. Starch nanocrystals were prepared by acid hydrolysis method. The sample with stable pH was examined under Transmission Electron Microscope. The size of starch crystals ranged from 500-1200 nm (Fig 14: B) on 6th day of acid hydrolysis. After 12th day of acid hydrolysis the size of the starch crystals reduced further which is evident from TEM analysis wherein the size of the crystals ranged from 25-50 nm **(Fig 14: C).** This is a simple methodology for synthesis of starch nanocrystals from potato starch. These nanocrystals can be used in nanocomposites to enhance the strength and barrier properties of the material. These nanocrystals of potato starch are eco-friendly (biodegradable) in nature which are easy to prepare and cost effective also as compared with other nanoparticles. These nanocrystals with further modification as per user's requirement can replace the metallic nanoparticles.

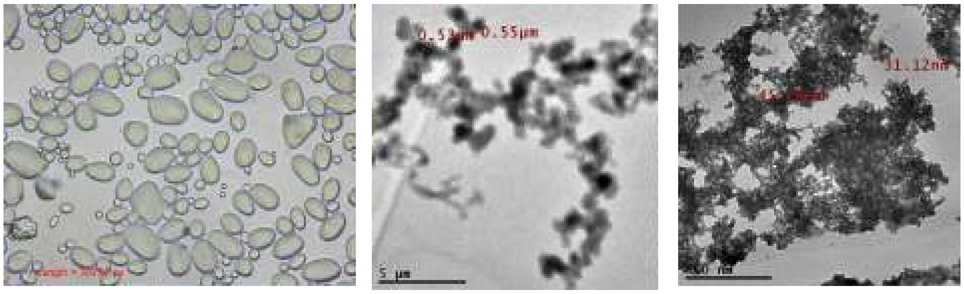


Fig. 14:(A) Starch granules of Kufri Chipsona-1 (B) formation of starch crystals after 6th and (C) nanocrystals after 12th days of hydrolysis

DIVISION OF SEED TECHNOLOGY

Production of nucleus and breeder seed of important notified varieties of potato

Potato seed tuber is vegetatively propagated and most essential input in successful potato cultivation and accounting for about 50% of the total cost of cultivation. Degeneration of potato seed stocks due to virus diseases is most limiting factor in potato seed production. Therefore, seed stocks should be free from viral and other seed-borne diseases. To maintain the higher productivity as well as yields, it is essential to have a scientifically sound proper seed production mechanism through which high degree of health standard of the seed potato crop is maintained. In this context, seed technology division in the institute has been set up with the mandate "to produce disease-free basic seed of notified varieties developed by the institute". Therefore, a program entitled "Production of nucleus and breeder seed of important notified varieties of potato" has been started under Revolving Fund Scheme. The nucleus and breeder seed production is being monitored by the scientists of the division at five different stations located in different regions of the country. The nucleus and breeder seed production and supply status of breeder seed for the plains during 2014-15 and hills in 2015-16 is summarized as below:

Seed Production

A. Plains (2014-15)

A total production of 3080.17 tons nucleus and breeder seed was achieved through both conventional and hi-tech seed production system from an area of 147.08 ha in plains. This includes 2131.65 tons nucleus and breeder seed produced through conventional system from 104.35 ha whereas, 948.52 tons from 42.73 ha through hi-tech system. The percentage of breeder seed from conventional system was 69.21% while, 30.79% through hi-tech system.

1. Conventional Seed Production System

Stage-I: A total production of 16.51 tons was achieved from an area of 2.11 ha (Table-1) with average production of 9.69, 6.33, 6.76 and 8.22 t/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively. To ensure the seed health, a decision was taken to raise the Stage-I crop under net house **(Fig. 1)**.

Fig. 1 : Stage-I crop under net house at Jalandhar

Stage-II: A total production of 103.37 tons was achieved from an area of 6.84 ha (Table-1) with average production of 15.62, 19.45, 11.08 and 26.14 t/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively **(Fig. 2).**

Fig. 2 : Stage-II crop under drip irrigation at Modipuram

Stage- III: A total production of 474.08 tons was achieved from an area of 20.78 ha (Table-1) with average production of 23.10, 24.25, 21.57 and 20.87 t/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-IV:A total production of 153.77 tons was achieved from an area of 74.63 ha (Table-1) with average production of 22.96, 20.90, 16.05 and 20.65 t/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Fig. 3).

Fig. 3 : Stage –IV seed production at Patna

Table 1: Station and variety wise area and production in conventional system

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area (ha)	Productio n (t)	Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
Modipuram										
K. Bahar	0.30	2.82	1.38	24.40	4.00	82.90	7.00	178.39	12.68	288.51
K. Pukhraj	0.04	0.41	0.24	3.72	0.55	11.05	4.00	93.30	4.83	108.48
K. Anand	0.03	0.37	0.20	2.94	0.40	9.60	2.00	40.28	2.63	53.19
K. Sadabahar	0.05	0.46	0.20	2.30	0.35	5.28	2.15	50.40	2.75	58.44
K. Garima	0.03	0.40	0.25	4.60	0.80	27.80	1.20	39.10	2.28	71.90
K. Khyati	0.07	0.84	0.23	4.50	1.50	39.35	3.20	84.89	5.0	129.58
K. Surya	0.03	0.25	0.20	1.95	0.30	7.20	1.50	35.29	2.03	44.69
K. Chipsona-1	0.06	0.53	0.22	3.20	0.45	10.15	4.40	95.24	5.13	109.12
K. Chipsona-3	0.03	0.26	0.20	2.50	0.45	10.80	1.50	37.09	2.18	50.64
K. Chipsona-4	0.04	0.37	0.25	3.70	0.65	13.40	1.30	36.54	2.24	54.01
K. Frysona	0.07	0.58	0.33	4.00	0.85	19.85	2.90	24.64	4.15	49.07
Total	**0.75**	**7.27**	**3.70**	**57.81**	**10.30**	**237.38**	**31.15**	**715.16**	**45.90**	**1017.61**
Jalandhar										
K. Chandramukhi	0.01	0.07	0.04	0.32	0.20	3.69	1.10	30.55	1.35	34.63
K. Jyoti	0.30	1.84	0.60	12.00	3.00	66.92	12.20	229.26	16.10	310.02
K. Badshah	0.01	0.10	0.04	1.90	0.25	2.91	1.00	23.83	1.30	28.74
K. Pukhraj	0.02	0.11	0.05	2.20	0.70	25.00	3.50	82.06	4.27	109.38
K. Pushkar	-	-	0.01	0.01	0.02	0.09	-	-	0.03	0.09
K. Chipsona-3	-	-	0.02	0.11	0.01	0.35	0.10	3.52	0.13	3.98
K. Khyati	0.02	0.13	0.05	0.80	0.10	3.75	1.00	24.06	1.17	28.75
K. Surya	0.01	0.08	0.05	0.19	0.10	3.49	0.60	14.16	0.76	17.92
K. Shailja	-	-	0.05	0.18	-	-	-	-	0.05	0.18
Total	**0.37**	**2.34**	**0.91**	**17.70**	**4.38**	**106.20**	**19.50**	**407.45**	**25.16**	**533.70**
Gwalior										
K.Chandramukhi	0.15	0.89	0.28	3.85	0.65	9.95	1.90	31.70	2.98	46.39
K. Jyoti	0.22	1.69	0.43	7.65	0.86	20.3	4.18	84.14	5.69	113.78
K. Sindhuri	0.13	0.99	0.43	0.23	1.00	22.2	5.62	69.15	7.18	92.57
K. Lauvkar	0.12	0.68	0.13	1.30	0.64	10.70	1.64	15.02	2.53	27.71
K. Chipsona-I	0.11	0.07	0.32	4.75	0.64	17.05	2.04	37.01	3.11	59.49
K. Chipsona-3	0.09	0.60	0.43	4.60	0.76	17.95	2.05	42.78	3.33	65.93
Total	**0.82**	**5.54**	**2.02**	**22.38**	**4.55**	**98.15**	**17.43**	**279.80**	**24.82**	**405.87**

Patna										
K. Pukhraj	0.014	0.15	0.03	0.66	0.75	17.11	1.20	36.21	1.994	54.12
K. Jyoti	0.038	0.28	0.04	0.48	0.45	9.06	2.70	61.88	3.228	71.69
K. Khyati	0.042	0.37	0.06	3.24	-	-	-	-	0.102	3.61
K. Arun	0.011	0.09	0.02	0.28	0.35	6.18	0.75	11.58	1.131	18.14
K. Sindhuri	0.030	0.17	0.06	0.83	-	-	1.90	25.61	1.990	26.62
K. Lalit	0.030	0.30	-	-	-	-	-	-	0.030	0.30
Total	**0.165**	**1.36**	**0.21**	**5.49**	**1.55**	**32.347**	**6.55**	**135.28**	**8.475**	**174.47**
Grand Total	**2.105**	**16.51**	**6.84**	**103.37**	**20.78**	**474.08**	**74.63**	**1537.69**	**104.355**	**2131.65**

2. Hi-Tech Seed Production System

A total of 3,45,937 minitubers were produced out of which 37399 minitubers have been produced from microplants, 1297 from microtubers and 3,07,241 from aeroponic respectively **(Fig. 4).**

i) Generation-1: A total production of 144.13 tons was achieved in G -1 from an area of 8.26 ha with average production of 15.91, 24.63, 14.71 and 23.86t/ha at Modipuram,Jalandhar, Gwalior and Patna, respectively **(Table-2).**

ii) Generation-2: A total production of 804.39 tons was achieved in G-2 from an area of 34.47 ha with average production of 26.73, 22.29, 15.56 and 14.37t/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively **(Fig. 5).**

3. Total Supply of Breeder Seed

During 2014-15, 2416.16 tons of breeder seed was supplied to various Government and private agencies from stations **(Table-3)** and to different states **(Table-4).**

Fig. 4 : Hi-tech seed production system

B. Hills (2015-16)

1. Multiplication of Basic Material Maintenance of Mother Stock

A total no. of 65 individual mother tubers of 12 varieties were separately planted in sterilized soil in the cages and its mother plants were tested with ELISA/PCR against 29 viruses viz., PVX (Potato Virus-X), PVS(Potato Virus-S), PVY(Potato Virus-Y), PVA(Potato Virus-A), PVM(Potato Virus-M), PLRV(Potato Leaf Roll Virus) , PALCV (Potato Apical Leaf Curl Virus), APLV(Andean Potato Latent Virus), ABV(Arracaccha Virus B), APMV(Andean Potato Mottle Virus), PVT (Potato Virus-T), PYDV (Potato Yellow Dwarf Virus), TRSV (Tobacco Ring Spot Virus), TSV(Tobacco Streak Virus), TMV(Tobacco Mosaic Virus), TNV (Tobacco Necrosis Virus), TSWV (Tomato Spotted Wilt Virus), PMTV (Potato Mop Top Virus),

Fig. 5: G-2 crop under net house

Table 2: Station and variety wise area and production in hi-tech system

Variety	G1		G2		TOTAL	
	Area (ha)	Production (tons)	Area (ha)	Production (tons)	Area (ha)	Production (tons)
Modipuram						
K. Bahar	3.73	54.50	9.40	245.44	13.13	299.94
K. Frysona	0.5	8.35	2.05	61.00	2.55	69.35
K. Pukhraj	0.1	2.70	0.40	8.00	0.50	10.70
K. Sadabahar	0.1	2.43	0.35	9.10	0.45	11.53
K. Himalini	0.02	3.5	-	-	0.02	0.35
K. Surya	0.19	3.96	0.90	20.20	1.09	24.16
K. Khyati	0.65	11.4	5.00	143.45	5.65	154.85
K. Chipsona-1	0.02	0.42	-	-	0.02	0.42
K. Chipsona-3	0.47	8.8	2.00	50.90	2.47	59.70
K. Chipsona-4	0.38	5.1	1.50	39.20	1.88	44.30
Total	**6.16**	**98.0**	**21.60**	**577.29**	**27.76**	**675.29**
Jalandhar						
K. Chandramukhi	-	-	0.25	6.55	0.25	6.55
K. Jyoti	0.05	0.19	1.10	22.00	1.15	22.19
K. Badshah	0.10	0.44	0.60	12.00	0.70	12.44
K. Pukhraj	0.50	17.44	1.00	24.00	1.50	41.44
K. Pushkar	-	-	0.02	0.31	0.02	0.31
K. Chipsona-3	0.07	0.87	-	-	0.07	0.87
K. Khyati	0.10	3.0	0.50	10.50	0.60	13.50
K. Himalini	0.20	3.18	1.10	26.05	1.30	29.23
K. Shailja	-	-	0.20	4.92	0.20	4.96
Total	**1.02**	**25.12**	**4.77**	**106.32**	**5.79**	**131.45**
Gwalior						
K. Chandramukhi	-	-	0.22	3.65	0.22	3.65
K. Sindhuri	0.22	4.0	3.26	49.65	3.48	53.65
K. Lauvkar	0.30	3.65	0.17	3.50	0.47	7.15
Total	**0.52**	**7.65**	**3.65**	**56.81**	**4.17**	**64.46**
Patna						
K. Pukhraj	0.10	4.35	0.80	12.12	0.90	16.47
K. Khyati	0.12	1.43	0.35	7.44	0.47	8.87
K. Arun	0.03	0.41	0.30	4.54	0.33	4.95
K. Jyoti	-	-	0.10	2.77	0.10	2.77
K. Sindhuri	0.10	2.51	0.85	1.87	0.95	4.38
K. Ashoka	0.10	2.35	1.20	20.31	1.30	22.66
K. Kanchan	0.06	0.82	0.65	11.02	0.71	11.84
K. Chipsona-3	0.02	0.36	-	-	0.02	0.36
K. Surya	0.03	1.13	0.20	3.92	0.23	5.05
Total	**0.56**	**13.36**	**4.45**	**63.96**	**5.01**	**77.32**
Grand Total	**8.26**	**144.13**	**34.47**	**804.39**	**42.73**	**948.52**

Table 3:Station and variety wise supply (tons)

Sl. No.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
1.	KufriJyoti	-	273.36	83.65	64.00	**421.01**
2.	KufriBahar	434.74	-	-	-	**434.74**
3.	Kufri Chipsona-1	95.66	-	36.54	-	**132.20**
4.	KufriKhyati	235.95	34.81	-	7.37	**278.13**
5.	KufriLauvkar	-	-	18.50	-	**18.50**
6.	Kufri Chipsona-3	90.04	3.79	42.13	-	**135.96**
7.	KufriBadshah	-	35.80	-	-	**35.80**
8.	Kufri Surya	57.15	14.52	-	3.88	**75.55**
9.	KufriSindhuri	-	-	117.95	27.25	**145.20**
10.	K. Chandramukhi	-	37.04	35.19	-	**72.23**
11.	KufriSadabahar	62.15	-	-	-	**62.15**
12.	KufriAnand	41.59	-	-	-	**41.59**
13.	KufriFrysona	87.94	-	-	-	**87.94**
14.	Kufri Chipsona-4	78.09	-	-	-	**78.09**
15.	KufriHimalini	0.05	26.83	-	-	**26.88**
16.	KufriArun	-	-	-	16.20	**16.20**
17.	KufriAshoka	-	-	-	19.60	**19.60**
18.	KufriShailja	-	4.81	-	-	**4.81**
19.	Kufri Kanchan	-	-	-	10.91	**10.91**
20.	KufriGarima	48.39	-	-	-	**48.39**
21.	KufriPushkar	-	0.30	-	-	**0.30**
22.	KufriPukhraj	103.98	119.37	-	46.65	**270.00**
	Total	**1335.72**	**550.63**	**333.96**	**195.85**	**2416.16**

CMV (Cucumber Mosaic Virus), TRV(Tobacco Rattle Virus), PVYn(Potato virus Yn), PRDV (Potato Rough Dwarf Virus), ACMV (African Cassava Mosaic Virus), PLV (Potato Latent Virus), PVYc (Potato Virus Yc), TBRV (Tomato Black Ring Virus), TYLCV (Tomato Yellow Leaf Curl Virus) and SQMV (Squash Mosaic Virus) as well as PCR for PALCV, PSTVd, PVY, PLRV, PVA, PVM, PVS, PVX. After harvesting, all the virus-free, true to type, uniform size genetically pure tubers of 12 varieties were selected and aseptically maintained at 4ºC as basic material. A total of 10 varieties were made free from pathogens by carrying out series of testing through PCR/ELISA and were included in the microplants multiplication and supply chain.

2. Seed Production

During 2015-16, a total production of 78.34 tons of nucleus and breeder seed was achieved in both conventional and hi-tech seed production system from an area of 5.39 ha in hills. Presently 86.24% nucleus and breeder seed has been produced through conventional system whereas, 13.76% through hi-tech system in hills.

I. Conventional system:

i) Tuber indexing: During 2015-16, total no. of 1408 tubers of different commercial potato varieties were indexed at Kufri /Fagu.

ii) Stage-I: A total production of 2.51 tons was achieved from an area of 0.13 ha with

Table-4: Variety and agency wise breeder seed supply from plains (t) during 2014-15

S. N.	Variety	Bih	HR	CG	MH	GJ	HP	Keral	J&K	MP	NSC	PB	UK	UP	WB	NHRDF	NABARD	Uni.	Auction	Pvt/ Farmer	ICAR/F OC	Total
1.	K. Frysona	-	-	-	-	0.1	-	-	-	-	-	-	-	58.0	-	-	-	-	9.8	19.4	0.64	**87.94**
2.	K. Khyati	-	-	-	-	-	-	-	-	-	-	26.3	-	162.45	-	7.25	-	2.66	43.3	33.96	2.210	**278.13**
3.	K. Sadabahar	-	-	-	-	-	-	-	-	-	-	-	-	43.4	-	-	-	0.1	14.51	3.8	0.34	**62.15**
4.	K. Arun	5.2	-	0.3	-	-	-	-	-	-	-	4.0	-	-	4.0	-	-	0.4	-	1.27	1.03	**16.20**
5	K. Himalini	-	-	-	-	-	-	-	17.0	-	-	-	-	-	3.0	-	-	0.01	0.10	5.66	1.11	**26.88**
6	K. Kanchan	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	0.01	**10.91**
7	K. Anand	-	-	-	-	-	-	-	-	4.5	-	-	-	15.0	-	-	-	0.1	8.5	12.7	0.79	**41.59**
8	K. Chipsona-1	-	-	-	-	-	-	-	-	15.29	-	3.9	-	75.45	-	12.5	-	-	9.62	13.95	1.49	**132.2**
9	K. Pukhraj	29.1	5.0	7.75	19.4	-	-	-	-	4.5	-	34.8	-	49.5	19.7	-		14.56	18.9	60.60	6.19	**270.00**
10	K. Ashoka	5.8	-	-	-	-	-	-	-	5.2	-	-	-	-	3.5	3.5	-	0.4	-	0.85	0.35	**19.6**
11	K. Shalja	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	-	0.01	0.02	2.283	-	**4.81**
12	K. Lauvkar	-	-	-	-	-	-	-	-	13.7	-	3.9	-	-	-	-	-	-	-	0.9	-	**18.5**
13	K. Jyoti	9.55	-	7.2	-	0.1	68.1	1.5	26.5	13.05	6.0	10.5	12.0	-	121.9	8.5	13.4	5.06	1.2	107.24	9.21	**421.01**
14	K. Sinduri	-	-	3.7	-	-	-	-	-	9.75	-	26.4	-	40.0	-	24.0	-	0.2	-	39.35	1.8	**145.2**
15	K. Badshah	-	-	11.5	-	2.25	-	-	-	-	-	6.9	-	9.7	-	-	-	0.01	0.5	4.93	0.01	**35.80**
16	K. Bahar	-	-	-	13.4	-	-	-	-	2.6	-	1.8	-	222.3	-	-	-	0.1	81.6	110.3	2.64	**434.74**
17	K.CM	-	-	8.9	-	-	5.4	-	-	6.05	-	2.7	-	2.9	23.2	-	9.5	0.02	0.6	12.96	-	**72.23**
18	K. Chipsona-3	-	-	33.65	-	-	-	-	-	21.28	-	-	-	31.15	4.75	-	-	-	15.79	26.96	2.39	**135.97**
19	K. Chipsona-4	-	-	-	-	-	-	-	-	-	-	-	2.0	61.6	0.5	6.3	-	-	7.55	-	0.14	**78.09**
20	K. Surya	-	-	-	-	0.25	-	-	-	-	1.5	-	-	37.5	2.3	18.8	-	0.18	5.56	7.78	1.68	**75.55**
21	K. Garima	-	-	-	22.8	-	-	-	-	-	-	-	-	-	-	-	-	-	14.3	10.3	0.99	**48.39**
22	K. Pushkar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	**0.3**
	Total	**58.65**	**5.0**	**73.0**	**55.6**	**2.7**	**73.5**	**1.5**	**46.0**	**95.92**	**7.5**	**121.2**	**14.0**	**808.95**	**182.85**	**80.85**	**22.9**	**23.81**	**232.14**	**477.08**	**33.01**	**2416.16**

Bih= Bihar, HR= Haryana, CG= Chhattisgarh, MH= Maharashtra, GJ= Gujarat , HP= Himachal Pradesh, J&K= Jammu and Kashmir, MP= Madhya Pradesh, NSC=National Seed Corporation , PB=Punjab, UK= Uttarakhand, UP= Uttar Pradesh, WB= West Bengal, NHRDF =National Federation for Horticulture and Rural Development, NABARD=National Bank of Agriculture and Rural Development, Uni.= University, Pvt/Farmer= Private, ICAR/FOC=Indian Council of Agriculture Research/Free of Cost

Table 5: Variety wise area and production in conventional system

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area (ha)	Production (tons)	Area (ha)	Production (tons)	Area (ha)	Production (tons)	Area (ha)	Production (tons)	Area (ha)	Production (tons)
K. Jyoti	0.080	1.48	0.15	1.94	0.33	5.90	1.22	16.57	1.78	25.89
K.Girdhari	0.015	0.30	0.07	0.77	0.18	1.70	0.60	6.83	0.865	9.60
K.Himalini	0.017	0.42	0.05	0.84	0.15	2.55	0.90	14.63	1.117	18.44
K.Shailja	0.009	0.20	0.07	1.01	0.16	2.25	0.20	3.34	0.439	6.79
K.Kanchan	0.005	0.07	0.06	0.45	0.08	1.04	0.20	3.35	0.345	4.90
K.Himsona	0.002	0.01	-	-	-	-	-	-	0.002	0.01
K.Giriraj	0.002	0.03	-	-	-	-	0.10	1.90	0.102	1.92
Total	**0.13**	**2.51**	**0.40**	**5.01**	**0.90**	**13.44**	**3.22**	**46.62**	**4.65**	**67.56**

average production of 19.21 t/ha at Fagu.

iii) Stage-II: A total production of 5.01 tons was achieved from an area of 0.40 ha with average production of 12.53 t/ha at Fagu.

iv) Stage- III: A total production of 13.44 tons was achieved from an area of 0.90 ha with average production of 14.93 t/ha at Fagu.

v) Stage-IV: A total production of 46.62tons of breeder seed was achieved from an area of 3.22 ha with average production of 14.48 t/ha at Kufri **(Table-5).**

II. Hi-tech system

i) Generation-1: A total production of 3.08 tons was achieved from an area of 0.26 ha with average production of 11.85 t/ha at Fagu (Table-6).

ii) Generation-2: A total production of 7.70 tons was achieved from an area of 0.48 ha with average production of 16.04 t/ha at Kufri.

ii) Supply of Breeder Seed from Hills (2015-16)

During current year, a total of 78.34 tons nucleus and breeder seed was produced from hill station of Kufri and Fagu. Total 53.90 tons breeder seed was supplied to different Government and private agencies **(Table-7).**

C. Production and Supply of Quality Seed

A total quality seed production of 67.85 tons of five varieties was achieved from 9.76 ha area during 2015-16 at Ooty (Table-8). During 2015-16, no indent was received for quality seed from horticultural department. Therefore, 47.54 t of quality seed was supplied to the farmers and the remaining was kept for own planting. An amount of Rs. 8.63 lakhs has been generated as farm revenue for the year 2015-2016.

Table 6: Variety wise area and production in hi-tech system

Variety	G1		G2		TOTAL	
	Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
V. Kufri						
K. Jyoti	0.04	0.23	0.06	0.30	0.10	0.53
K.Girdhari	0.10	1.00	0.12	2.20	0.22	3.20
K.Himalini	0.06	1.15	0.30	5.00	0.36	6.35
K. Kanchan	0.03	0.35	-	-	0.03	0.35
K. Giriraj	0.02	0.22	-	-	0.02	0.22
K.Shailja	0.01	0.13	-	-	0.01	0.13
Total	**0.26**	**3.08**	**0.48**	**7.70**	**0.74**	**10.78**

Table 7: Variety and agency wise breeder seed supply (tons)from Kufri

Agency	Kufri Jyoti	Kufri Himalini	Kufri Girdhari	Kufri Kanchan	Kufri Shailja	Kufri Giriraj	Total
HimachalPradesh	3.00	2.00	2.00	-	1.50	-	**8.50**
Jammu and Kashmir	1.00	6.00	2.00	-	-	-	**9.00**
ArunachalPradesh	1.00	-	-	1.00	-	-	**2.00**
Uttrakhand	-	2.50	1.00	-	1.00	0.50	**5.00**
Meghalaya	2.00	-	-	-	-	-	**2.00**
Manipur	1.00	-	-	1.00	-	-	**2.00**
Tripura	1.00	1.00	-	-	-	0.50	**2.50**
ICAR/CPRI	1.70	1.60	1.48	-	0.25	0.10	**5.12**
Private/Farmers	4.72	6.78	2.17	1.59	1.77	0.76	**17.78**
Total	**15.42**	**19.88**	**8.65**	**3.59**	**4.52**	**1.86**	**53.90**

Table 8: Quality seed production of different crop season at Ooty

Sl. No.	Variety	Summer season		Autumn season		Spring season	
		Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
1.	KufriSwarna	3.28	12.94	1.30	21.22	0.36	7.00
2.	KufriGirdhari	3.76	18.29	0.12	0.32	0.04	0.35
3.	KufriHimalini	0.46	5.10	0.10	1.70	0.03	0.50
4.	Kufri Jyoti	0.20	0.16	-	-	-	-
5.	KufriNeelima	-	-	0.08	0.02	0.03	0.26
	Total	**7.70**	**36.48**	**1.60**	**23.26**	**0.46**	**8.11**

Table 9 : Quality seed production in Shillong

Sl. No.	Variety	Conventional system		Hi-tech system		Total		Total Supply (t)
		Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)	
1.	Kufri Jyoti	1.37	5.80	0.29	3.62	1.66	9.42	8.99
2.	KufriGiriraj	0.35	3.02	0.13	1.54	0.48	4.56	1.60
3.	KufriGirdhari	0.68	3.76	0.45	1.99	1.13	5.75	3.48
4.	KufriHimalini	0.74	7.78	0.54	3.18	1.28	10.96	6.23
5.	KufriHimsona	0.44	0.83	0.55	1.10	0.99	1.93	1.17
6.	KufriMegha	-	-	1.54	7.39	1.54	7.39	4.83
7.	Kufri Kanchan	-	-	0.12	0.78	0.12	0.78	-
	Total	**3.58**	**21.19**	**3.62**	**19.60**	**7.20**	**40.79**	**26.32**

A total quality seed production of 40.79 tons was achieved from 7.20 ha under both conventional and high-tech system at Shillong **(Table-9).** An amount of Rs. 7,09,890 has been generated from the sale of quality seed at Shillong. The total area planted against each of the specific variety and their production and supply is given in Table-9.

D. Supply of Indexed Tubers to Mao, Imphal, Govt. of Manipur

As per the MoU between ICAR-CPRI, Shimla and Government of Manipur, regarding the breeder seed production at Mao farm, Manipur, ICAR-CPRI has to supply virus free tubers from stage-1 after indexing. Tuber indexing and scooped eye planting was carried out at Fagu farm and the growing plants were tested in the division through ELISA. A total no. of 87 indexed tubers comprising 50 of Kufri Jyoti and 37 of Kufri Kanchan were supplied in clonal form for further multiplication in subsequent cycles to augment seed potato production in Manipur and supply chain in NE regions.

E. Supply of Microplants to Different Seed Agencies

A total 138 virus-free *in vitro* culture tubes of basic seed material comprising 17 different varieties viz., Kufri Jyoti, Kufri Bahar, Kufri Khyati, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Pukhraj, Kufri Frysona, Kufri Chandramukhi, Kufri Lauvkar, Kufri Surya, Kufri Badshah, Kufri Girdhari, Kufri Himalini, Kufri Gaurav, Kufri Garimaand Kufri Mohan were supplied to 21 different seed producing organizations in India **(Table-10)** and a revenue of Rs. 6,90,000/- has been generated.

Table 10: Microplants supply to different Seed Producing Organization

S.No.	Name of the firm	Varieties supplied
1.	M/s Sekhon Biotech Pvt. Ltd., Rupnagar, Punjab	K. Jyoti, K.Chipsona -I, K. Lauvkar, K. Badshah, K. Bahar, K . Pukhraj, K. Surya, K. Chandramukhi, K . Khyati, K. Chipsona-3, K. Himalini, K. Mohan
2.	M/s Merino Industries Ltd. Village Achheja, P.O Hapur-245 11, Ghaziabad (U.P)	K.Chipsona-I, K.Chipsona-3, K.Chipsona-4, K. Khyati, K. Pukhraj, K. Bahar, K. Jyoti
3.	M/s Bhatti Tissue Tech, Vill. Alipur, P.O Mithapur, Distt. Jalandhar-144 002 (Punjab)	K. Jyoti, K.Chipsona -I, K. Lauvkar, K. Badshah, K. Bahar, K. Pukhraj, K. Surya, K. Chandramukhi, K . Khyati, K. Himalini
4.	M/s Sandhu Farms, VPO Udhpur, Jalandhar, Punjab	K. Pukhraj, K. Jyoti, K. Lauvkar, K. Badshah, K.Chipsona-I, K.Chipsona-3, K. Bahar
5.	M/s GRS Bioplants, Kabirpur, Firozabad, UP	K. Bahar, K. Pukhraj
6.	Deputy Director Horticulture, Horticulture Biotechnology Centre, Shamgarh, Karnal	K Khyati, K. Pukhraj, K. Chipsona-1
7.	M/s Kalinidi Agro Biotech Ltd., Gurgaon, Haryana	K Jyoti, K. Pukhraj, K. Chipsona-1
8.	M/s Neva Plantation Pvt. Ltd. Village Gopalpur, Tehsil Palampur, Distt. Kangra-176059 (H.P)	K. Jyoti, K.Chipsona -I, K.Chipsona -3, K.Chipsona-4, K. Lauvkar, K. Badshah, K. Bahar, K. Pukhraj, K. Chandramukhi, K. Khyati
9.	M/s Sreedhar Apex Biotech, Assam	K. Pukhraj, K. Khyati
10.	M/s Mahindra HZPC Pvt Ltd., Mohali, Punjab	K. Jyoti, K. Bahar, K. Pukhraj, K. Badshah, K. Chipsona-1, K Khyati, K Frysona
11.	M/s Pallishree Limited, Arambagh, Hoogly (W.B.)	K. Chandramukhi, K Jyoti, K. Pukhraj

12.	M/s Breme Developers Pvt. Ltd., A Green Technology Company, Mandi, HP.	K. Jyoti, K. Lauvkar, K. Pukhraj, K. Bahar, K Frysona, K. Chipsona-1, K. Chipsona-3
13.	M/s Sagar Biotech, Top Floor, Tip Top Complex, V.P.O Takurdwara, Tehsil Palampur, Distt. Kangra (HP)	K. Jyoti, K. Lauvkar, K. Pukhraj , K Frysona, K. Chipsona-1, K. Chipsona-3, K. Badshah, K. Bahar
14.	M/s Rhizobia Technologies Pvt. Ltd., Ahmadabad	K. Pukhraj, K. Badshah, K. Lauvkar
15.	M/s Siddhi Vinayak Agri Processing Pvt. Ltd., Row House 1, Konark Riveria, Yerawada, Pune (Maharashtra)	K. Pukhraj, K. Badshah, K. Lauvkar, , K Frysona, K. Chipsona-3, K. Bahar
16.	M/s Micropropagation Technology Park, TERI, Gurgaon, Haryana	K. Pukhraj
17.	M/s Sun Agrico Pvt. Ltd., Vadodra, Gujarat	K. Lauvkar, K. Chipsona-3, K. Chipsona-4
18.	M/s AKM Sabirijman, KrishiRasayan, Kolkata	KCM, K. Pukhraj, K. Jyoti
19.	M/s Merino Industries Ltd. Village Achheja, P.O Hapur-245 11, Ghaziabad (U.P)	K. Chipsona-1, K. Chipsona-3, K. Pukhraj, K. Lauvkar, K. Bahar, K. Badshah
20.	M/s Cadila Pharmaceuiticals Ltd., Agro Division, Plot No.735, Prakuriti Farm, Haripur, Tal Dascroi, Ahmadabad (Gujarat)	K. Jyoti, K. Chandramukhi
21.	M/s Sashanka Tissue Tech Pvt. Ltd. , Ranchi Jharkhand	K. Chipsona -4, K. Chipsona -3, KCM, K. Jyoti, K. Lauvkar, K. Himalini, K. Gaurav,

A total of 668 culture tubes of 16 varieties were supplied to different seed production stations/centers i.e. Modipuram, Jalandhar, Patna and Shillong **(Fig.6).**

F. Revenue under RFS by sale of breeder seed:

A total of Rs. 7,73,83,181/- has been generated by the sale of breeder seed under Revolving Fund Scheme (RFS) from Modipuram (Rs. 4,12,83,490), Jalandhar (Rs. 1,94,91,271), Gwalior (Rs. 1,19,30,370) and Patna (46,78,050).

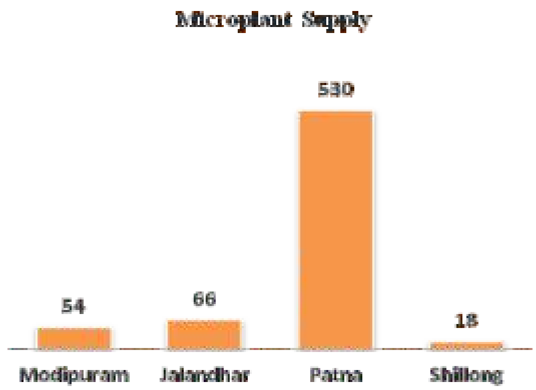


Fig. 6: Microplant supply to different stations

DIVISION OF SOCIAL SCIENCE

Assessment of potato technologies and its transfer to stakeholders for improving potato production

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

Seed potato utilization in Madya Pradesh and Gujarat states of India

Madhya Pradesh and Gujarat are major potato producing states of India. They together contribute 9.3% area of total potato area in the country and produced nearly 11% of total production of India. Both of these states are having advantage in production of processing potatoes in the country due to suitable climatic conditions. However, seed potato for these states are mostly supplied by Punjab and UP. A Survey was conducted regarding seed potato utilization and marketing in Madhya Pradesh and Gujarat states. In Madhya Pradesh, Indore and Dewas districts were surveyed covering 83 farmers, 11 traders and 2 District Agricultural Officers. In Gujarat, Anand and Banaskantha district were surveyed covering 86 farmers, 8 traders and 2 District Agricultural Officers. Variety wise potato area, extent of availability of healthy seed to farmers and constraints of potato growers in selected states were studied through primary data.

Variety wise potato area

Variety wise potato area was assessed in both the states. In Madhya Pradesh processing varieties Kufri Chipsina-3 (26.5% area) and Kufri Chipsona-1 (24.3% area) were the leading potato variety closely followed by Kufri Jyoti (22.1% area). Kufri Lauvkar was the fourth (11.52% area) leading variety among the farmers. In case of Gujarat, Kufri Pukhraj (42.4% area) was the leading potato variety closely followed by Kufri Badshah (37.1% area). Kufri Luvkar (11.8 % area) was third popular variety among the farmers.

Variety wise availability of healthy seed potato

In Madya Pradesh, majority of the farmers were of the opinion that healthy seed of Kufri Lauvkar, Kufri Chipsona-3 and Kufri Jyoti were easily available to them. Kufri Chipsona 1 was not easily available to farmers. In case of Gujarat, cent percent farmers were of the opinion that quality seed of potato varieties Kufri Pukhraj, Kufri Jyoti and Kufri Badshah were easily available to all the potato growers. Nearly 30% farmers denied the availability of healthy seed of Kufri Lauvkar.

Constraints in seed potato cultivation

Constraints of potato farmers were studied in terms of their severity which was reflected by the proportion of positive responses. Nearly 48.2 percent of farmers in Madhya Pradesh and 32.5 per cent in Gujarat reported that "non availability of quality seed" was the number one constraint for them. Expensive seed potato was found to be the second important constraint in both these states as reported by 25.6% farmers from Gujarat and 28.9% farmers from MP. Higher cost of farm inputs, unavailability of fertilizers on time was other major constraints in MP and Gujarat.

Adoption of improved potato varieties and technologies in Meghalaya and Assam

An intensive survey was carried out during 2015 in the two major potato producing states in the north eastern region of India i.e., Assam and Meghalaya. Major potato producing districts from Meghalaya i.e., East Khasi Hills and adjoining part of West Khasi Hills district while two major potato producing districts from Assam namely Darrang and Barpeta were selected for the study. A total of 210 potato farmers were surveyed for the study.

Status of potato cultivation in Meghalaya

It was observed that majority (64 %) of farmers directly engaged in the farming in the potato growing area of Meghalaya were women. The average size of total land holding was about 2.5 acres. Out of total cultivated land, nearly 49 % acreage was occupied by the potato in the region. Farmers of Meghalaya cultivate potato during summer season under rainfed condition. Other competitive crops were cabbage, cauliflower, maize, radish, French bean, carrot, Knol khol etc used to grow in the summer season. Only few farmers of the region followed potato based cropping sequences.

Incidence of late blight was major limiting factor of potato cultivation in this region. Some farmers used pesticide for control of disease and pest. White grub is second most important problems of potato cultivation followed by weed infestation. Bacterial wilt is another new problems emerging in this region. No assured irrigation facility was available in this region. Manual planting is common in Meghalaya. Mechanisation of potato cultivation in this region is negligible. Most of the farmers used their own planting material of potato, sometimes they also purchase the seed from state and central government office. There is no cold storage facility in this region and farmers store the potato in their local wooden storage. Farmers are not facing any problems regarding sale of potato in the market in the Meghalaya. Kufri Jyoti, Kufri Megha and Kufri Giriraj were major varieties grown in Meghalaya. **(Fig. 1)**

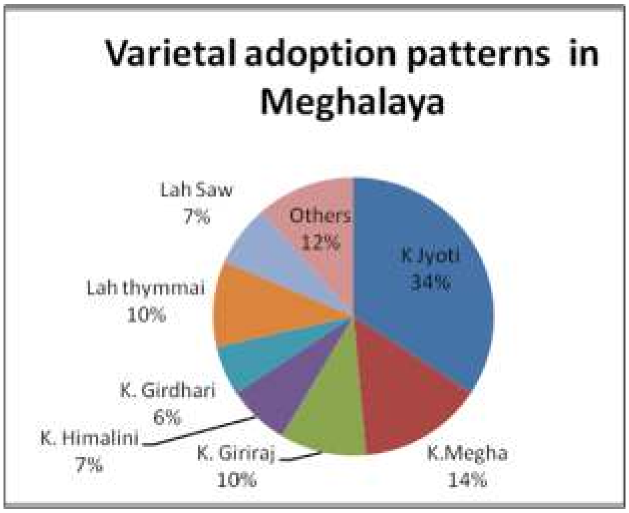


Fig. 1 : Varietal adoption patterns in Meghalaya

Status of potato cultivation in Assam

Average size of holding in Darrang and Barpeta district of Assam was found to be 3.24 and 2.44 acres, respectively. Almost, equal i.e. 38 per cent area under potato cultivation in the both district during season. The major disease of potato i.e late blight locally known as blood bimar rog in Assam, caused severe losses in potato productivity. The lack of suitable variety was another bottle neck in adoption of potato technologies. Supply of quality seed to the farmers through the government was very less and almost negligible to this region. Most of the farmers of both district purchased the seed potato from the local market supplied by the traders from Bengal/Jalandhar/Bihar. There was no cold storage in both the district and farmers has to sale their potato in the harvesting season in local market and kept potato only for table purpose at home. Cost of planting material was almost four-five times higher than sale price of potato. Adoption pattern of major potato varieties grown in selected regions of Assam are shown through **(Fig. 2).**

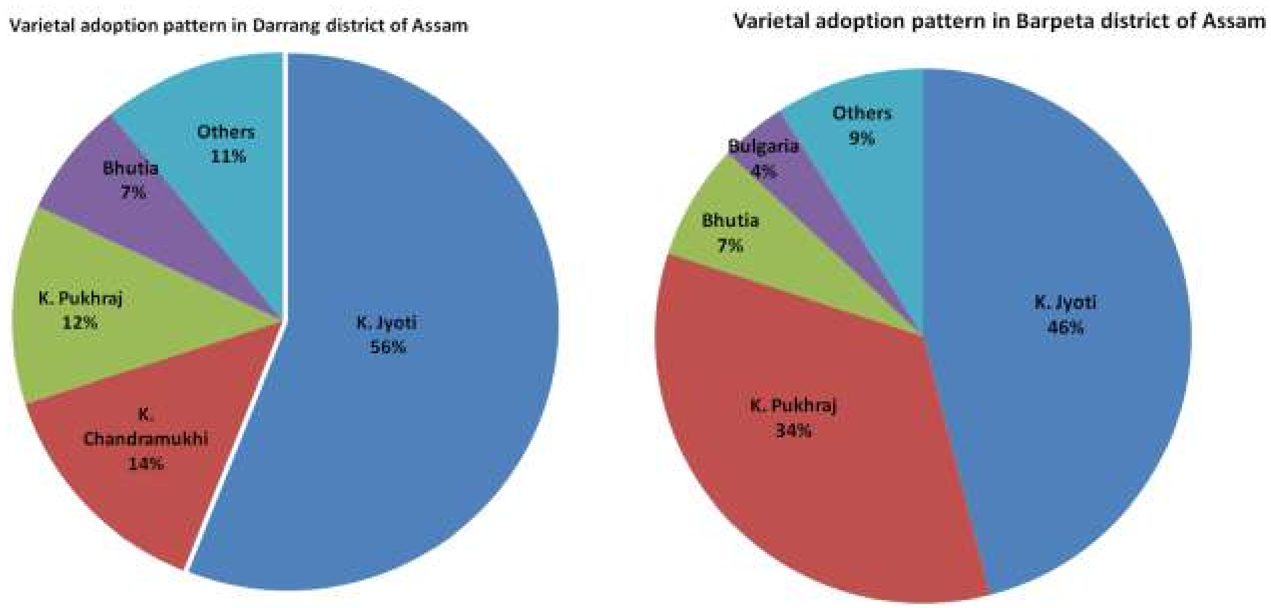


Fig. 2: Varietal adoption pattern in selected districts of Assam

Assessment of improved potato varieties

On-farm demonstration in Himachal Pradesh

Overall, 30 demonstrations were laid out in different locations of HP namely Shimla, Mandi and Kullu districts to assess the performance of potato variety Kufri Himalini and Kufri girdhari at farmers' field.

In Talai, village of Shimla district, 10 varietal demonstrations were laid out to show the farmers, the superiority of new potato variety Kufri Himalini over existing Kufri Jyoti. Similarly, in Matiana and Theog villages of Shimla, Kufri Girdhari was demonstrated to farmers using all the recommended package of practices in demonstration plots. The average yield of demonstrated variety Kufri Himalini was found to be 16.3 t/ha which was significantly higher than the control variety Kufri Jyoti in Talai village. The demonstration plots of late blight resistant variety Kufri Girdhari gave higher yield i.e 19.04 t/ha yield as compared to existing variety Kufri Jyoti (12.5 t/ha) thus having an yield advantage of 55.2 per cent in Matiana and Theog.

In Anni village of Kullu district, 6 demonstrations of Kufri Girdhari were laid out at farmer's field. The observations were recorded from time to time. Analysis of data revealed that the demonstrated variety Kufri Himalini gave 11.2 t/ha yield which was higher than locally cultivated Kufri Jyoti (8.7 t/ha). Low yield was recorded mainly due to high rainfall resulting in rottage of tubers in field. Similarly, in Janjaylee village of Mandi district of HP, 6 demonstrations of Kufri Girdhari were laid out. The yield level were compared with local variety Kufri Jyoti and it was found that Kufri Girdhari gave an average yield of 16.2 t/ha while control variety Kufri Jyoti gave only 11.2 t/ha yield. Thus, Kufri Girdhari recorded an yield increase of 44.6 per cent over local old variety.

On-farm demonstrations in Uttar Pradseh

Farmers field demonstrations: In view of popularize the new potato varieties and improved cultivation practices of potato, developed by the institute, 14 field demonstrations were conducted at three locations like Hapur, Meerut and Muzafarnagar districts of Uttar Pradesh at farmers' field During the year 2015-16.

Field demonstrations conducted on improved variety Kufri Garima: A total of 5 field demonstrations on new variety namely Kufri Garima were conducted at 4 locations in three districts like Hapur , Meerut and Muzafarnagar districts in Uttar Pradesh on area of 0.05 ha. In Kufri Garima variety 20.3% of increased in yield was recorded over yield of popular variety of Kufri Bahar in five trials when crop was harvested after 95-100 days. Average tuber yield from five demonstrations was varied from 230 to 300.0 q/ha in Kufri Garima under recommended practices in comparison to Kufri Bahar, It was varied from 190-250 q/ha. under farmers practices.

Field demonstrations on quality potato seed production in non traditional area of Muzafarnagar district. Nine demonstrations were conducted in a cluster of three villages of farmers fields with full agronomic practices for quality potato seed production. All the practices of potato cultivation were monitored by CPRI staffs during the crop season. The seed yield levels were varied from 192.5 to 223.0 q/ha.

Front Line Demonstrations (FLDs) in Bihar

FLD on Seed Plot Technique for production of good quality foundation seed in farmers' fields

Lack of good quality seeds is one of the major problems faced by potato growers, there is a need of adoption of seed plot technique by potato growers for production of good quality seed in order to address this problem. Keeping this in view, 50 potato growers were selected for laying out demonstration plots on Seed Plot Technique in potato farmers' fields of East Champaran District, Bihar during the current crop season (2015-2016). A total of 52 demonstrations were laid out in 17 villages selected from three blocks (Chakia, Mehsi and Piprakothi) of this district. Breeder seed (22 quintals of Kufri Jyoti, 12 quintals of Kufri Sindhuri, 9 quintals Kufri Pukhraj, 3.5 quintals Kufri Ashoka and 3.5 quintals of Kufri Khyati) were distributed among 50 selected potato growers in the district for production of good quality seed in their fields. In addition to breeder seeds, other necessary production inputs (fertilizers, insecticides, fungicides and herbicides) were also distributed following the recommendations of the institute for quality seed production. The seed crop was raised following Seed Plot Techniques (SPT). Before planting, a training programme on quality seed production was also organized involving scientists from different divisions for successful implementation of the programme. Moreover, farmers' knowledge has been strengthened through distribution of related publications, fields' visit, SMS services and other advisory services. The agronomic practices were supervised at farmers' fields by scientists and technical staffs at regular intervals. A total of 382.5 quintal potato seed was produced. The seeds were kept in cold store for sale or planting in the next season.

A comparison of seed yield between demonstrated practice (Seed Plot Technique) and farmers' practices/local practice revealed that potato variety Kufri Pukhraj attained highest yield of 221.88 q/ha which was subsequently followed by Kufri Khyati (201.14 q/ha), Kufri Sindhuri (196.32 q/ha), Kufri Jyoti (194.77 q/ha) and Kufri Ashoka (191.25). It was also observed that the average yield of demonstrations (201.07 q/ha) was 44.32 per cent higher than the average yield of farmers practices, which is only 139.32 q/ha.

Demonstration of High Yielding Potato varieties at Farmer's Field in Gaya, Bihar

Five varietal demonstration trials were laid out in Mocharim villages of Gaya district, Bihar. Under this, three high yielding varieties, namely Kufri Pukhraj, Kufri Jyoti and Kufri Sindhuri were distributed among five potato growers (all women). Local variety C-1 which is one of the popular varieties in Gaya district was used as a local check. Kufri Pukhraj gave highest yield of 181.25 q/ha in Gaya district of Bihar which was subsequently followed by Kufri Jyoti (178.15 q/ha) and Kufri Sindhuri (175 q/ha). It was also found that the average of three improved high yielding varieties gave 26.94 per cent more yield than the average of local check C-1.

Impact of training programme: An 8-days Model Training course sponsored by Directorate of Extension, Govt. of India was organized on “Model Training Course on Post Harvest Management & Processing of Potatoes” from October 27 to Nov. 3, 2015. The objective of this training was to enhance the knowledge and skills of trainees regarding important post-harvest activities like marketing, storage and processing technologies. The training was attended by 22 participants from 9 states. Several methods of training such as lecture-cum discussion, practical sessions, field visits, video film shows etc. were used during this programme. To assess the impact of this training, pre and post training evaluation was conducted using a questionnaire. 100 per cent of the trainees were fully satisfied with the classroom and lab facilities provided during training. 80-90% of trainees were fully satisfied with boarding and lodging facilities as well as training content and faculty. The overall knowledge of the participants as a result of training was improved by 22%. At the end of the training course the reaction of the training was ascertained with the help of pre-structure schedule. The training was rated as excellent by 80% of the participants as very good by 20% of them. They were of the view that the acquired knowledge would be very helpful while dealing with the problems in post-harvest losses at farmers' field. Besides, their knowledge on processing aspects shall left different states to promote small scale entrepreneurship amongst the farmers, women groups and un-employed youth.

Transfer of Technology

Technology transfer activities organized by ICAR-CPRI, Shimla

As per its mandate, the Division of Social sciences organized a large number of technology transfer activities related to potato production during the year 2015-16. These extension activities included organization of training programmes for farmers and extension functionaries from different public and private sector organizations, laying out varietal demonstrations on farmers' field, putting up exhibition stall of the institute in various national and international events and organizing live phone in programmes on All India Radio as well as Doordarshan for farmers and other stakeholders. This kind of activities helped in creating awareness and improving knowledge of farmers as well as other stakeholders viz. scientists, teachers, processors, entrepreneurs in the field of potato Research and Development. Organization of innovative extension programme like Potato School on AIR, Shimla, initiation of Mera Gaon Mera Gaurav programme at Headquarters and Regional centres and conduct of eight days Model Training Course sponsored by Directorate of Extension, Govt. of India for officers of different State Development Deptt. were the major highlights of Technology Transfer activities during the year 2015-16.

A. **Organization of trainings:** A Total of fifteen (15) training programmes for scientists, farmers, extension functionaries and other stakeholders were organized at CPRI Headquarters, Shimla. All the aspects of scientific potato production viz. seed preparation, planting, fertilizer application intercultural operations, irrigation, water management, disease and pest management, harvesting, processing, storage and marketing were covered during these trainings courses. The trainees were exposed to a series of lectures, practical classes and film shows on above mentioned topics. In these lectures, different audio-visual aids were used by the faculties along with live samples to make the training more effective. Besides this, field visits to different places like CPRS, Kufri-Fagu, Directorate of Mushroom Research, Solan, UHF, Nauni etc were also organized for trainees **(Table 1).**

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

SI No.	Title of the Training Course	Date and Duration	No. of Farmers/Officers	Sponsoring agency
1.	*Aloo beej utpadan evam vipanan prabandhan*	April 13-17, 2015 (5 days)	13	Department of Horticulture and Forestry, Bhopal, MP
2.	*Aloo beej utpadan evam vipanan prabandhan*	April 20-24, 2015 (5 days)	13	Department of Horticulture and Forestry, Bhopal, MP
3.	*Aloo beej utpadan evam vipanan prabandhan*	April 27- May 01, 2015 (5 days)	12	Department of Horticulture and Forestry, Bhopal, MP
4.	*Aloo beej utpadan evam vipanan prabandhan*	May 05- 09, 2015 (5 days)	16	Department of Horticulture and Forestry, Bhopal, MP
5.	*Aloo beej utpadan evam vipanan prabandhan*	May 12-16, 2015 (5 days)	16	Department of Horticulture and Forestry, Bhopal, MP
6.	*Laghu vyavsayiyon ke liye aloo prasanskaran par vyavharik prashikshan*	June 19-20, 2015 (2 days)	22	ICAR-Central Potato Research Institute, Shimla
7.	*Adhunik taknik dwara beej evam bhojya aloo utpadan*	June 22-24, 2015 (3 days)	13	Project manager, UGVS-ILSP, Uttarakhand
8.	*Beej aloo utpadan taknik*	September 09-11,2015 (3 days)	10	Director, Horticulture, District Tikamgarh, MP
9.	*Adhunik taknik dwara prasanskrit aloo utpadan*	September 24-26, 2015 (3 days)	26	Project Director, ATMA, Sabarkantha, Gujarat
10.	*Adhunik taknik dwara prasanskrit aloo utpadan*	October 06-08, 2015 (3 days)	25	Project Director, ATMA, Sabarkantha, Gujarat
11.	*Prasanskaran hetu aloo utpadan evam fasalottar prabandhan*	October 27-29, 2015 (3 days)	22	Deputy Director (Horticulture), Sabarkantha, Gujarat
12.	" Package of Practices and Disease and Pest Management in Potato Production"	November 18-20, 2015 (3 days)	18	Dr. Reddy's Foundation, Midnapore, West Bengal
13.	*Aloo ki fasal me mulyawardhan*	Nov. 30-Dec. 02, 2015 (3 days)	26	Project Director, ATMA, Banaskantha, Gujarat
14.	*Aloo ki fasal me mulyawardhan*	December 09-11, 2015 (3 days)	28	Project Director, ATMA, Banaskantha, Gujarat
15	*Paudha kism aur krishak adhikar sanrakshan*	23 Jan., 2016 (One Day)	100	PPV & FRA, New Delhi

B. Kisan Gosthi/Awareness camps: ICAR-CPRI, Shimla organized following Kisan Gosthies/awareness camps at different locations for the benefit of potato growers.

- Organized Farmer-Scientist interaction and Technology Demonstration on 23rd December, 2015 during celebration of Jai Kisan Jai Vigyan Week in which 30 farmers participated and benefitted.
- Organized Training cum Exhibition on Potato Cultivation on 22nd August, 2015 during celebration of Institute Foundation day. A total of 17 farmers benefitted.
- Organized Kisan Gosthi on the launch of Mera Gaon Mera Gaurav programme on 15th Sept., 2015 at Cheog Panchayat of Shimla district in which 100 farmers benefitted.
- Organized a Kisan gosthi on 15th March, 2016 at Sunni, Shimla district in which 92 farmers participated and benefitted.

C. Demonstrations: A total of 80 on-farm demonstrations were laid out in Bihar, UP and HP. Out of these, 30 demonstrations were laid out in Shimla, Mandi and Kullu districts of Himachal Pradesh during the year 2015-16. New potato varieties like Kufri Himalini and Kufri Girdhari were demonstrated to farmers in all these locations. The results clearly showed that late blight resistant varieties Kufri Girdhari and Kufri Himalini yielded higher than control variety Kufri Jyoti. Another 50 demonstrations were laid out in different districts of Bihar and Uttar Pradesh.

D. Organization of Aloo Pathshala on All India Radio, Shimla

ICAR-Central Potato Research Institute, Shimla in collaboration All India Radio, Shimla organized an innovative Extension Programme "Aloo Pathshala" on AIR, Shimla. This programme was started to generate awareness about scientific potato cultivation practices among farmers of Himachal Pradesh and nearby states. A total of 13 Radio talks were delivered during the programme on all the aspects of potato cultivation and post harvest management technologies by expert scientists of ICAR-CPRI, Shimla. These talks were broadcasted during the crop season in hills i.e May-August, 2015 during Krishi Jagat programme on AIR, Shimla. Thousands of farmers benefitted from this programme. A question was asked during each episode and based on correct answers received from potato growers, selected farmers were awarded during ICAR -CPRI Foundation day programme of the institute. A detail of all the Radio talks along with experts and date of broadcasting is given below.

Table 2: Radio talks delivered during Aloo Pathshala Programme at AIR, Shimla

Sl. No.	Topic	Experts	Date of braodcasting
1.	*Bharat evam Himachal Mein alu ka itihas evam vikas*	Dr. Bir Pal Singh	06.5.2015
2.	*Himachal Pradesh ke liye bhojya evam vidhyan hetu aalu ki kismien*	Dr. Vinay Bhardwaj	13.5.2015
3.	*Beej khet vidhi dwara beej aalu ka swasth utpadan*	Dr. Vinod Kumar	20.5.2015
4.	*Alu ki kheti mein ekikrit urvarak prabandhan*	Dr. VK Dua	27.5.2015
5.	*Alu ki kheti mein kharpatvaron ki roktham evam jal prabandhan*	Dr. Jagdev Sharma	03.6.2015
6.	*Alu ka picheta jhulsa rog tatha uski roktham*	Dr. Sanjeev Sharma	10.6.2105
7.	*Alu ke kand janit evam vishanu rog tatha unki roktham*	Dr. Vinay Sagar	17.6.2015
8.	*Aalu ki fasal ko nuksan pahunchane wale keet evam unki roktham ke upaay*	Dr. M. Nagesh	24.6.2015
9.	*Beej alu ka nirikshan evam pramanikaran*	Dr. K K Pandey	01.7.2015
10.	*Alu ki khudai, grading evam upchar*	Dr. Ashwani Sharma	08.7.2015
11.	*Alu ka bhandaran evam prasanskaran utpaad*	Dr. Brajesh Singh	15.7.2015
12.	*Alu ke kison hetu sansthan ke krishi prasar karyakram*	Dr. Dhiraj Kumar	22.7.2015
13.	*Alu pathshala par adharit kison ke patron ke uttar*	Dr. N K Pandey Dr. Dhiraj Kumar	29.7.2015

E. **Live phone in programme on Shimla Doordarshan:** Expert scientists from different discipline of potato research and development from CPRI Shimla participated in 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 **(Table 3).**

Table 3: Live phone in programme on Doordarshan, Shimla during 2015-16

Sl. No.	Date	Topic	Name of Experts
1.	April, 2015	Planting Seed Potato in higher hills of HP	Dr. Vinod Kumar Dr. N K Pandey
2.	May, 2015	Inter - Cultural operations and harvesting of potato in Mid hill of HP	Dr. Ashwani Sharma Dr. Jagdev Sharma
3.	June, 2015	Post-harvest operations storage & marketing of potato in mid hills of HP	Dr. Alka Joshi Dr. Pinky Raigond
4.	July, 2015	Disease management in potato in higher hills of HP	Dr. Ravinder Kumar Dr. Vinay Sagar
5.	August, 2015	Inter-cultural practices and pre harvest operations in potato in higher hills of HP	Dr. Vinod Kumar Dr. Dhiraj Kumar
6.	September, 2015	Harvesting and post harvest operations in potato in higher hills of HP	Dr. Brajesh Singh Dr. N K Pandey
7.	October, 2015	Seed preparation & Planting of potato in lower hills of HP	Dr. Ashwani Kumar Dr. Jagdev Sharma
8.	November, 2015	Inter-cultural operation and weed management in potato	Dr. VK Dua Dr. Pooja Chaukhande
9.	December, 2015	Disease & Pest Management in potato	Dr. Ravinder Kumar Dr. Sridhar J.
10.	January, 2016	Varietal requirement, Planting and fertilizer application in potato in mid hills of HP	Dr. Vinod Kumar Dr. Dalamu
11.	February, 2016	Inter-cultural operations and harvesting of potato in HP	Dr. Ashwani Kumar Dr. Brajesh Singh
12.	March, 2016	Disease and pest management in potato in mid hills of HP	Dr. Sanjeev Sharma Dr. Venkateswarlu v.

F **Organization/Participation in agricultural fair/exhibitions:** ICAR-CPRI, Shimla organized as well as participated in many exhibitions organized at different locations. CPRI stall was put to showcase varieties and production technologies of potato. A large No. of farmers benefitted from these exhibitions. List of these exhibitions is given below.

- Participated in National Mushroom Mela at Directorate of Mushroom research, Chambaghat, Solan on 10th September, 2015.
- Organized exhibition of potato technologies at Institute campus during Foundation Day celebration on 22nd August, 2015.

- Exhibition organized during on the occasion of Jai Kisan Jai Vigyan Week at ICAR-CPRI, Shimla on 23rd Dec., 2015.

Activities of Agriculture Technology Information Centre (ATIC)

Sale and distribution of CPRI technical and extension bulletins: A total of 1738 technical and extension bulletins were sold through ATIC. Moreover, several publications like CPRI profile, Crop Calendar and leaflets related to potato technologies were distributed free of cost to the Scientist, Extension workers and Farmers. A total of 20 CDs of PPM (Potato Pest Manager) and CAAPS (Computer Aided Advisory System for Potato Crop Scheduling) were also sold through ATIC. Altogether revenue generated through sale of publications and CDs/Expert system was of value Rs 80,100/-.

Dissemination of knowledge to visitors: A total of 2008 stake holders visited in the institute during the period under report. The visitors included 1344 B.Sc./M.Sc./Ph.D students of various universities of different states, 569 farmers from different states of the country and 95 scientist/extension worker/state level agriculture and horticulture officer. They visited institute museum as well as a Farmer's Museum in which the technologies developed by CPRI were displayed using posters, panels, live samples and models etc. The methodology and advantages of these technologies were explained by the ATIC staff to the visitors.

Extension activities at CPRI Campus, Modipuram

A. Trainings

✓ Training on “Potato seed production and marketing” was organized during 26-30 September, 2015 for 35 farmers of various districts of Uttar Pradesh. This training was sponsored by SAMETI, Rehmankhera, Lucknow (UP) under ATMA project.

✓ Training on “Integrated pest, disease and nutrients management in potato crop” was organized during 12-16 October, 2015 for 31 farmers of various districts of Uttar Pradesh. This training was sponsored by SAMETI, Rehmankhera, Lucknow (UP) under ATMA project.

✓ One day training programme on “Botanical Identification of potato varieties” for 6 supervisors/officers of M/s Merino Industries, Hapur (UP) was organized on 05 January, 2016.

B. Participation in Kisan Mela, Krishi Pardarshini and Exhibition by CPRI Campus, Modipuram

✓ “Virat Krishi Mela avam Krishi Goshthi” during 25-27 February, 2016 at Krishi

Bhavan Campus, Delhi Road, Meerut organized by Department of Agriculture, Meerut-Saharanpur zones, Uttar Pradesh. About 500 farmers visited CPRI stall.

- ✓ Three days “Krishi Unnati Mela” held at ICAR – IARI, New Delhi during 19-21 March, 2016. Mela was inaugurated by Hon'ble Prime Minister of India. During the Mela technologies developed by the Institute were demonstrated and explained to 2000-2500 farmers of various states of India.
- ✓ “Krishi avam Gramya Vikas Pradarshni” during 09-11 October, 2015 at Pt. Deen Dayal Dham, Farha, Mathura, Uttar Pradesh organized by Pt. Deen Dayal Upadhayay Smriti Mahotsav Samiti. About 400 farmers visited stall.
- ✓ Exhibition on the launching of Mera Gaon Mera Gaurav at Kakda village of Muzaffarnagar district organized by IARI, New Delhi on 20th December, 2015. About 300 farmers and 100 agriculture students visited stall.
- ✓ Participated and put up stall in “Kharif Kisan Sammelan evam pradarshani” on 27th June 2015 organized by Krishi Vigyan Kendra, Baghra, Muzaffarnagar, UP.

C. **Jai Kisan Jai Vigyan week:** This week was celebrated during 23-29 December, 2015. During this week following extension activities organized to discuss and demonstration of potato products and technologies.

- Exhibition-cum-training on “Aloo ki vaigyanik Kheti” at Campus for farmers. 40 farmers participated in this event on 23 December, 2015
- Exhibition on “Improved potato production technologies” for agricultural students on 24 December, 2015. A total of 101 students participated in this function.
- A “Field day” was organized on 29 December, 2015 in Sohajani Tagan in Muzzaffarnagar district.

B. Mera Gaon Mera Gaurav: This innovative programme was initiated at campus during 2015-16. Three multidisciplinary teams of 5 scientists each was constituted for this purpose. A total of 15 villages, 5 each from Meerut, Hapur and Muzaffarnagar districts of UP were adopted by the team of scientists. Regular activities like visit to adopted villages, baseline survey and providing advisories were conducted.

E. **World Soil Day** was celebrated on 5th December, 2015. A "Kisan Goshthi" on "Soil Health Management" was organized on this occasion for 65 farmers invited from Paswara village, block Machhra of Meerut district. A total of 102 "Soil Health Cards" were distributed to the farmers after testing their soil samples.

F. **Visitors and phones attended:** Total 268 farmers from various districts of UP, Haryana, Rajasthan and Madhya Pradesh and 106 students visited Campus to know the potato farming activities at the campus. A total number of 46 queries of potato growers were answered through phone.

G. **Live phone**-in programme

Live phone in programme on Doordarshan, New Delhi during 2015-16			
Sl. No.	**Month**	**Topic**	**Experts**
1.	February 2016	Live-Phone - in programme on Krishi Darshan	Dr. S K Luthra
2.	September 2015	Aloo mein samyik karya in "Hellokisan"	Dr. VK Gupta
3.	December 2015	Aloo ki dekhbhal on "Hellokisan"	Dr. VK Gupta
4.	January 2016	Aloo ki khudai aur rakhrkhao on "Hellokisan"	Dr. VK Gupta

Extension activities at CPRS, Patna

A. **Training programmes organized during 2015-16**

✓ Three on farm trainings of 1 day duration were organized at Gaya (Bihar), Motihari (Bihar), and Latehar district (Jharkhand). A total of 230 farmers from these districts participated and benefitted.

✓ One day training was organized at CPRS, Patna on improved techniques of potato cultivation. A total of 125 farmers participated from different districts of Bihar in this programme.

B. **Demonstrations: A** total of 50 Front Line Demonstrations on quality seed production through Seed Plot Technique were laid out in different villages of East Champaran district of Bihar for the benefit of potato growers.

C. **Exhibitions:** CPRS, Patna participated in following exhibitions and showcased the potato technologies developed by the institute.

- ✓ Horti Sangam organized at Motihari district of Bihar during 10-12 April, 2015.
- ✓ Laying of foundation stone of ICAR-IARI, Jharkhand cum Horti Sangam organized by NHB at Barhi, Jharkhand during 27-28 June, 2015.
- ✓ Agricultural farmers' fair organized at Piprakothi, Motihari, Bihar during 22-23 August, 2015.
- ✓ National farmers' fair organized by IIVR, Varanasi on 30 Jan., 2016. The stall of CPRI, Shimla was adjudged the best among all institutes.
- ✓ Scientists-farmers' interaction-cum-exhibition organized at Gandhi maidan, Patna on 25th December, 2015.
- ✓ Participated and put up stall in exhibition organized by ICAR Research Complex for Eastern Region, Patna on Feb., 22, 2016.
- ✓ Agricultural fair organized by ICAR-IISR Regional Centre in Motipur, Bihar on 5th March, 2016.

Live phone in programme on Doordarshan, Patna during 2015-16			
Sl. No.	**Month**	**Topic**	**Experts**
1.	August 2015	*Prasanskaran hetu aalu ki kismet avm sheet bhandaar se nikalne ke pashchat bijai hetu kando ki dekhbhaal*	Dr. Shambhu Kumar
2.	November 2015	*Aloo fasal ki dekhbhal avm keet vyadhi se suraksha*	Dr. Shambhu Kumar
3.	December 2015	*Aloo bhandaran ke samay dekhbhaal*	Dr. Shambhu Kumar
4.	February 2016	*Aloo fasal ki samsamayik dekhbhaal*	Dr. Shambhu Kumar

E. Other extension related activities

- ✓ World Soil Day and Soil Health Card Distribution Ceremony were organized in collaboration with KVK, Piprakothi at KVK Piprakothi, East Champaran (Bihar) on 5th December, 2015.
- ✓ Training programme cum showcasing of technical know-how of potato farming was organised to celebrate Jai Kisan Jai Vigyan Week on 28th December, 2015 at CPRS, Patna. 125 potato growers participated in the programme.
- ✓ Exposure visit of 47 potato growers from East Champaran district, Bihar to Krishi Unnati Mela at ICAR-IARI, New Delhi during 19th - 21th, March, 2016.

Extension activities at CPRS, Gwalior

A. Training: The centre organized training programme on potato cultivation for 9 students of ITM University on 5th January, 2016.

B. Jai Kisan Jai Vigyan Week was celebrated at the station in which 51 farmers from nearby area were exposed to modern techniques of potato cultivation by the expert scientists on 29th Dec., 2015.

C. Visitors attended: A total 700 farmers from various districts of Madhya Pradesh and other states of India visited the station and apprised about potato technologies by experts from CPRS Gwalior during the period under report.

Extension activities at CPRS, Jalandhar

A. Training programmes

" Aeroponic training on "Fabrication and Commissioning of Aeroponics System" was organized for four participants during 17-19 June, 2015.

✓ A One day training programme on Potato diseases identification for seed certification was organized for Punjab State Seed Certification Authority staff on 1st Dec., 2015 in which 30 staff participated and benefitted.

✓ Training programme on "Seed production technology and certification standards before planting" was conducted at ICAR-CPRS, Jalandhar for 5 PAU officials during 21-23 Dec., 2015.

✓ Training on Seed Production was conducted for a group of 49 students along with three Faculty Members from Lyallpur Khalsa College on 26 Feb., 2016.

B. Demonstration: Demonstration on field operations for potato seed production and potato products was presented to the team of Doordarshan Kisan Channel during Feb., 2016.

C. Scientist-farmer interaction was organized on 29th Dec., 2015 during the celebration of "Jai Kisan Jai Vigyan" week in which 60 farmers participated.

D. World Soil Day was celebrated at ICAR-CPRS, Jalandhr, in which 100 Soil Health Cards were distributed amongst the farmers of nearby villages on 5th Dec., 2015. On this occasion MLA, Sardar Sarwan Singh Phillour distributed health cards to the farmers

E. Visitors attended: A total 195 farmers and other stakeholders from various districts of Punjab visited the station and were acquainted with recent potato technologies.

Extension activities at CPRS, Shillong

A. Trainings Programmes

✓ 10 days training programme on "Potato Tissue Culture/Micro-propagation" was conducted for two Research Associates from Mao Regional Potato Farm, Manipur during 20-29 August 2015.

✓ One day training programme on "Processing of potato chips" was organized on 29th Dec, 2015. About 30 farmers participated in the training programme.

✓ One day training on improved potato cultivation was organized on 25th Feb, 2016 at Mawthawpdah village, South West Khasi Hills district. 50 farmers participated in the training.

B. Exhibitions: CPRS shillong participated and put an exhibition stall in following functions.

" Kisan Mela-cum-Exhibition on 16th July, 2015 at Krishi Vigyan Kendra, East Khasi Hills, 5th Mile, Upper Shillong.

✓ Kisan Mela-cum-Training programme on

23rd February, 2016 at State Biological Control Laboratory, 5th Mile, Upper Shillong.

Extension activities at CPRS, Ooty

✓ Training programme on Quality seed potato production and its storage was organized during 21-23 Dec., 2015 in which 30 farmers participated and got trained.

✓ 10 Front line demonstrations were laid out in Hassan district of Karnataka during June-Sept., 2015 in which performance of varieties namely Kufri Himalini, Kufri Surya and Kufri Jyoti at Hassan was shown to farmers of nearby areas.

✓ On the occasion of Jai Kisan, Jai Vigyan week, a Field Day programme was organized on 26th December, 2015 in Ooty taluka to see the suitability of new potato varieties. A total of 40 farmers participated in this function. A scientist-farmer interaction was also organized on 29th December.

✓ Exhibited a stall during Parliamentary committee meeting on official language on 5th Sept., 2015 at Ooty, Tamil Nadu.

✓ Exhibited a stall during "Tribal farm innovators day" organized by ICAR-IISWC, Research Centre, Ooty on 27th Feb., 2016. Altogether, 200 farmers visited CPRS stall during the event.

✓ Another exhibition stall was put up during National science day on 28 Feb., 2016 at Radio Astronomy Centre, TIFR, Muthorai, Ooty. Total 500 students visited the stall.

Library and Documentation Services

In accordance of one of the CPRI mandate "To act as national repository of scientific information relevant to potato" CPRI Library and Documentation Services unit was established in 1956 with a modest collection of 256 documents. Presently this library stacked more than 67 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 given here below:

Resource Development

At the headquarter (Shimla), a total of 305 documents were purchased, procured and added to library resources. The total collection at Shimla stand at 38808 documents comprised of 16010 books, 15164 back volume of journals, 2657 serials, 2236 annual reports, 582 theses, 251 standards, 51 maps/atlases, 1663 reprints and 194 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 28027 books; journals back volumes and other documents i.e. AR/Reprints and Bulletins etc as per the details below **(Table-1).**

Table-1: Library Collection of CPRIC & CPRS

	Regional Stations	Books	Back vols. of Journals	Other Documents (AR/Rpr/Bull)	Total	Current Journals subscribed (Indian)
1	CPRIC, Modipuram	4554	5735	2819	13108	8
2	CPRS, Jalandhar	3188	1401	1235	5824	18
3	CPRS, Patna*	2060	1280	-	3340	11
4	CPRS, Gwalior*	1075	4	71	1150	-
5	CPRS, Ooty	1645	580	548	2773	10
6	CPRS, Shillong	1521	-	167	1688	4
7	CPRS, Kufri	144	-	-	144	
	TOTAL	14187	9000	4840	28027	49

**figure shown for CPRS Patna and Gwalior is for the year 2014-15*

Periodicals and Serials Management

Forty one serials title i.e. advances, annual reviews, reference annuals, yearbooks and statistical data publications etc. were purchased.

A total of 169 current journals comprising of 30 foreign and 139 Indian have been subscribed at Shimla. Out of which 18 foreign and 128 Indian journals were subscribed on payment basis and rest 23 on exchange or gratis. In all 1186 issues of such journals were received, marked and kept in library for use. Besides, 49 titles of different journals were subscribed at CPRS libraries. 305 books were classified, catalogued, labeled, pasted and transcribed and entered in Library Automation Software 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 3500+ journals from 821 national and international publishers 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 web sites were visited and information and data were downloaded for scientists' use.

Readers and Reference Service

A total of 1895 documents were circulated (borrowed and returned) for home studies and 7855 readers consulted 9501 documents within the library. Besides, 21 outside scientists and research scholars of various research organizations consulted the library resources. 17 new members were enrolled and 13 old members withdrew their library membership due to their transfer or retirement. At present 151 readers are active members of library including RAs/SRAs. Library received 9138 reference queries from the users of the library and responded to them satisfactorily. Besides, 711 job requests were received for 1,98,369 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

1186 issues of journals (912 issues of national and 274 issues of international journals) were scanned for potato literature and 73 potato articles were found and recorded. Approximately, 305 records of library resources have been successfully added 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 ICAR-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. In addition approximately 64,000 potato references searched, downloaded and supplied to scientists in response to their literature search requests.

Resource Generation and utilization

The library has generated the revenue of Rs. 5,65,284.00 which includes the amount charged on account of rendering CDROM searching & photocopying (Rs. 9000.00), IGNOU computer practical (Rs. 29,500.00) and library discount (Rs.5,26,784.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 36,87,000.00 was spent (under Plan Rs. 31,87,000.00 and Non-Plan Rs. 5,00,000.00) on purchase of library resources like books (Rs.20,40,751.00), and subscription of journals (Rs.15,47,216.00) at HQ library Shimla and Rs 99,033.00 on CPRS libraries.

CDS/ISIS Practical Training

As per MOU between CPRI and IGNOU, New Delhi, 21 days computer, IT, and database creation and operation practical session was organized during 6th Sept.– 26th Sept., 2015 for 12 MLIS and 16 BLIS students of IGNOU Study Center, Shimla.

Institute Research Committee Meeting

The Institute Research Committee Meeting (IRC), 2015 was held at ICAR-CPRI, Shimla during 23rd to 25th August, 2015 which was attended by 62 scientists from the Headquarters and Stations. The basic objective of this meeting was to review the achievements of 2014-15 and finalize the work plan for 2015-16 of different research programmes. The following major decisions were taken during the meeting:

1. Maintain proper records of vectors. Monitor the vector dynamics, their appearance and subsequent build up.
2. Potato varieties in seed chain (about 25) needs to be freed from all viruses. Therefore, to develop virus free tissue culture material, one contractual staff will be provided to Division of Crop Improvement by Division of Seed Technology.
3. Among the traits identified and prioritized for pre-breeding, heat tolerance should also be included.
4. All germplasm including tuberosum, andigena and wild clones need to be conserved in vitro on priority basis. Initially, 509 tuberosum accessions which are not available *in-vitro* form but are available in tuber form needs to be acquired at the time of planting from CPRS Jalandhar. Later on, all andigena accessions also needs to be conserved *in-vitro*.
5. In the potato germplasm repository, the wild potato accessions inhabitant of Chile region where from the *Solanum chilense* originated, needs to be identified and screened for identifying the sources of ToALCNDV resistance. Besides, efforts may be made to import resistant accessions.
6. A set of about 100 germplasm accessions needs to be studied for stability analysis of late blight resistance at Ooty, Shillong, Shimla and in sub-tropical plains for late blight incidence. Data should be recorded both in field and lab conditions keeping in view the proper pathogen load and its structure.
7. The clones of Kufri Bahar varying in tuber shape needs to be tested for somaclonal variations using different molecular markers.
8. The weightage score card for selection of advanced hybrids before introduction into AICRP (Potato) needs to be revisited in consultation with experts from other Divisions. The revised score card needs to be put on the ICAR-CPRI web page.
9. Henceforth, the red skin variety with red colouration retention up to an extent of 70% even after cold storage, should only be recommended. More emphasis should be on hybrids with intense red skin coupled with early maturity.
10. Cloning, construct development and development of transgenic will be carried out by respective scientists irrespective of divisions but after developing and successful screening, the transgenic lines will handed over to biotechnology section for planning and preparing application for further trials as per guidelines of GEAC, DBT, New Delhi.
11. The expression studies on two enzymes, sucrose phosphate synthase and sucrose phosphatase in cold induced sweetening needs to be carried out.
12. The experiment on effect of soil drenching with copper hydroxidebased fungicide/ bactericide on the management of bacterial wilt should initially be initiated at Shimla either in infected fields at Lower Lab or in artificial inoculation conditions in glass house. If chemical is found effective, large

scale experiments be done at Bhowali (Nainital).

13. Screen the germplasm for ToLCNDV-Potato resistance to find out better resistance source than Kufri Bahar.
14. The work on A1 and A2 mating type prevalence should be stopped for some time. Instead, emphasis should be given to establish the presence of oospores in nature.
15. Efforts should be made to categorize Indian population of *P. infestans* into US Type by standardizing desired parameters.
16. Efforts should be made to develop LFIA for detection of *P. infestans*.
17. The triplex material developed for very high resistance to PVY should be screened against all the three variants of PVY.
18. Survey in Himachal Pradesh for prevalence of *Thrips palmi* – the vector for GBNV.
19. Quantification of ToLCNDV-potato be repeated using qPCR.
20. Multiplex PCR should be developed on priority for major potato viruses.
21. The stability of PAP2 gene in imparting resistance against *R. solanacearum* should be checked up to 28 days post inoculation.
22. Workout vectorial efficacy of aphid species along with their sensitivity to flonicamid insecticide.
23. Identification and characterization of genes associated with flavouring compounds and their metabolism should be carried out.
24. Non-processing varieties with high sugar content may also be evaluated for development of microwaved chips to see the discolouration, if any during the process in potatoes.
25. Assessment of rots and their management in potato during post-harvest period needs to be worked out.
26. Identification of phenotypic markers related to keeping quality assessment be done for their utilization in breeding for improving shelf-life.
27. Further work on efficacy of organic compounds (obtained from ICAR-IARI) on sprout suppression should be carried out using processing varieties.
28. Potato variety Kufri Bahar will not be multiplied in tissue culture for seed production till the problem of tuber elongation is resolved.
29. Bower system developed at CPRS, Jalandhar should be passed on to other regional stations with the facility of aeroponics. Concerned scientists shall visit CPRS, Jalandhar to see the same and apply the same at their respective stations.
30. Recommendations on the concentrations of antibiotics to be used in tissue culture for seed production should be communicated to the regional stations.
31. In aeroponics, specific protocols may be developed for poor performing potato varieties.
32. In aeroponics at CPRIC, Modipuram, attempts should be made to improve the crop duration of Kufri Bahar.
33. Proper monitoring of aphids (appearance and build up) at weekly intervals should be carried out in seed crop at all the seed stations. The data registers are to be countersigned by the concerned Heads of Stations.
34. Gum boots/rubber shoes and apron should be made available at all the seed farms to the persons for rouging.
35. Survey should be conducted in early growing regions for finding out reasons for low adoption/non adoption of Kufri Surya.
36. Impact of CPRI varieties/technologies need to be worked out. To start with impact of Kufri Khyati may be worked out this year.

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INSTITUTE ACTIVITIES 2015-16

Research Advisory Committee meeting -2015

The twenty second meeting of the Research Advisory Committee (RAC) was held at the ICAR-Central Potato Research Institute, Shimla during 19-20 August, 2015 under the chairmanship of Dr. GL Kaul, Ex-Vice Chancellor, Assam Agricultural University, Jorhat. RAC members Dr Uday Kumar, UAS, Bangalore, Dr SJ Singh, Ex-Head, IARI Regional Station, Pune, Dr BK Pandey, PS, Horticulture Sciences Division, ICAR and non-official members Shri Kanwar Pratap Chaudhary and Shri Baldev Singh Bhandari attended the meeting. Director ICAR - CPRI, Shimla, programme leaders and all scientists of Headquarter also participated. The Chairman, Dr. GL Kaul, mentioning that it was the last year of current RAC, showed happiness over the fact that Institute responded to their decisions to almost 90-100% and it was a great satisfaction to them. He further said that Institute should take up studies to lower down the production cost. He also emphasized that every technology generated in the Institute should end up in the field. The progress of 18 old programmes was reviewed and the work plan of 10 new programmes was discussed during the meeting. The meeting ended with a formal vote of thanks by Dr. VK Dua, Member-Secretary, RAC.

ICAR-CPRI celebrated its 66th Foundation Day

ICAR-CPRI celebrated its 66th Foundation Day on 22nd August, 2015. Member, Agricultural Scientist Recruitment Board Dr. VN Sharda, graced the occasion as the Chief Guest of the function. Dr. PS Naik, Former Director, Indian Institute of Vegetable Research, Varanasi, was present as the Guest of Honour. Dr Bir Pal Singh, Director, CPRI welcomed all the dignitaries and briefed them about the function and achievements of CPRI in last 65 years. Dr. VN Sharda delivered the Foundation day lecture and congratulated CPRI for its achievement. He stressed on need for soil and water conservation in agriculture and also development of small and marginal farmers in the country through agricultural technologies. Two publications were released on this occasion namely "Vaigyanic vidhiyon dwara aaloo utpadan" and "Vision 2050 of CPRI.

The retired persons of CPRI were also felicitated during the function. Nearly 60 school children and 20 farmers from Himachal Pradesh and Uttar Pradesh participated in this function. School children were shown different labs of the institute to acquaint them about basics of scientific potato cultivation. Farmers were trained in quality seed potato production and disease and pest management by the experts scientists of the institute. During this function, CPRI Best Worker Awards were given to the staff in scientific, technical, administrative and supporting category. The farmers who participated in potato school on All India Radio, Shimla organized by the institute during 6 May, to 29 July, 2015 were given award and certificate by the Chief Guest

Institute Research Committee-2015

The Institute Research Committee Meeting (IRC), 2015 was held at ICAR-CPRI, Shimla during 23rd to 25th August, 2015 which was attended by 62 scientists from the Headquarters and Regional Stations. The basic objective of this meeting was to review the achievements of 2014-15 and finalize the work plan for 2015-16 of different research programmes. Dr BP Singh, Director, CPRI and Chairman, IRC in his opening remarks welcomed all participants and stated that performance of the institute is judged at the ICAR through RFD and CPRI has been ranked at number one in the Horticultural Division. He further added that Head of Divisions should visit the regional stations to review the scientific progress. Dr Singh mentioned that secondment is essential for the delivery of the institute.

Hindi Chetna Maas

The institute celebrated the Hindi Pakhwada from 14 September to 13 October, 2015. Several competitions related to essay writing, Hindi word knowledge, Hindi typing, quiz etc were held in which many staff of CPRI participated. Hindi Divas was also celebrated at CPRI Stations viz. Modipuram, Jalandhar, Patna, Gwalior, Ooty and Shillong. The winners of these competitions were awarded with prizes by Dr BP Singh, Director, CPRI. He also emphasized on more and more use of Hindi in the day to day work of the Institute.

Swachh Bharat Abhiyan at Shimla

During the National Cleanliness Drive as a part of Swachh Bharat Abhiyan undertaken from 26-31 October, 2015, Safai work was done in the Institute campus and nearby public places. Institute adopted a place/village called Kanlog near its campus for implementation of Cleanliness Drive as a part of Swachh Bharat Abhiyan. Similar activities were exercised at all the regional stations of the Institute.

Model Training Course organized at CPRI, Shimla

ICAR-CPRI, Shimla successfully organized an 8 days Model Training Course on "Post-harvest management and processing of potato" during October 27 to November 3, 2015. The objectives of this training was to enhance the knowledge and skills of trainees regarding latest technologies for scientific methods of processing potato cultivation and post-harvest management. A total of 22 Agriculture/Horticulture officers from 8 State Development Deptt. working in the field of potato R&D participated in this programme. A variety of training methods viz. lecture-cum-discussion, practical sessions, skill demonstration, field visits and video film shows were used during summer school. Field visits to CPRS farm at Kufri-Fagu and DMR, Solan were also organized during the course.

Workshop on Advance technologies of potato cultivation in Hyderabad

A state-level workshop on Advance technologies of potato cultivation was organized by the Department of Horticulture, Telangana State, Hyderabad in collaboration with CPRI, Shimla on 26 and 27 November 2015. About 200 potato growers from Medak, Ranga Reddy, Khammam and Adilabad districts attended the training, which was followed by field trips to potato growers at Zaheerabad, Medak district at on 27.11.2015. Dr. P. M. Govindakrishnan, PC, AICRP (Potato), Dr. N. K. Pandey, Head, Division of Social Sciences, Dr. Brajesh Singh, Head, Division of CPB & PHT, and Dr. M. Nagesh, Head, Divison of Plant Protection were the resource persons.

Jai Kisan, Jai Vigyan week celebrated at ICAR-CPRI, Shimla

For the celebration of Jai Kisan-Jai Vigyan week from 23-29 December, 2015, a "Farmer-Scientist Interaction and Technology Demonstration" was organized at CPRI, Shimla on 23rd December, 2015. A total of 30 farmers from different villages of Shimla district participated in this function. Lecture on Improved methods of potato cultivation was organized along with demonstration of modern potato varieties and technologies for participating farmers. Selected farmers were awarded during the function for maintaining their soil health. Similar kind of programmes were organized at different Regional Stations of the institute during the Jai Kisan - Jai Vigyan week.

MoU signed for two potato technologies with private companies

MoU for the technology entitled “Dehydration of potatoes” was signed during the year for commercialization on non-exclusive basis as per the guidelines of ICAR with two parties namely M/s Goli Wala Foods, Ghatlodia, Ahmedabad and M/s. Sunripe Agro Products Ltd. Hyderabad. The main objective of the MoU is the value addition of potato on large scale, which will result in increased potato utilization, solve the problem of storage and help the farmers by getting remunerative prices. This will also result in significant reduction of post-harvest losses (PHLs) in potato, which are at present very high (about 16 per cent) in India. CPRI has also signed MoU for another technology entitled “Processing of potatoes into chips, French fries and other products” with M/s Goli Wala Foods, Ghatlodia, Ahmedabad in March, 2016

IJSC Meeting

Three Institute Joint Staff Council meetings were organized during May, August and March in the year 2015-16 at CPRI, Shimla. First two meeting were chaired by the then Director CPRI, Dr BP Singh and after his superannuation the last meeting was chaired by Dr. SK Chakrabarti, the newly appointed Director of CPRI. Agenda items related to different issues of staffs of CPRI, Shimla and other regional stations were discussed and several important decisions were taken during these meetings.

Potato stakeholders meet at CPRS, Jalandhar

The 4th potato stakeholders meet, 2016 was held at ICAR-Central Potato Research Station, Jalandhar on 16th January 2016. Dr BP Singh Hon'ble Director ICAR-CPRI, Shimla was the Chairman of the meet. All the scientists, Dr NK Pandey, Dr Sanjeev Sharma, various potato stakeholders and about 40 progressive farmers attended the meet. Chairman Dr BP Singh stressed the importance of the stakeholders' meeting asserting it as an important platform for all Scientists, companies and farmers related to potato for exchanging their views. He also assured the stakeholder that ICAR-CPRI is always ready to help all stakeholders. The meeting ended with a vote of thanks by the Head, ICAR-CPRS, Jalandhar.

Parliamentary committee on Rajbhasha visited ICAR-CPRS, Gwalior

The Parliamentary committee on Rajbhasha Hindi visited CPRS, Gwalior on 5th Feb., 2016 to review the work done in Hindi language by the centre and other organizations located in Gwalior. Director, ICAR-CPRI, Shimla welcomed the committee and apprised them about the progress of work done on official language by the institute. The committee lauded the efforts of CPRI for promoting the work in Hindi.

Secretary, DARE and Director General, ICAR visited ICAR- Central Potato Research Station, Patna

Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR visited ICAR- Central Potato Research Station, Patna on 5th March, 2016. He was accompanied with Dr. JS Sandhu, DDG (Crop Sciences) and Dr. BP Bhatt, Director, ICAR-RCER, Patna. Dignitaries went around the campus to assess the progress of various activities of the station. They visited experimental plots particularly varietal demonstrations, aeroponic system and tissue culture lab. Dr. Manoj Kumar, Head of the station briefed them about various ongoing research, extension and other activities at the station. In his address, Dr. Mohapatra said that he was very happy with the recent achievements of the station, especially with the production of good quality seeds for the eastern plains. He advised scientists to take the challenges for addressing the present agricultural problems in multidisciplinary collaborative manner with ICAR-RCER and other similar working institutes. He also emphasized that young scientists should work on emerging issues like nutritional value, climate change, etc in participatory mode.

Institute Management committee (IMC) meeting held at ICAR-CPRIC, Modipuram

Institute Management Committee (IMC) meeting was held at ICAR-CPRIC, Modipuram on 29th March, 2016 in the chairmanship of Dr SK

Chakrabarti, Director, ICAR-CPRI Shimla. Other members Dr JC Rana, Principal Scientist, New Delhi, Baldeo Singh Bhandari from Sirmour (HP), Shri Kanwar Pratap Singh Chaudhary from Delhi and Sh KP Sharma, Senior Administrative Officer, CPRI, Shimla also participated in this meeting. Important decisions related to management of institute activities and work were taken by the committee.

Additional Secretary and Financial Advisor, ICAR/DARE visited ICAR-CPRI, Shimla

Additional Secretary and Financial Advisor of ICAR/DARE visited CPRI, Shimla during 25-26 March, 2016 to discuss and review the financial progress of this institute. He interacted with all the staff of this institute in Auditorium and explained about the rules and regulations to be followed during expenditure of public money. He stressed on the need for result oriented research work by the institute.

Foreign Visits by CPRI Scientists

Sl. No.	Name of the scientist place & duration
1.	Dr. Jagesh Kumar Tiwari (SS), CPRI, Shimla for availing postdoctoral research from the University of Adelaide, Australia under "Endeavour Research Fellowship 2015" w.e.f. 15.05.2015 to 14.11.2015.
2.	Dr. Bir Pal Singh, Director, CPRI, Shimla for attending the International Potato Centre (CIP) Board of Trustees Meeting 2015 to be held in Lilongwe, Malawi during 18-22 May, 2015.
3.	Dr. Vinay Bhardwaj, Sr. Scientist, CPRI, Shimla for participation in the workshop on "Potato crop protection, with emphasis on the forecasting and control of potato late blight for Asia Pacific Region" at China during 15-19th June, 2015
4.	Dr. Bir Pal Singh, Director, CPRI, Shimla for participation in the 9th World Potato Congress- 2015 as International Advisor on potato and Co-Chair the technical session on Mechanization at Beijing, China during 27-31 July, 2015.
5.	Dr. Bir Pal Singh, Director, CPRI, Shimla for attending the "Board of Trustees Meeting 2015" to be held at Lima Peru during 01-04 December, 2015.

Training and Capacity Building

Training and capacity building programmes attended by Scientific, Technical and Administrative staffs of ICAR-CPRI, Shimla

Sl. No.	Name & Designation	Training/Workshop Programme	Date & Venue
1.	Dr. Rajender Singh, Sr. Scientist	Refresher Course on "Agricultural Management"	July 13 -25, 2015 at NAARM, Hyderabad
2.	Drs. Name Singh, PS & SP Singh, PS	Short training course on "Smart agro-input delivery approaches based on hydrogels and other polymeric carriers for improved crop health and productivity"	July 21 -30, 2015 at IARI, New Delhi
3.	Dr. Shashi Rawat, Sr. Scientist	Training programme on "Improving e-Governance in Agriculture"	July 24, 2015 at SAMETI, Mashobra, Shimla
4.	Sh. Yogesh Kumar Gupta, Sr. Technical Officer	Training programme on "Competency Enhancement Program for Technical Officers of ICAR"	August 19 -28, 2015 at NAARM, Hyderabad
5.	Dr. Pooja Chaukhande, Scientist	International training programme on "Leadership and career advancement for Women Scientist/Technologists"	August 28 – September 01, 2015 at IISER, Pune
6.	Dr.Prince Kumar, Scientist	Winter School entitled "Advance soil biological approaches for enhancing carbon sequestration and mitigate climate change"	September 02 -22, 2015 at IISS, Bhopal
7.	Dr. Dhiraj Kumar Singh, Scientist	Training programme on "Quantitative Techniques for Business Managers and Social Scientists"	September 07 -12, 2015 at NAARM, Hyderabad
6.	Dr. Pooja Chaukhande, Scientist	Training programme on "Advances in Applications of Nanotechnology"	October 05 -09, 2015 at Central Institute for Research on Cotton Technology , Mumbai

8.	Sh. CP Sharma, AF&AO	Training Programme on "Public Procurement"	January 11 -16, 2016 at Faridabad
9.	Drs. Som Dutt, Sr. Scientist & Prashant G. Kawar, Sr. Scientist	Refresher Course on "Agricultural Research Management"	February 23 – March 05, 2016 at NAARM, Hyderabad
10.	Dr. Sridhar J., Scientist	Training programme on "Taxonomy of Insects and Mites"	March 02 -22, 2016 at University of Agricultural Sciences, Bangalore
11.	Dr. V Venkateswarlu	Training Programme on "Nanotechnology Applications in Agriculture"	November 16 to 27, 2015 at NST lab, TNAU, Coimbatore
12.	Drs SK Luthra and VK Gupta	UPKAR project meeting on "Evaluation and promotion of processing varieties of potato in selected regions of UP & potato based RTE products"	8th October 2015 at CPRIC,Modipuram
13.	Drs. Sanjeev Sharma, Sr. Scientist & Sundaresha S., Scientist	Workshop on "Rapid Diagnostic Tools for Phytophthora"	September 08, 2015 at IIHR, Bangalore
14.	Drs. Sanjeev Sharma, Sr. Scientist & Sundaresha S, Scientist	Workshop on "Fungi Data Base -An Integrated Functional Genomics Database for Fungi"	September 09 -12, 2015 at IIHR, Bangalore
15.	Drs. Devendra Kumar, PS & Bandana, Scientist	Workshop on "Advances in Packaging Technology"	October 06 -07, 2015 at IIT, Roorkee, Saharanpur, UP
16.	Dr. Hemant B. Kardile, Scientist	Workshop on "System Biology: An Understanding of Bacterial Genomics and Proteomics"	November 26-28, 2015 at HPU, Shimla
17.	Dr. Dalamu, VK Gupta and Babita Chaudhary	DUS Workshop on India -Germany bilateral cooperation in seed sector	23rd -24th November, 2015 at NRCPB, New Delhi

18.	Dr. Hemant Kardile, Scientist	DBT sponsored workshop-cum training program on "System Biology: An understanding of bacterial genomics and proteomics"	26-28, November, 2015, HPU Shimla
19.	Drs. SK Luthra and Devendra Kumar	Workshop on Roadmap for Agricultural Development in Upper Gangetic Plains Regions	4^{th} December 2015, IIFSR, Modipuram, Meerut & IVRI, Izatnagar, Bareilly, UP
20.	Dr. Jagesh Kr Tiwari	Environmental risk assessment of genetically engineered (GE) plants	22-23 February 2016.
21.	Dr. Clarissa Challam	Stakeholders workshop of FoodSTART+	8 March, 2016, Shillong
22.	Dr. M. Nagesh	Workshop on IPM in vegetables	IIVR, Varanasi
23.	Dr. M. Nagesh and Dr. S.K. Chakrabarti	Brainstorming on IPM in major crops, IPM Package for potato and harmonization of IPM Packages under Horticultural crops.	16-17 February, 2016 at NASC Complex, New Delhi
24.	Dr. NK Pandey	Workshop of Nodal Officers of HRD of ICAR Institutes	10-12 February, 2016 at NAARM, Hydrabad
25.	Dr. Dhiraj Kumar Singh	ICAR-IFPRI Capacity building programme on "Methodologies in Agricultural Extension Research"	21-24 Sept., 2015 NAS Complex, New Delhi

Education, Awards & Honours

Conference/Seminar/Symposium attended by ICAR-CPRI staff

Sl. No.	Name & Designation	Training Programme	Date & Venue
1.	Dr. Prince Kumar, Scientist	Agri. Search 2050	May 18, 2015 at NASC Complex, Pusa, New Delhi
2.	Drs. Anuj Bhatnagar, PS, SP Singh, PS, Dhruv Kumar, PS, Murlidhar J Sadawarti, Scientist, Mehi Lal, Scientist	National Conference on "Dynamics of Smart Horticulture for Livelihood and Rural Development"	May 28-31, 2015 at Chitrakoot, Satna, Distract, MP
3.	Dr. Rakesh Mani Sharma, Sr. Librarian	National Conference on "Agricultural Librarians and User Community (NCALUC-2015)"	June 17-19, 2015 at IVRI, Izatnagar, UP
4.	Dr. S Roy, PS	National Seminar on "Climate Change and Smart Agriculture Technologies"	June 13-14, 2015 at RVSKVV, Gwalior
6.	Drs. M. Nagesh, PS & Head, Plant Protection &Kamlesh Malik, PS	XVIII Group Meeting of AINP on white grubs & other Soil Arthropods Pests"	June 19-20, 2015 at CSKHPKV, Palampur, HP
7.	Dr. Baswaraj Raigond, Scientist	International Conference on "Electron Microscopy"	July 06-10, 2015 at Bhabha Atomic Research Centre, Mumbai
8.	Drs. EP Venkatasalam, Sr. Scientist, Aarti Bairwa, Scientist, Sanjeev Kumar, Sr. Scientist & Sundresha S., Scientist	03rd International Symposium on "Phytophthora: Taxonomy, Genomics, Pathogenicity, Resistance & Disease Management"	September 09-12, 2015 at IIHR, Bangaluru
9.	Drs. BP Singh, Director, NK Pandey, PS & Head, VK Dua, PS & Head, Brajesh Singh, PS & Head, KK Pandey, PS & Head, Tanuja Buckshet, Scientist, M Nagesh, PS & Head, Vinay	Participation in the 33rd AICRP (Potato) Group Meeting	September 19-21, 2015 at GP Pant University of Agriculture & Technology, Pantnagar, Uttrarakhand

	Bhardwaj, Sr. Scientist & Act. Head, Sanjeev Sharma, Sr. Scientist, SK Kaushik, Joint Director, Kamlesh Malik, PS, Sanjay Rawal, PS, SK Luthra, PS, VK Gupta, Sr. Scientist, Vinod Kumar, PS & Act. Head, JS Minhas, PS & Head, Raj Kumar, PS, Prince Kumar, Scientist, Manoj Kumar, PS & Head, Shambhu Kumar, PS, SK Singh, PS, Rahul Bakade, Scientist, S Roy, PS & Head, SP Singh, PS, TK Bag, PS & Head, SK Yadav, Scientist, EP Venkatasalam, Sr. Scientist & Act. Head, R Sudha, Scientist, Aarti Bairwa, Scientist & Prashant G. Kanwar, Sr. Scientist		
10.	Dr. Anuj Bhatnagar, PS	National Seminar on "Contextural Relevance of ITK in the field of Plant Protection"	October 15-16, 2015 at NCIPM, New Delhi
11.	Drs. Devendra Kumar, PS, Brajesh Singh, PS & Head, Pinky Raigond, Scientist	03rd International Plant Physiology Congress on "Challenges and Strategies in Plant Biology Research"	December 11-14, 2015 at School of Life Science, JNU, New Delhi
12.	Er. Sunil Gulati, Scientist, SG (FM&P)	50th Annual Convention of ISAF and Symposium on Agricultural Engineering in Nation Building: Contributions and Challenges	January 19-21, 2016 at College of Agricultural Engineering and Technology, Orissa
13.	Dr. S Roy, PS & Head	National Symposium on "Microbial Diversity and its Impact"	February 18-19, 2016 at Kolkata
14.	Dr. Prince Kumar, Scientist	Indian Ecological Society Conference 2016 – Natural Resource Management and Ecological Perspectives	February 18-20, 2016 at SKUAST, Jammu

15.	Drs. RP Pant, PS, Mehi Lal, Scientist	IPS 06th International Conference on "Plant, Pathogens and Peoples"	February 23-27, 2016 at NASC Complex, New Delhi
16.	Drs. Anuj Bhatnagar, PS, Dhruv Kumar, PS, Prince Kumar, Scientist	National Seminar on "Agriculture Resourse Management for Sustainability and Eco-Restoration"	March 11-13, 2016 at Bikaner
17.	Dr. RK Singh, Sr. Scientist	National conference on "Rural Livelihood Security through Innovative Agri-entrepreneurship (RLSIAe)"	March 12-13, 2016 at BAMETI, Bihar
18.	Dr. SK Luthra, PS	National Symposium on Genomics & Molecular Breeding	March 28-29, 2016 at CCS University, Meerut
19.	Dr. Devendra Kumar	UGC sponsored National Seminar on "The Role of Biology in Bringing Second Green Revolution"	11th October, 2015 at MS (PG) College Saharanpur, UP
20.	Dr. Raj Kumar	Potato stakeholders meeting	16th January 2016 at ICAR-CPRS Jalandhar
21.	Dr. SK Luthra	National Symposium on Genomics and Molecular Breeding organized by Dept. of Genetics & Plant Breeding, CCSU, Meerut	28-29th March 2016 at CCS University, Meerut
22.	Dr. M. Nagesh	33rd All India coordinated research project on vegetable crops	21-24 May 2015.

Awards, Honours and Recognition

- **CPRI best worker award for year 2015**

S.No.	Name of the the Person	Category	Award	Year
1.	Dr. Shashi Rawat Drs. SP Singh & SK Luthra (Jointly)	Scientific	CPRI Best Worker Award	2015
2.	Smt. Shelly Chopra, Tarvinder Kochhar (Jointly) and Sh. Rajdeep Bux & Onkar Singh (Jointly)	Technical	CPRI Best Worker Award	2015
3.	Sh. Dhani Ram & Roshan Lal Verma (Jointly) and Sh. Deep Ram & Smt. Poonam Sood (Jointly)	Administrative	CPRI Best Worker Award	2015
4.	Sh. Maharaj Singh Sh. Narender Sood & Charan Dass (Jointly)	Supporting	CPRI Best Worker Award	2015

- **Other Awards & Honours**

1.	Drs. SK Luthra, RK Rana, Manoj Kumar and Devenda Kumar were elected Fellow of the Indian Potato Association, CPRI, Shimla (2014).	3.	Dr. SK Luthra acted as member of Advisory Committee in National Symposium on Genomics & Molecular Breeding organized by Dept. of Genetics & Plant Breeding, CCSU, Meerut, 28-29 March, 2016.
2.	Dr. Jagesh Kr Tiwari got Australian Endeavour Research Fellowship Award-2015" by the Govt. of Australia	4.	Dr. Devendra Kumar served as Associate Editor in Editorial Manager (Springer) for the Indian Journal of Plant Physiology (An International Journal of Plant Physiology), IARI New Delhi.

Promotions / Retirements / Transfers / Deaths

Scientific Staff

Joining

1. Sh. Bapi Das, Scientist (Veg. Science) on 10-04-2015(FN).
2. Sh. Pardeep Kumar, Scientist (Gen. & Pl. Breeding) on 10-04-2015(FN).
3. Smt. Divya K Lekshmanan, Scientist (Veg. Science) on 10-04-2015(FN).
4. Dr. (Mrs.) Babita Chaudhary, Sr. Scientist (Plant Breeding), CRIJAF Barrackpore, Kolkota Station at Pratapgarh (UP) joined at CPRIC, Modipuram on 08-05-2015(FN).
5. Dr. Sarla Yadav, Scientist (Plant Breeding), IARI, New Delhi joined at CPRS, Patna on 01-06-2015(FN).
6. Dr. Birpal Singh, Ex-Director, CPRI, Shimla re-employed to the post of Director, CPRI, Shimla from 01-07-2015(FN).
7. Smt. Sugani Devi, Scientist(Veg. Sci.) on 12.10.2015.
8. Smt. Suman Lata, Scientist (Ag. Biotechnology) on 12-10-2015.
9. Sh. Mohd. Abas Shah, Scientist (Ag. Entomology) on 09-10-2015.
10. Sh. Mhatre Priyank Hanuman, Scientist (Nematology) on 12-10-2015.
11. Sh. Brajesh Nare, Scientist (Farm Machninery and Power Engg.) on 12-10-2015.
12. Sh. Mharishi Tomar, Scientist (Plant Biochemistry) on 12-10-2015.
13. Sh. Amit Kumar Singh, Scientist (Agricultural Meterology) on 12-10-2015.
14. Dr. SK Chakrabarti, Director, CTCRI, Trivanthapuram joined to the post of Director, CPRI, Shimla on 27.01.2016 (AN).

Transfer

1. Dr. Malkhan Singh Gurjar, Scientist (Plant Pathology), CPRS, Shillong relieved to join IARI, New Delhi with effect from 30-04-2015 (AN).
2. Ms. Rinki, Scientist (Plant Physiology), CPRI, Shimla relieved to join at IIWBR, Karnal with effect from 25-04-2015 (AN).
3. Dr. Rajesh Kumar Rana, Principal Scientist (Agril. Economics) relieved to join at National Centre for Agricultural Economics and Policy Research, New Delhi from 04-06-2015 (AN).
4. Dr. SK Singh, Principal Scientist (Agronomy) relieved to join at IVRI, Varansi from 02.09.2015 (AN).
5. Dr. KK Pandey, Principal Scientist (Plant Pathology) relieved to join at IIVR, Varansi from 15.12.2015 (AN).
6. Dr.(Smt.) Alka Joshi, Scientist (Food Technology) relieved to join at IARI, New Delhi on 19-12-2015 (AN).
7. Dr. SK Kaushik, Principal Scientist relieved to join at NBPGR, New Delhi from 11.01.2016 (AN).
8. Dr. Prashant G Kawar, Sr. Scientist relieved to join at Directorate of Floricultural Research, Pune from 12.02.2016 (AN).
9. Sh. Amit Kumar Singh, Scientist (Agri. Meteorology) relieved to join at IGFRI, Jhansi from 05-03-2016 (AN).

10. Smt. Suman Lata, Scientist (Agril. Biotechnology), CPRIC, Modipuram relieved to join at IARI, New Delhi from 05.03.2016 (AN).

Promotions under CAS

1. Dr. Shambhu Kumar, Sr. Scientist, CPRS, Patna promoted as PS with effect from 27-07-2013.
2. Dr. Vinod Kumar, Sr. Scientist , CPRS, Kufri promoted as PS with effect from 26.12.2013.
3. Dr. (Mrs.) Pinky Raigond, Scientist from RGP of Rs.6,000 to Rs.7,000 w.e.f. 28-04-2014.
4. Dr. (Mrs.) Bandna, Scientist from RGP of Rs.6,000 to Rs.7,000 w.e.f. 11-05-2014.
5. Dr. Baswaraj Raigond, Scientist from RGP of Rs. 6,000 to Rs.7,000 w.e.f. 04-11-2013.
6. Dr. Sundersha S, Scientist from RGP of Rs. 6,000 to Rs.7,000 w.e.f. 01-09-2014.
7. Dr. Murlidhar J Sadawarti, Scientist from RGP of Rs. 6,000 to Rs. 7,000 w.e.f. 01-09-2014.
8. Dr. Dhiraj Kumar Singh, Scientist from RGP of Rs. 6,000 to Rs. 7,000 w.e.f. 20-04-2014.
9. Sh.VU Patil, Scientist from RGP of Rs. 6,000 to Rs. 7,000 w.e.f. 10-02-2014.
10. Dr. Sanjay Kumar Yadav, Scientist from RGP of Rs. 6,000 to Rs. 7,000 w.e.f. 20-04-2014.

Retirements

1. Er. Manjit Singh, Scientist (SG), CPRS, Jalandhar on 31.05.2015 (AN).
2. Dr. Birpal Singh, Director, CPRI, Shimla on 30-06-2015 (AN).

Technical Staff

Promotions

1. Sh. Chander Mohan Singh Bist , Sr. Tech. Officer, w.e.f. 24.12.2012 , CPRI, Shimla.
2. Sh. Permesh Dutt, Sr. Technician w.e.f. 31.12.2014, CPRI, Shimla.
3. Sh. Sunil Kumar Singh, Sr. Technician w.e.f. 14.4.2015, CPRS, Patna.
4. Sh. Ramhet Singh, Sr. Technician w.e.f. 1.1.2015, CPRS, Gwalior.
5. Sh. Ram Jiven, Tech. Asstt. w.e.f. 8.9.2014, CPRS, Kufri.
6. Sh. SDA Rizvi, Tech. Asstt. w.e.f. 23.1.2015, CPRS, Patna.
7. Smt. Jatinder Kaur Arora, Tech. Asstt. w.e.f. 10.8.2015, CPRI, Shimla.
8. Sh. Kulwinder Singh, Sr. Tech. Asstt. w.e.f. 4.3.2015, CPRS, Jalandhar.
9. Sh. Naresh Chand Sharma, Sr. Tech. Asstt., w.e.f. 28.2.2015, CPRI, Shimla.
10. Sh. Parveen Kumar, Sr. Tech. Asstt. w.e.f. 7.3.2015, CPRS, Jalandhar.
11. Sh. Rakesh Srivastava, Tech. Officer w.e.f. 12.7.2015, CPRS, Patna.
12. Sh. Sheesh Ram Thakur, Tech. Officer w.e.f. 5.5.2015, CPRI, Shimla.
13. Sh. Rajendra Kumar Samadhiya, Sr. Tech. Officer, w.e.f. 25.3.2015, CPRS, Gwalior.
14. Sh. Harvir Singh, Sr. Tech. Officer, w.e.f. 30.9.2014, CPRIC, Modipuram.
15. Dr. Sumita Sharma, Sr. Tech. Officer w.e.f. 28.5.2015, CPRI, Shimla.
16. Sh. DP Gautam, Tech. Officer, w.e.f. 21.2.2015, CPRI, Shimla.
17. Sh. Ravinder Kumar, Tech. Asstt. w.e.f. 30.6.2014, CPRI, Shimla.
18. Sh. Prithi Raj, Tech. Asstt. w.e.f. 22.6.2014, CPRI, Shimla.

19. Sh. Anil Kumar Chandel, Tech. Asstt. w.e.f. 27.9.2014, CPRS, Jalandhar.
20. Smt. Ruma Chakrabrati, Sr. Tech. Officer w.e.f. 21.6.2014, IARI, New Delhi.
21. Sh. Rajdeep Bux, Sr. Tech. Officer w.e.f. 14.10.2014, CPRI, Shimla.
22. Sh. BS Latwal, Ex-CTO w.e.f. 27.8.2014, CPRI, Shimla.
23. Smt. Shelly Chopra, ACTO w.e.f. 23.1.2015, CPRI, Shimla.
24. Sh. Kapil Kumar Sharma, ACTO w.e.f. 23.2.2015, CPRS, Jalandhar.
25. Sh. RK Verma, CTO, w.e.f. 2.12.2015, CPRIC, Modipuram.
26. Dr. SBS Parihar, Ex- ACTO w.e.f. 1.1.2010, CPRIC, Modipuram.
27. Dr. Kopil Dey, Ex-ACTO w.e.f. 1.1.2011, CPRS, Patna.
28. Smt. Tarvinder Kochhar, ACTO, w.e.f. 8.6.2015, CPRI, Shimla.
29. Sh. Dharminder Verma, ACTO, w.e.f. 15.6.2015, CPRI, Shimla.

Transfer

1. Sh. Rakesh Hada, Tech. Asstt., CPRS, Gwalior Transferred to CSWCR & TI, Dehradoon .

Probation

1. Sh. Sita Ram, Technician, CPRI, Shimla.
2. Sh. Laiq Ram, Technician, CPRI, Shimla.
3. Sh. Satpal Singh, Technician, CPRIC, Modipuram.
4. Sh. Pawan Kumar, Technician, CPRS, Jalandhar.
5. Sh. Tara Chand, Technician, CPRS, Gwalior.
6. Sh. Bijindra Singh, Technician, CPRS, Gwalior.
7. Sh. Pravesh Kumar, Technician, CPRS, Patna.
8. Sh. Surender Pal, Technician, CPRI, Shimla.

Retirements

1. Sh. Ashwani Kumar Sharma, ACTO, CPRS, Jalandhar retired on 30.4.2015.
2. Sh. Nirmal Singh Tech. Asstt. CPRS, Jalandhar retired on 30.5.2015.
3. Sh. B. Chandran, TO, CPRS, Muthorai retired on 30.5.2015.
4. Sh. BS Latwal, CTO, CPRI, Shimla retied on 30.6.2015.
5. Sh. Bhuneshwar Prasad, Tech. Asstt., CPRS, Patna retired on 31.7.2015.
6. Sh. KS Negi, T.O. CPRI, Shimla retired on 31.8.2015.
7. Sh. Kundan Singh, TO, CPRIC, Modipuram retired on 31.8.2015.
8. Dr. TK Sinha, CTO, CPRI, Shimla retired on 30.11.2015.
9. Sh. E. Syiemlieh, TO, CPRS, Shillong, retired on 31.12.2015.
10. Sh. RK Sharma, TO, CPRIC, Modipuram retired on 31.12.2015.
11. Sh. Agrenand Singh, Sr. Tech. Asstt., CPRS Patna retired on 31.12.2015.
12. Sh. Jagdish Chand, Technical Officer, CPRS, Jalandhar retired on 31.1.2016.
13. Sh. Parkash Chand, Sr. Tech. Asstt. CPRI, Shimla retired on 31.3.2016.

Administrative Staff

Promotions

1. Sh. Ram Chand, Personal Assistant promoted to the post of Private Secretary w.e.f. 01.04.2015.

2. Sh. Jagbir Singh, Assistant, CPRIC, Modipuram promoted to the post of Asstt. Admn. Officer, CPRS, Patna w.e.f. 07.04.2015.

3. Sh. Om Parkash, UDC, CPRI, Shimla promoted to the post of Assistant w.e.f. 13.04.2015.

4. Sh. Ashwani Gupta, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 29.04.2015.

5. Smt. Nirmala Chauhan, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 12.08.2015.

6. Sh. Rajesh Kumar, Personal Asstt. promoted to the post of Private Secretary w.e.f. 18.11.2015.

7. Sh. AD Sharma, AAO, CPRI, Shimla promoted to the post of AO at DMR, Solan.

8. Sh. Chanda Ram, Asstt., CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 13.01.2016.

9. Smt. Sandhya Kapila, UDC, CPRS, Jalandhar promoted to the post of Assistant w.e.f. 13.01.2016 (AN).

10. Smt. Shyam Lata Beakta, UDC, CPRI, Shimla promoted to the post of Assistant w.e.f. 13.01.2016.

11. Sh. Tej Singh, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 18.01.2016.

12. Smt. Geeta Devi, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 09.02.2016.

13. Smt. Shashi Bala Thakur, Personal Assistant, CPRI, Shimla promoted to the post of Private Secretary w.e.f. 09.02.2016.

14. Sh. KC Chopra, Assistant, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 26.02.201615.

15. Sh. Prem Chand Sharma, Assistant, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 08.04.2016.

Financial Up-gradation

Sl. No.	Name & Designation of the Officials	Granted financial up gradation under MACP Scheme
1.	Smt. Chandni Bhagta, UDC, CPRS, Kufri.	Granted 2nd MACP w.e.f. 06.10.2014 in the PB Rs. 5200-20200+2800 GP
2.	Sh. Atar Singh, LDC, CPRIC, Modipuram.	Granted 2nd MACP w.e.f. 04.3.2013 in the PB Rs.5200-20200+ GP 2000
3.	Sh. Rakesh, UDC, CPRS, Jalandhar.	Granted 2nd MACP w.e.f. 11.11.2015 in the PB Rs.5200-20200 +2800GP Rs. GP
4.	Sh. Mahendra Singh, Asstt., CPRIC, Modipuram.	Granted 3rd MACP w.e.f. 28.06.2014 in the PB Rs.9300-34800+ GP 4600
5.	Sh. Rakesh, UDC, CPRS, Jalandhar.	Granted 2nd MACP w.e.f. 11.11.2015 in the PB Rs.5200-20200 +2800GP Rs. GP

Transfer within Institute

1. Sh. Surender Singh, Assistant transfer from CPRIC, Modipuram and he joined at CPRS, Patna w.e.f. 14.9.2015.
2. Sh. Krishan Lal, Assistant transfer from CPRS, Patna and he joined at CPRI, Shimla w.e.f. 18.12.2015.
3. Sh. Baldev Raj, Asstt. Admn. Officer from CPRIC, Modipuram and he joined at CPRI, Shimla w.e.f. 31.03.2015.
4. Sh. Sandeep Verma, UDC from CPRIC, Modipuram and he joined at CPRI, Shimla w.e.f. 08.05.2015.

Retirement

1. Sh. Laiq Ram Verma, Assistant,CPRI, Shimla retired on 31.07.2015.
2. Sh. Roshan Lal Verma, Private Secretary, CPRI, Shimla retired on 30.09.2015.
3. Sh. Mahendra Singh, Assistant, CPRIC, Modipuram retired on 30.09.2015.
4. Sh. Baldev Raj, AAO, CPRI, Shimla retired on 30.11.2015.
5. Sh. Naresh Kumar, Assistant, CPRS, Jalandhar retired on 31.12.2015.
6. Sh. Roshan Lal, AAO, CPRI, Shimla retired on 31.01.20167.
7. Sh. HK Sen, Private Secretary, CPRS, Patna retired on 31.01.2016.

Skilled Support Staff

Regularization of Casual workers (with Temporary Status) on a temporary post of to Skilled support staff, in group 'C':

1. Sh. Lala Ram, S/o Sh. Mansa Ram, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
2. Smt. M. Anagamma W/o Late Sh. Muthuvearan, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Muthorai (TN).
3. Sh. Munna Singh S/o Sh. Udhya Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
4. Sh. Kali Charan S/o Sh. Shri Lal, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
5. Sh. Tilak Singh S/o Sh. Kanhai, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
6. Smt. Sodha Devi W/o Sh. Nirma, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
7. Sh. Net Ram S/o Sh. Ghammandi, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
8. Sh. Mangal S/o Sh. Maharaj Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
9. Sh. Jandel Singh S/o Sh. Sugar Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
10. Sh. Bhagirath S/o Sh. Babu Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
11. Sh. Rajinder Singh S/o Sh. Kahan Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRI,Shimla (H.P.).
12. Sh. Ramdin S/o Sh. Kalyan Singh, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).
13. Sh. Sikander Singh S/o Sh. Baijnath, Skilled Support Staff (Group 'C') in PB Rs. 5200-20200 +1800/-GP CPRS, Gwalior (M.P.).

Probations & Confirmation

1. Sh. Rajvir Singh, SSS, CPRIC, Modipuram.
2. Sh. Raj Kumar, SSS, CPRIC, Modipuram.
3. Sh. Sudesh Pal Singh, SSS, CPRIC, Modipuram.
4. Sh. Tej Bir Singh, SSS, CPRIC, Shimla.
5. Sh. Gyanendra Kumar, SSS, CPRIC, Modipuram.
6. Sh. Rishipal, SSS, CPRIC, Modipuram.

Grant of IInd MACP

1. Smt. Rashpal Devi, Skilled Support Staff, CPRS, Jalandhar granted IInd MACP w.e.f. 15.2.2014.
2. Sh. Jagtey, Skilled Support Staff, CPRIC, Modipuram granted IInd MACP w.e.f. 06.10.2014.
3. Sh. Sanjeevan Kumar, Skilled Support Staff, CPRI, Shimla granted IInd MACP w.e.f. 26.10.2014.
4. Sh. Ram Lubhaya, Skilled Support Staff, CPRS, Jalandhar granted IInd MACP w.e.f. 02.6.2015.
5. Sh. Jagat Kumar, Skilled Support Staff, CPRS, Patna granted IInd MACP w.e.f. 13.6.2015.

Retirement

1. Sh. Narender Kumar, Cook, ICAR-CPRI, Shimla (31.7.2015).
2. Sh. Ashok Kumar Dev, Skilled Support Staff, ICAR-CPRS, Shillong (29.2.2016).
3. Sh. Shiv Nath Singh, Skilled Support Staff, ICAR-CPRS, Patna (29.2.2016).

Station –wise Staff Sanctioned

List of Scientific staff at ICAR-CPRI, Shimla & its Regional Stations as on 31.03.2016

Director: Dr. SK Chakrabarti

AICPIP Unit

1. Dr. PM Govindakrishnan, Project Coordinator
2. Dr. Raja Shankar, Sr. Scientist

Division of Crop Improvement

3. Dr. Vinay Bhardwaj, Sr. Scientist & Act. Head
4. Dr. Rajendra Singh, Sr. Scientist
5. Dr. Jagesh Kumar, Scientist
6. Sh. Virupakshagauda U Patil, Scientist
7. Dr.(Ms) Dalamu, Scientist
8. Dr.(Mrs.) G Vanishree, Scientist
9. Sh. Hemant Babasaheb Kardile, Scientist

Division of Seed Technology

10. Dr. (Mrs.)TanujaBuckseth, Scientist

Division of Crop Production

11. Dr. VK Dua, Principal Scientist & Head
12. Dr. Jagdev Sharma, Principal Scientist
13. Dr. (Ms.) Chaukhande Pooja Baldeo, Scientist

Division of Social Sciences

14. Dr. NK Pandey, PS & Head
15. Dr. Dhiraj Kumar Singh, Scientist

Division of Plant Protection

16. Dr. M. Nagesh, PS & Head
17. Dr. Sanjeev Sharma, Sr. Scientist
18. Dr. Vinay Sagar, Sr. Scientist
19. Dr. (Ms) Jeevalatha A, Scientist
20. Dr. Baswaraj R., Scientist
21. Dr. Sundersha S, Scientist
22. Dr. Ravinder Kumar, Scientist
23. Dr. Vallepu Venkateswarlu, Scientist
24. Dr. Shridhar Jandrajupalli, Scientist
25. Dr. (Ms.) Aarti Bairwa, Scientist

Division of Crop Phy., Biochem. & PHT

26. Dr. Brajesh Singh, P S & Head
27. Dr. Som Dutt, Sr. Scientist
28. Dr. (Mrs.) Pinky Raigond, Scientist
29. Sh. Maharishi Tomar, Scientist

AKMU Cell

30. Dr. Shashi Rawat, Sr. Scientist

CPRI Campus, Modipuram

31. Dr. Devendra Kumar, PS
32. Dr. (Mrs.) Kamlesh Malik, PS
33. Dr. SK Luthra, Principal Scientist
34. Dr. Name Singh, Principal Scientist
35. Dr. Vinay Singh, Principal Scientist
36. Dr. Anuj Bhatnagar, Principal Scientist
37. Dr. MA Khan, Principal Scientist
38. Dr. Rajender Prasad Pant, Principal Scientist
39. Dr. Sanjay Rawal, Principal Scientist
40. Dr. Dhruv Kumar, Principal Scientist
41. Dr. Vijai Kishore Gupta, Sr. Scientist
42. Dr. Babita Chaudhary, Sr. Scientist
43. Dr. Mehi Lal, Scientist
44. Dr. (Ms) Bandna, Scientist

CPRS, Jalandhar

45. Dr. JS Minhas, Officiating Head
46. Dr. (Mrs.) Ashiv Mehta, P S
47. Dr. Raj Kumar, PS
48. Er. Sukhwinder Singh, Scientist SG

49. Er. Sunil Gulati, Scientist (SG)
50. Dr.(Ms) Ratna Preeti Kaur, Scientist
51. Dr. Prince Kumar, Scientist
52. Dr. Mohd. Abas Shah, Scientist
53. Mrs. Sugani Devi, Scientist
54. Sh. Brajesh Nare, Scientist

CPRS, Gwalior

55. Dr. S Roy, Head
56. Dr. Shiv Pratap Singh, Principal Scientist
57. Dr. Murlidhar J. Sadawarti, Scientist

CPRS, Shillong

58. Dr. TK Bag, Head
59. Ms. Clarissa Challam, Scientist
60. Sh. Pardeep Kumar, Scientist
61. Sh. Bappi Dass, Scientist

CPRS, Muthorai

62. Dr. EP Venkatsalam, Sr. Scientist & Incharge
63. Dr. (Ms.) R. Sudha, Scientist
64. Dr. (Mrs.) Divya K Lekshmanan, Scientist
65. Sh. Mhatre Priyank Hanuman, Scientist

CPRS, Kufri

66. Dr. Vinod Kumar, PS & Incharge
67. Dr. Ashwani Kumar Sharma, Sr. Scientist

CPRS, Patna

68. Dr. Manoj Kumar, Head, CPRS, Patna
69. Dr. Shambhu Kumar, Principal Scientist
70. Dr. Raj Kumar, Sr. Scientist
71. Sh. Rahul R Bakade, Scientist
72. Sh. Pynbianglang Kharumunid, Scientist
73. Dr. Sarla Yadav, Scientist
74. Dr. Sanjay Kumar Yadav, Scientist

List of Technical Staff, ICAR-CPRI, Shimla & Regional Stations as on 31.3.2016.

1. Dr. Rakesh Mani Sharma, ACTO
2. Sh. Kameshwar Sen, Sr. TO.
3. Sh. AK Atrey, Sr. TO
4. Dr. Sushil Kumar, ACTO
5. Smt. Shelly Chopra, ACTO
6. Sh. Parvesh Jassal, Sr. TO
7. Sh. Yogesh, Sr. TO
8. Smt. Tarvinder Kochhar, ACTO
9. Sh. Dharminder Verma, ACTO
10. Sh. Kana Singh Chauhan, TO
11. Sh. Harwinder Singh, TO
12. Sh. Tilak Raj, TO
13. Sh. Prithi Raj, Tech. Asstt.
14. Sh. CMS Bist Sr. TO
15. Sh. Laiq Ram, Technician
16. Mrs. Shruti Gupta, TO
17. Dr. Sumita Sharma, Sr. TO
18. Sh. Sita Ram, Technician
19. Sh. Rajdeep Bux, Sr. TO
20. Sh. Surender Pal, Technician
21. Sh. Rakesh Kumar Patyal, Tech. Asstt.
22. Sh. Yash Pal Sharma, Sr. T. Asstt
23. Sh. Rajinder Kumar, Tech. Asstt.
24. Sh. Sheesh Ram Thakur, TO
25. Sh. Vinod Kumar, TO
26. Sh. Naresh Kumar Sharma, Sr. T. Asstt.
27. Mrs. Manjit Syal, Tech Asstt.
28. Sh. Hari Kishore, Tech. Asstt.
29. Sh. Dharm Prakash Gautam, TO
30. Mrs. Asha Thakur, Tech. Asstt.

31. Sh. Ranjesh Bhardwaj, Tech. Asstt
32. Sh. Rakesh Kumar, Tech. Asstt.
33. Sh. Naresh Chand Sharma, Sr. T. Asstt.
34. Sh. Deep Ram, Tech. Asstt.
35. Mrs. Jatinder Kaur Arora, Tech. Asstt.
36. Sh. Ram Singh, Tech. Asstt.
37. Mrs. Madhu Bala, Tech. Asstt.
38. Sh. Dharminder Kr. Gupta, Tech. Asstt.
39. Sh. Jagdish Chand (Welder), Sr. Technician
40. Sh. Naresh Kumar, Tech. Asstt.
41. Sh. Parmesh Dutt, Sr. Technician
42. Sh. Ravinder Kumar, Tech. Asstt.
43. Sh. Onkar Singh Rana, Tech. Asstt.
44. Sh. Sushil Singh, Sr. T. Asstt.
45. Sh. Jagdish Chand Carpenter, Sr. Technician
46. Sh. Ashok Kumar, Tech. Asstt.
47. Sh. Roop Lal, Tech. Asstt.
48. Sh. Vijay Kumar, Tech. Asstt.
49. Sh. Ram Dayal, Sr. Technician
50. Sh. Anil Kumar Dubey, Sr. Technician
51. Sh. Neem Chand, Sr. Technician
52. Sh. Dev Raj, Sr. Technician
53. Sh. Mansha Ram, Technician
54. Sh. Arjun Dass, Technician
55. Sh. Vinod Gir, Technician

CPRS Kufri

56. Sh. Kedar Singh, Tech. Asstt.
57. Sh. Ajit Singh, Tech. Asstt.
58. Sh. Mohan Lal, Sr. Technician
59. Sh. Ram Jivan, Tech. Asstt.

CPRIC, Modipuram

60. Sh. Islam Ahmed, CTO
61. Sh. Ram Kumar Verma, CTO
62. Sh. Balak Ram Singh, ACTO
63. Sh. Mahesh Kumar, ACTO
64. Sh. Mahipal Singh Bharti, ACTO
65. Sh. Ramesh Chand ACTO
66. Sh. Harvir Singh, ACTO
67. Dr. Ashok Kumar, ACTO
68. Sh. Krishan Pal Singh, ACTO
69. Sh. Satandar Kumar, Sr. TO
70. Sh. Naresh Kumar Sood, TO
71. Sh. Om pal, Sr. TO
72. Mrs. Kusum Singh, Sr. TO
73. Sh. Harvir Singh, Sr. TO
74. Sh. Santosh Kumar, Sr. TO
75. Sh. Omvir Singh, TO
76. Sh. Murari Lal, Sr. TO
77. Sh. Vijay K. Yadav, TO
78. Sh. Subhash Chand, Sr. TO
79. Dr. Vineet Sharma. Sr. TO
80. Sh. Avinash Chaudhary, Sr. TO
81. Sh. Jasvir Singh, Sr. TO
82. Sh. Dinesh Singh Sr. TO
83. Sh. Ved Singh, TO
84. Sh. Pushpender, Sr. TO
85. Sh. Krishan Pal Singh, Tech. Asstt.
86. Sh. Vipin Kumar, Sr. Technician
87. Sh. Satpal Singh, Technician
88. Sh. Rambir Singh, Sr. Technician
89. Sh. Mahesh Pal, Sr. Techn (T-I-3)
90. Sh. Narayan Singh, Sr. Techn (T-I-3)
91. Sh. Kehar Singh, Sr. T. Asstt.
92. Sh. Pawan Kumar Malik, Tech. Asstt.
93. Sh. Madan Pal, Technician
94. Sh. Kamal Singh, Sr. Technician

95. Sh. Udaivir Singh, TO
96. Dr. Sanat Kumar, Sr. TO
97. Sh. UP Paudel, Tech. Asstt.

CPRS, Jalandhar

98. Sh. Jaswinder Singh, Sr. TO
99. Sh. Yogesh Kumar Gupta, Sr. TO
100. Sh. Kapil Kr. Sharma, ACTO
101. Sh. Pawan Kumar, Technician
102. Sh. Akhilesh Kumar Singh, Sr.TO
103. Sh. Gurdev Singh, TO
104. Sh. Anil Kumar Chandel, Tech. Asstt.
105. Sh. Som Dutt, Sr. T. Asstt.
106. Sh. Praveen Kumar , Sr. T. Asstt.
107. Sh. Narinder Mayer, Sr. T. Asstt.
108. Sh. Pradeep Kumar Upadhaya, Tech. Asstt.
109. Sh. Bhag Singh, Tech. Asstt.
110. Sh. Kulwinder Singh, Sr. T. Asstt.
111. Sh. Vijay Kumar Rai, Sr. Technician
112. Sh. Munna Lal, ACTO

CPRS Patna

113. Sh. Arun Kumar Singh, ACTO
114. Sh. Arjun Kumar Sharma, Sr. TO
115. Sh. Rakesh Srivastava, TO
116. Sh. Anil Kumar, Sr. T. Asstt
117. Sh. Alekh Narain, Sr. T. Asstt.
118. Sh. SDA Rizvi, Tech. Asstt.
119. Sh. Narendra Kumar, Sr. Technician
120. Sh. Lal Babu Dass, Sr. Technician
121. Sh. Sunil Kumar Singh, Sr. Technician
122. Sh. Pravesh Kumar, Technician

CPRS Gwalior

123. Sh. Surendar Singh , Sr. T. Asstt.
124. Sh. Chet Ram Technician
125. Sh. Rajinder Kumar Samadhiya, Sr. T. Asstt.
126. Dr. Yogendra Pal Singh, Sr. TO
127. Sh. Sanjay Kr. Sharma, Sr. TO
128. Sh. Shyam Kumar Gupta, TO
129. Sh. Radha Kishan, Tech. Asstt.
130. Sh. Nihal Singh, Tech. Asstt.
131. Sh. Parkash Ram, Technician
132. Sh. Bijendra Singh, Technician
133. Sh. Tara Chand, Technician

CPRS Shillong

134. Sh. Bosterwell Langstieh, Sr. T. Asstt.
135. Sh. Hesting Jyrwa, Sr. T. Asstt.
136. Sh. PR Khongbuh, Tech. Asstt.
137. Sh. Ram Dass Rai, Tech. Asstt. (T-I-3)
138. Sh. S. Nongrum, Sr. Technician

CPRS Muthorai

139. Sh. V Rajendran, TO
140. Sh. R Lakshmanan, Tech. Asstt.
141. Sh. B Suresh, Technician

List of Administrative staff at ICAR-CPRI, Shimla & its Regional Stations as on 31.03.2016

1. Sh. K.P. Sharma, AO

Establishment Section

2. Sh. Joginder Singh Thakur , AAO
3. Smt. Shashi Bala Thakur, PS to CAO
4. Smt. Poonam Sood, Asstt.
5. Smt. Meena Verma, Asstt.
6. Smt. Sunita Thakur, Asstt.
7. Sh. Om Parkash, Asstt.
8. Sh. Padam Chand, LDC

Bill & Cash Section

9. Sh. Hira Nand Sharma, AAO/DDO
10. Sh. Amar Chand, Asstt.
11. Ms. Reeta Walia, Asstt.

12. Sh. Ashwani Gupta, UDC Cum Cashier
13. Sh. Tej Singh, UDC
14. Sh. Raghubir Singh, LDC

Audit Section

15. Sh. Tej Singh Bhati, FAO
16. Sh. Chander Prakash, AF&AO
17. Dr. Ashish Dhangar, AF&AO
18. Smt. Babli Bhawani, Asstt.
19. Sh. PC Sharma, Asstt.
20. Sh. Jai Ram Thakur, Asstt.
21. Sh. Jagdish Chand, Asstt.
22. Miss Prawartika Das, Asstt.
23. Smt. Shyam Lata Beakta, Asstt.
24. Sh. Sandeep Verma, UDC
25. Smt. Geeta Devi, UDC
26. Smt. Sonia Chauhan, LDC

Estt. II Section

27. Sh. Amar Dev Sharma, AO
28. Sh. KC Chopra, AAO
29. Smt. Urmila Verma, Asstt.
30. Sh. Narender Paul, LDC
31. Smt. Punam Jyoti, LDC

Store Section

32. Sh. Dhani Ram, AAO
33. Sh. Chanda Ram, AAO
34. Sh. Jagdish Chand, Asstt.
35. Sh. Krishan Lal, Asstt.
36. Sh. Hans Raj, UDC
37. Sh. Kundan, LDC
38. Sh. Mohinder Singh, LDC
39. Sh. Gokal Ram, LDC

PME Cell

40. Sh. Deep Ram, UDC
41. Sh. Sachin Kanwar, UDC
42. Sh. Rakesh Negi, LDC

Vigilance Section

43. Sh. Pawan Kumar, UDC

AICPIP Unit

44. Smt. Nirmala Chauhan, UDC

Engineering Section

45. Smt. Kanta Rani, Asstt.

Crop Production

46. Sh. Girish Thakur, Steno. Gr. III

Plant Protection Divn.

47. Sh. Gurjeet Singh, Pvt. Secy.

Director Cell

48. Sh. Ram Chand, Pvt. Secy.

Hindi Section

49. Sh. Suresh Kumar, PA

CPRS, Kufri

Smt. Chandni Bhagta, UDC

CPRIC, Modipuram

Sh. Miraj-Ul-Haq, AAO
Sh. Sandeep, Asstt.
Sh. Santosh Kumar, UDC
Smt. Sneh Lata, LDC
Smt. Seema Verma, LDC
Sh. Atar Singh, LDC
Sh. Ashok Kumar, LDC
Sh. Rajesh Kumar, PS

CPRS, Jalandhar

Sh. Jeevan Kumar, AAO
Sh. Suresh Kumar Verma, PA
Sh. Sukhpal Sharma, Asstt.
Smt. Sandhya Kapila, Asstt.
Sh. Rakesh, UDC
Smt. Bimla Salhotra, UDC
Smt. Daishey Tuli, LDC
Sh. Naresh Kumar, LDC
Sh. Daljeet Singh, LDC

CPRS, Gwalior

Sh. Krishan Lal, AAO

Sh. Pradhuman Kumar Sarswat, UDC

Sh. Kamal Chand Verma, UDC

Sh. Ashish Kalyan, LDC

Sh. Shri Krishan, LDC

CPRS, Muthorai

Smt. IC Dharmapaul, Asstt.

Smt. M. Rani, Asstt.

CPRS, Patna

Sh. Jagbir Singh, AAO

Sh. Surender Singh, Asstt.

Sh. Ramesh Kumar Gupta, UDC

Sh. Akhilesh Singh, LDC

List of Skilled Support Staff, ICAR-CPRI Shimla and its Regional Stations as on 31.03.2016

CPRI, Shimla.

1. Sh. Narain Dass, SSS (SS Gr. IV)
2. Sh. Maharaj Singh, SSS (SS Gr. III)
3. Sh. Khem Chand, SSS (SS Gr. III)
4. Sh. Charan Dass , SSS (SS Gr. III)
5. Sh. Roshan Lal, SSS(SS Gr. III)
6. Sh. Kanhiya Prasad ,SSS(SS Gr. III)
7. Sh. Bir Bhadur, SSS(SS Gr. III)
8. Sh. Piar Chand, SSS (SS Gr. III)
9. Sh. Subhash Chand, SSS (SS Gr. III)
10. Sh. Mansa Ram, SSS (SS Gr. III)
11. Sh. Babu Ram, SSS (SS Gr. III)
12. Sh. Ramesh Kumar, SSS (SS Gr. III)
13. Sh. Rajinder Kumar, SSS (SS Gr. II)
14. Sh. Kulwant Singh, SSS (SS Gr. II)
15. Sh. Sanjeevan Kumar, SSS (SS Gr. II)
16. Smt. Kamla Devi, SSS (SS Gr. II)
17. Sh. Ashok Kumar, SSS(SS Gr. I)
18. Sh. Narender Kumar , SSS(SS Gr. I)
19. Smt. Kajal, SSS (SS Gr. I)
20. Sh. Padam Dev, SSS(SS Gr. I)
21. Sh. Roshan Lal, SSS(SS Gr. I)
22. Smt. Manjit , SSS(SS Gr. I)
23. Sh. Amar Nath, SSS(SS Gr. I)
24. Sh. Hira Singh, SSS(SS Gr. I)
25. Sh. Rajinder Singh, SSS

CPRI Cantten Staff

1. Sh. Nand Lal, Wash Boy

CPRS Kufri

1. Sh. Hira Singh , SSS(SS Gr. III)
2. Sh. Saran, SSS (SS Gr. III)
3. Smt. Muni Devi, SSS (SS Gr. II)
4. Smt. Indira Devi, SSS (SS Gr. II)
5. Sh. Madan Lal, SSS (SS Gr. I)
6. Sh. Sita Ram, SSS (SS Gr. I)
7. Sh. Roop Singh, SSS (SS Gr. I)
8. Sh. Jia Lal, SSS (SS Gr. I)
9. Smt. Sodha Devi, SSS

CPRIC Modipuram

1. Sh. Suraj Singh , SSS (SS Gr. III)
2. Sh. Mangtey , SSS (SS Gr. III)
3. Sh. Satya Pal Singh, SSS (SS Gr. II)
4. Sh. Amiruddin, SSS (SS Gr. II)
5. Sh. Jagtey, SSS (SS Gr. II)
6. Sh. Som Pal, SSS (SS Gr. II)
7. Sh. Krishan Pal, SSS (SS Gr. I)
8. Sh. Mani Ram, SSS (SS Gr. I)
9. Sh. Rajpal, SSS (SS Gr. I)
10. Sh. Rajvir Singh, SSS (SS Gr. I)
11. Sh.Raj Kumar, SSS (SS Gr. I)
12. Sh. Sudesh Pal, SSS(SS Gr. I)
13. Sh. TejBir Singh, SSS (SS Gr. I)
14. Sh. Gyanendra Kumar, SSS (SS Gr. I)
15. Sh. Sohan Pal, SSS (SS Gr. I)

16. Sh. Ramphal, SSS (SS Gr. I)
17. Sh. Mukesh, SSS (SS Gr. I)
18. Sh. Murari, SSS (SS Gr. I)
19. Sh. Rajpal Singh, SSS (SS Gr. I)

CPRS Jalandhar

1. Sh. Komal, SSS (SS Gr. III)
2. Ms. Niranjan Kaur, SSS (SS Gr. II)
3. Sh. Gian Singh, SSS (SS Gr. II)
4. Sh. Karnail Singh, SSS (SS Gr. II)
5. Sh. Satnam Singh, SSS (SS Gr. II)
6. Mrs. Passo, SSS (SS Gr. II)
7. Smt. Rashpal Devi, SSS (SS Gr. II)
8. Sh. Ram Lubhaya, SSS (SS Gr. II)
9. Sh. Ram Prakash, SSS (SS Gr. II)
10. Sh. Sukhwinder, SSS (SS Gr. II)
11. Sh. Subhash, SSS (SS Gr. II)
12. Sh. Hans Raj, SSS (SS Gr. II)
13. Sh. Jagai Ram, SSS (SS Gr. II)
14. Sh. Paramjit Singh, SSS (SS Gr. II)
15. Sh. Manjinder Singh, SSS (SS Gr. I)
16. Sh. Ram Sarup, SSS (SS Gr. I)
17. Sh. Joginder Pal, SSS (SS Gr. I)
18. Sh. Ram Nath, SSS (SS Gr. I)
19. Sh. Jagan Nath, SSS (SS Gr. I)
20. Sh. Niril, SSS (SS Gr. I)

CPRS Patna

1. Smt. Tara Devi, SSS (SS Gr. III)
2. Sh. Tapan Burman, SSS (SS Gr. III)
3. Sh. Ram Kisun Ram, SSS (SS Gr. II)
4. Sh. Teka Rai, SSS (SS Gr. II)
5. Sh. Jagat Kumar, SSS (SS Gr. II)
6. Sh. Ram Balak Rai, SSS (SS Gr. II)
7. Sh. Bishun Rai, SSS (SS Gr. I)

CPRS, Gwalior

1. Sh. Ram Babu, SSS (SS Gr. II)
2. Sh. Mohan Lal, SSS (SS Gr. II)
3. Sh. Ramji Lal, SSS (SS Gr. II)
4. Sh. Shiv Singh, SSS (SS Gr. II)
5. Sh. Niranjan Singh, SSS (SS Gr. II)
6. Sh. Kailash, SSS
7. Sh. Ram Singh, SSS
8. Sh. Jagdish, SSS (SS Gr. II)
9. Sh. Ram Rattan, SSS (SS Gr. II)
10. Sh. Shyam Singh, SSS (SS Gr. II)
11. Sh. Parkash Tomar, SSS (SS Gr. II)
12. Sh. Virendra Singh, SSS (SS Gr. II)
13. Sh. Ranbir Singh, SSS (SS Gr. II)
14. Sh. Kallu, SSS (SS Gr. II)
15. Sh. Ashok Kumar, SSS (SS Gr. II)
16. Smt. Vimla Devi, SSS (SS Gr. I)
17. Sh. Jaswant Singh, SSS (SS Gr. I)
18. Sh. Kedar, SSS (SS Gr. I)
19. Sh. Sonpal, SSS(SS Gr. I)
20. Sh. Parasu Ram, SSS (SS Gr. I)
21. Sh. Punjab Singh, SSS (SS Gr. I)
22. Sh. Ram Parkash, SSS (SS Gr. I)
23. Sh. Bharat Singh, SSS (SS Gr. I)
24. Sh. Munnu Singh, SSS (SS Gr. I)
25. Sh. Lala Ram, SSS
26. Sh. Munna Singh, SSS
27. Sh. Kali Charan, SSS
28. Sh. Tilak Singh, SSS
29. Sh. Net Ram, SSS
30. Sh. Mangal, SSS
31. Sh. Jandel Singh, SSS
32. Sh. Bhagirath, SSS
33. Sh. Ramdin, SSS
34. Sh. Sikander Singh, SSS

CPRS Shillong

1. Sh. Bat Bok Kharir , SSS(SS Gr. IV)
2. Sh. Ram Ekbal Rai , SSS (SS Gr. III)
3. Smt. Theibet Thawmuit, SSS (SS Gr. III)

4. Mrs. Tellinora, SSS (SS Gr. III)

5. Km. Thapa , SSS (SS Gr. III)

CPRS Muthorai

1. Smt. Rajamma, SSS (SS Gr. I)

2. Sh. K. Ramasamy, SSS (SS Gr. I)

3. Sh. J. Bhojan, SSS (SS Gr. I)

4. Smt. S. Pankajam, SSS (SS Gr. I)

5. Smt. M. Anagamma, SSS

Discipline-wise Sanction/Filled /Vacant position of the Scientists as on 31.03.2016

SI. No	Discipline	Scientist (including Sr. Sci.&PS promoted Through CAS)			Senior Scientist (DR)			Principal Scientist (DR)			TOTAL		
		S	F	V	S	F	V	S	F	V	S	F	V
1.	AGRICULTURAL BIOTECHNOLOGY	4	3	1	-	-	-	-	-	-	4	3	1
2.	AGRONOMY	4	5	(-)1	-	-	-	1	2	(-)1	5	7	(-)2
3.	AG. ENTOMOLOGY	6	4	2	1	1	-	-	-	-	7	5	2
4.	AG. ECONOMICS	3	-	3	-	-	-	-	1	(-)1	3	1	2
5.	AG METROLOGY	1	-	1	-	-	-	-	-	-	1	-	1
6.	AGRICULTURAL MICROBIOLOGY	3	-	3	-	-	-	-	-	-	3	-	3
7.	AG. STATASTICS	1	-	1	-	-	-	-	-	-	1	-	1
8.	COM. APPLN.	1	1	-	-	-	-	-	-	-	1	1	-
9.	AG. EXTENSION	3	2	1	-	-	-	1	-	1	4	2	2
10.	AGRI. PROCESS ENGINEERING	1	-	1	-	-	-	-	-	-	1	-	1
11.	AG. ENGG.(FM&P)	3	3	-	-	-	-	-	-	-	3	3	-
12	AG. ENGG (ASPEE)	-	-	-	-	-	-	-	-	-	-	-	
13	AG. CHEMISTRY	-	1	(-)1	-	-	-	-	-	-	-	1	(-)1
14	PL.BIOCHEMISTRY	2	2	-	1	1	-	-	-	-	3	3	-
15	FOOD TECHNOLOGY	2	-	2	-	-	-	-	-	-	2	-	2
16	GEN. & CYTOGEN	-	2	(-)2	-	-	-	-	-	-	-	2	(-)2
17	VEG. SCIENCE	14	12	2	2	1	1	4	-	4	20	13	7
18	NEMATOLOGY	2	2	-	-	-	-	1	1	-	3	3	-
19	GENETICS AND PLANT BREEDING	9	5	4	4	3	1	1	-	1	14	08	6
20	PL. PATHOLOGY	10	6	4	2	3	(-)1	1	2	(-)1	13	11	2
21	PL. PHYSIOLOGY	4	4	-	1	-	1	-	1	(-)1	5	5	-
22	SOIL SCIENCE SOIL CHEM./ FERT. MICRO	5	1	4	-	-	-	-	1	(-)1	5	2	3
23	SOIL PHY. & SOIL WATER CONSERV.	-	-	-	-	-	-	-	-	-	-	-	-
24	S EED SCIENCE AND TECHNOLOGY	5	3	2	-	1	(-)1	1	-	1	6	4	2
25	FLEXI DISCIPLINES	-	-	-	2	-	2	-	-	-	2	-	2
26	JOINT DIRECTOR	-	-	-	-	-	-	1	-	1	1	-	1
	TOTAL	83	56	27	13	10	3	11	08	3*	107	74	33

S-Cadre Strength F-In position V-Vacancy *Reserved for Heads of Divisions(The process is on)
After adjustment of the proposed six Sr. Scientists to be filled at entry level(vide letter NO. 10-02/Estt.I/Vol.III/8536 dated 4.12.2015)

SCIENTIFIC STRENGTH
STATIONWISE SANCTION /FILLED /VACANT POSITION AS ON 31-03-2016

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 including AICPIP	5	5	-	10	5	5	29	20	9	44	30*	14
2.	Kufri	-	-	-	1	-	1	2	2	-	3	2	1
3.	Jalandhar	1	-	1	2	-	2	10	10	-	13	10	3
	Modipuram	1	-	1	4	4	-	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	5	4	11	7	4
7.	Ooty	1	-	1	-	-	-	3	4	(-)1	4	4	-
8.	Shillong	1	1	-	-	-	-	5	3	2	6	4	2
	Total	11	08	3	19	10	9**	77	56	21	107	74	33

*Excluding RMP

** As per Council's instructions requision for 6 posts of Sr. Scientists to fill up at entry level has already been sent.

LIST OF ADMN. STAFF (SANCTION & FILLED AS ON (31.3.2016)

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**	***Vacant***
Chief Admn. Officer	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	**-**	**1**
*FAO **(in lieu of Sr. Fin. & A/Cs Officer)***	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	**01**	**-**
Admn. Officer	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	**02**	**-**
Asstt. Admn. Officer	5	6	1	1	2	1	1	1	-	-	-	-	1	1	-	-	10	**10**	**-**
Asst.Fin. & A/Cs Officer	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	**02**	**-**
Asstt. Director (OL)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	**-**	**1**
Private Secretary	3	3	-	-	1	1	-	-	-	-	-	-	-	-	-	-	04	**04**	**-**
Personal Assistant	7	1	1	1	-	-	1	-	-	-	-	-	1	-	-	-	10	**02**	**8***
Stenographer Grade-III	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**01**	**+1**
Assistant	20	15	1	2	3	1	1	-	2	-	1	-	1	1	1	2	30	**21**	**09**
UDC	05	09	3	2	3	1	1	2	1	-	1	1	2	1	1	-	17	**16**	**01**
LDC	14	09	2	3	3	4	1	2	1	-	-	-	2	1	1	-	24	**19**	**05**
Total	**61**	**49**	**08**	**09**	**12**	**8**	**5**	**5**	**4**	**0**	**2**	**1**	**7**	**4**	**3**	**2**	**102**	**78**	**25**

1. Five for DR and three for promotion and one for LDCE.(Two DR post requisition has already been sent to ICAR) 2. One post of UDC by downgrading as LDC advertised for CPRS, Shillong. 3.*Post advertise for filling up as Stenographer Grade-III in lieu of PA Case referred to ICAR for permission for filling up as the three Stenographer Grade-III in lieu of PA

SANCTIONED FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.03.2016, BASED ON REVISED CADRE STRENGTH

Functional Group	Hqrs.		Shillong		Jalandhar		Modipuram		Gwalior		Patna		Ooty		Kufri		Total		
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	V
Field Farm Technician (FFT)																			
Cat. I																			
Jr. Tech. Asstt. / Sr. Field Asstt./ Field Asstt.	29	30	5	3	8	5	13	10	4	4	12	7	4	3	8	4	83	66	17
Cat. II																			
Sr. Tech. Asstt. (T-4) Tech. Asstt. (T-3)	9	8	-	-	4	4	13	13	2	2	3	2	-	-	-	-	31	29	02
Cat. III																			
Farm Supdt. T-6	-	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	2	2	0
Lab. Technician-																			
Cat. I																			
Computer (T-2)	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	3	0
Projector Operator, T-2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0
Cat. II																			
Lab. Tech. (T-4)/ Lab. Tech. (T-3)	3	2	-	-	1	-	1	1	1	1	-	-	-	-	-	-	6	4	2
Lib. Information / Documentation																			
Cat. II																			
Lib. Asstt. (T-3)	1	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2	1
Asstt. Librarian (T-5)	1	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1*	0
Documentalist , T-2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Tech. Asstt. (Stat.) (T-3)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Photography																			
Cat. I																			
Photographer /	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Press & Editorial Staff Cat. II																			
Hindi Translator , T-3	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	1	1
Cat. III		-																	
Computer programmer T-6	1		-	-	-	-	-	1	-	-	-		-	-	-	-	1	1	-
Workshop &Engg. Staff																			
Cat. I																			
Blacksmith-cum-Carpenter	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Sr. Mechanic (T-2)	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	2	2	0
Fitter (T-1)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Welder	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0
Mechanic cum Electrician	1	1	-	-	2	1	1	1	-	-	-	-	-	-	-	-	4	3	1
Operator Electrical	1	2	-	-	-	1	1	-	-	-	1	-	-	-	-	-	3	3	0
Driver	3	3	2	1	2	1	2	3	2	-	2	1	-	-	-	-	13	9	4
Tractor Driver	1	1	1	1	1	1	4	2	3	3	1	-	1	-	-	-	12	8	4
Cat. II																			
Foreman (T-4)	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	2	2	0
Asstt. Foreman (T-3)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	0
Overseer (Civil) T-3	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0
Cat. III																			
Instrument Engineer, T-7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Total	61	55	08	05	22	15	42	38	13	11	19	10	05	03	08	04	178	141	37

Sr. No.	Category	Sanctioned	Filled	Vacant
1.	Category–I	125	98	27
2.	Category– II	49	40	09
3.	Total– III	04	03	01
	Total	178	141	37

SANCTIONED STRENGTH OF SKILLED SUPPORTING STAFF AS ON 31.03.2016

Grade	Sanctioned	Filled	Vacant
SS Grade-I	82*	45+13	24
SS Grade-II	65	42	23
SS Grade-III	39	22	17
SS Grade-IV	18	02	16
Sub Total	**204**	**124**	**80**
Canteen Staff			
Cook	1	0	1
Tea Maker	1	0	1
Wash Boy	1	1	0
Grand Total	**207**	**125**	**82**

Station-wise/Grade-wise list of the Skilled Supporting Staff 31.03.2016

Station	Sanctioned Strength	Grade - IV	Grade - III	Grade - II	Grade - I	Total
Shimla	75	01	11	04	09	25+1* Canteen staff
Kufri	12	--	02	02	05	09
Modipuram	42	--	02	04	13	19
Jalandhar	26	--	01	13	06	20
Patna	20	**--**	02	04	01	07
Gwalior	12	-	-	15	19	34
Shillong	12	01	04	-	-	05
Muthorai	08	-	-	-	05	05
Total	**207**	**02**	**22**	**42**	**58**	**124+1=125**

*1 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 31.3.2016 of CPRI showing number of SCs, STs, OBCs & Women

Category	Sanctioned	Filled	SC	ST	OBC	Women
Scientific	107*	74*	11	05	12	16
Technical	178	141	32	05	14	10
Administrative	102	78	20	02	05	21
Skilled Support Staff	207**	125**	37	05	13	17

*Including One RMP

** Including One Canteen Staff

Classified Abstract of Expenditure of Plan, Non-plan and Receipt

Details of Plan Expenditure

S.NO	Head	RE Allocation (Rs.)	Expenditure (Rs.)
1	**2**	**3**	**4**
	Grants in Aid -Capital Works		
A.1	Land	0.00	0.00
B.1	Office Buildings	684000.00	683603.00
B.2	Residential Buildings	1100000.00	1100000.00
B.3	Other Works	0.00	0.00
	Total: Works	**1784000.00**	**1783603.00**
	Other Capital Expenditure		
C.	Equipments	18023000.00	18023308.00
D.	Information Technology	97000.00	97354.00
E.	Library Books and Journals	3187000.00	3186688.00
F.	Vechicles and Vessels	0.00	0.00
G.	Livestock	0.00	0.00
H.	Furniture & Fixtures	0.00	0.00
I.	Others	0.00	0.00
	Total: Other Capital Expenditure	**21307000.00**	**21307350.00**
	Total Grant In Aid - Capital	**23091000.00**	**23090953.00**
	Grants in Aid -Salaries		
	Establishment Expenses		
A.1	Establishment Charges	0.00	0.00
A.2	Wages	0.00	0.00
A.3	Overtime Allowaces	0.00	0.00
	Total: Establishment Expenses	**0.00**	**0.00**

	Total Grant In Aid- Salaries	0.00	0.00
	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	2565000.00	2564181.00
B.	Foreign TA	0.00	0.00
	Total: Travelling Allowances	**2565000.00**	**2564181.00**
	Research and Operational Expenses		
A.	Research Expenses	28654000.00	26142609.00
B.	Operational Expenses	6265000.00	6262618.00
	Total: Research and Operational Expenses	**34919000.00**	**32405227.00**
	Administrative Expenses		
A.	Infrastructure	0.00	1508673.00
B.	Communication	0.00	186102.00
C.1	Repairs/Maintenance - Equipments, Vechicles & others	0.00	23056.00
C.2	Repairs/Maintenance - Office Building	0.00	171754.00
C.3	Repairs/Maintenance - Resedential Building	0.00	0.00
C.4	Repairs/Maintenance - Minor Works	0.00	0.00
D.	Others (excluding TA)	0.00	623255.00
	Total: Administrative Expenses	**0.00**	**2512840.00**
	Miscellaneous Expenses		
A.	HRD	496000.00	298059.00
B.	Other Items (Fellowships, Scholarships etc.)	0.00	0.00
C.	Publicity & Exhibitions.	0.00	69392.00
D.	Guest House - Maintenance	0.00	128137.00
E.	Other Miscellaneous	0.00	0.00
	Total: Miscellaneous Expenses	**496000.00**	**495588.00**
	Total Grant in Aid - General	**37980000.00**	**37977836.00**
	Grand Total : Capital + Revenue + (salaries) + Revenue (General)	**61071000.00**	**61068789.00**

Revenue Receipts

S.No	Particulars	Amount (Rs.)
1	Sale of Farms Produce	11560585.00
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	81500.00
6	Sale of Live Stocks	0.00
7	Income from Royalty, Sale of Publications and Advertisement	139836.00
8	Licence Fee	1355011.00
9	Interest earned on Loans and Advances	1061974.00
10	Leave Salary and Pension Contribution	0.00
11	Receipts from Schemes	0.00
12	Analytical and Testing Fee	462775.00
13	Pre-shipment Fee	0.00
14	Application fee from candidates	502940.00
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	4135640.00
19	Income generated from Internal Resource Generation	1356688.00
20	Net profit in Revolving Funds	-11654965.00
21	Recoveries of Loans and Advances	1846121.00
22	Miscellaneous Receipts	3293060.00
	Break up : Grand Total	**14141165.00**
Revenue Receipts :		12213544.00
Loan Recoveries :		1846121.00
Sale of Assets :		81500.00
	Grand Total	**14141165.00**

Details of Institute Non Plan Expenditure

(Amount in Rupees)

Sl. No.	Head	Allocation Govt. Grant	Allocation Internal resources+additional amount provided by Hq out of Council's share	TOTAL ALLOCATION	Expenditure (Govt. Grant)	Expenditure (Govt. 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	1000000.00	500000.00	1500000.00	935983.00	499036.60	1435019.60
	D, Information Technology	0.00	0.00	0.00	0.00	0.00	0.00
	E. Library Books and Journals	300000.00	200000.00	500000.00	299863.00	200000.00	499863.00
	F. Vehicles and Vessels	0.00	0.00	0.00	0.00	0.00	0.00
	G. Livestock	0.00	0.00	0.00	0.00	0.00	0.00
	H. Furniture & fixtures	300000.00	0.00	300000.00	293402.00	0.00	293402.00
	I. Others	0.00	0.00	0.00	0.00	0.00	0.00
	Total: Other Capital Expenditure	1600000.00	700000.00	2300000.00	1529248.00	699036.60	2228284.60
	Total Grants in Aid - Capital	**1600000.00**	**700000.00**	**2300000.00**	**1529248.00**	**699036.60**	**2228284.60**
	Grants in Aid - Salaries						
	Establishment Expenses						
	A.1 Establishment Charges	295000000.00	5000000.00	300000000.00	273578276.00	0.00	273578276.00
	A.2 Wages	5500000.00	0.00	5500000.00	4355480.00	46343.00	4401823.00
	A.3 Overtime Allowance	0.00	0.00	0.00	0.00	0.00	0.00
	Total: Establishment Expenses	300500000.00	5000000.00	305500000.00	277933756.00	46343.00	277980099.00
	Total Grants in Aid - Salaries	**300500000.00**	**5000000.00**	**305500000.00**	**277933756.00**	**46343.00**	**277980099.00**
	Grants in Aid - General						

Pension and Retirement Benefits						
A. Pension & Other Retirement Benefits	135000000.00	60000000.00	195000000.00	134990296.00	60000000.00	194990296.00
Total: Pension and Retirement Benefits	135000000.00	60000000.00	195000000.00	134990296.00	60000000.00	194990296.00
Travelling Allowances						
A. Domestic TA / Transfer TA	1500000.00	0.00	1500000.00	1499034.00	0.00	1499034.00
B. Foreign TA	0.00	0.00	0.00	0.00	0.00	0.00
Total: Travelling Allowances	1500000.00	0.00	1500000.00	1499034.00	0.00	1499034.00
Research and Operational Expenses						
A. Research Expenses	12000000.00	0.00	12000000.00	12000158.00	0.00	12000158.00
B. Operational Expenses	7000000.00	2000000.00	9000000.00	6999607.00	2000000.00	8999607.00
Total: Research and Operational Expenses	19000000.00	2000000.00	21000000.00	18999765.00	2000000.00	20999765.00
Administrative Expenses						
A. Infrastructure	13000000.00	1000000.00	14000000.00	12999268.00	999000.00	13998268.00
B. Communication	800000.00	0.00	800000.00	799628.00	0.00	799628.00
C.1 Repairs/Maintenance - Equipments,Vehicles& Others	3200000.00	0.00	3200000.00	3195955.00	0.00	3195955.00
C.2 Repairs/Maintenance - Office building	2000000.00	0.00	2000000.00	1999798.00	0.00	1999798.00
C.3 Repairs/Maintenance - Residential building	2000000.00	0.00	2000000.00	1999640.00	0.00	1999640.00
C.4 Repairs/Maintenance - Minor Works	500000.00	0.00	500000.00	499631.00	0.00	499631.00
D. Others (excluding TA)	6500000.00	2000000.00	8500000.00	6499207.00	2000000.00	8499207.00
Total: Administrative Expenses	28000000.00	3000000.00	31000000.00	27993127.00	2999000.00	30992127.00
Miscellaneous Expenses						
A. HRD	400000.00	0.00	400000.00	399391.00	0.00	399391.00
B. Other Items (Fellowships, Scholarships etc.)	0.00	0.00	0.00	0.00	0.00	0.00
C. Publicity & Exhibitions	100000.00	0.00	100000.00	98828.00	0.00	98828.00
D. Guest House – Maintenance	0.00	100000.00	100000.00	0.00	96300.00	96300.00
E. Other Miscellaneous	100000.00	0.00	100000.00	92009.00	0.00	92009.00
Total: Miscellaneous Expenses	600000.00	100000.00	700000.00	590228.00	96300.00	686528.00
Total Grants in Aid - General	**184100000.00**	**65100000.00**	**249200000.00**	**184072450.00**	**65095300.00**	**249167750.00**
Grand Total : Capital + Revenue (Salaries)+	**486200000.00**	**70800000.00**	**557000000.00**	**463535454.00**	**65840679.60**	**529376133.60**
Loan and Advances		1300000.00	1300000.00		1089500.00	1089500.00