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Compilation and production:
NK Pandey, Dhiraj K Singh, Rakesh Kumar and Sachin Kanwar

Photograph
Dharmendra Kumar Gupta

Published by
Dr S.K. Chakrabarti
Director
Central Potato Research Institute, Shimla-171001 (Himachal Pradesh)
Email: directorcpri@gmail.com, director.cpri@icar.gov.in
Website: http://cpri.icar.gov.in
Phone: 0177-2625073
Fax: 0177-2624460

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Email : aop144@gmail.com

Preface

The green revolution took the country out of the "ship to mouth" existence to a status of food surplus nation enabling her to enact the "right to food" act in the year 2013. However, income of farmers in real term has not appreciated adequately during this time causing wide spread agrarian distress. Therefore, a paradigm shift is necessary now from the policy of mere food production to income security of farmers. Horticulture will play a pivotal role towards realization of that stupendous goal. Most of the horticultural crops including potato have the potential to give high economic return per unit farm area. Central Statistical Organization (CSO) data on the value of output for year 2013-14 revealed that fruits and vegetable crops on average generate Rs. 3.30 lakh worth of output per hectare compared to Rs. 37.50 thousand in the case of cereals and Rs. 29 thousand from pulses and Rs. 48.70 thousand from oilseeds. Because of that, diversification to horticultural crops has been advocated by both NITI Aayog and NAAS for doubling farmers' income by 2022. Potato as the principle vegetable crop of India will play an important role towards achieving that target. Though potato came to this ancient land only about 400 years ago during Mughal dynasty, today India is the second largest potato producer in the world and contributes nearly 11% of world potato production. Potato production is increasing at an ACGR of ~ 3.5% and the prediction is that India would require potato production of about 56.15 and 124.88 million metric tonnes during 2025 and 2050, respectively. On the other hand, all the natural resources including soil, water, and energy are under severe constraint. Inputs for agricultural production will also become scarcer and dearer with time. It is also imperative that future food production technologies should be carbon neutral and sustainable. Under this background, we have to strike a balance between cutting edge technologies and their environmental cost for sustainable production enhancement of potato. The ICAR-Central Potato Research Institute (ICAR-CPRI) is fully aware of this challenge and is pursuing strategic and applied research for addressing those challenges. The present report gives an overview of the salient achievements obtained from prioritized research undertaken during 2016-17 by the institute. The institute released a new potato variety Kufri Mohan that has been notified by the Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops for cultivation in northern, central and eastern plains of India.Promising anthocyanins rich (MSP/15-51) and carotenoids rich (MSP/15-26) potato hybrids have identified. Complete genome analysis of potato dry rot pathogen *(Fusarium sambucinum)* and bacterial wilt pathogen *Ralstonia* *solanacearum* was carried out which will help in designing effective management schedules for these diseases. For on-the-spot detection of glucose in potato tubers, highly sensitive, quick dipstick kits were developed. The institute produced 3063.97 metric tonnes of nucleus and breeder seed and distributed to different stakeholders. Surveys conducted in Bihar, West Bengal and Punjab revealed that cost of cultivation in case of potato in those states varied from ` 1.06 to 1.43 lakhs/ha.

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 R&D activities as per plan and bringing out the results in time. I would also thank Chairperson and members of new RAC who guided us and gave 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 informative. I am extremely grateful to Dr. Trilochan Mahapatra, Secretary, DARE and Director General, ICAR, for his constant support and guidance. I would also place on record my thanks to DDG (Horticultural Science) and ADG (HS-II) for providing necessary direction, guidance and suggestions.

(SK Chakrabarti)
Director

Contents

ICAR-CPRI: An Introduction

The ICAR-Central Potato Research Institute was established during August 1949 at Patna (Bihar) on the recommendation of the then Agricultural Advisor to the Government of India, Sir Herbert Steward under the Ministry of Agriculture, Government of India. The institute was later on, shifted to Shimla in 1956 in order to facilitate hybridization work in potato breeding programme 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 seven regional stations located across the country *viz.* Modipuram (U.P), 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 has created the state-of-the-art laboratories for conducting basic and strategic research in different areas of potato. The All India Coordinated Research Project on potato (AICRP-Potato) is also located in this institute and has been functioning since 1971. It has 25 regional centers located in nearly all agro climatic zones of the country to test the performance of new potato varieties and technologies in different locations. An Agricultural Technology Information Centre (ATIC) is also functioning in the institute which looks after the transfer of technology activities of the institute. The institute 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 67 scientists, 138 technical staffs and 74 administrative staffs working on potato crop.

The Mission

To 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 non profit scientific institution under the Indian Council of Agricultural Research, working exclusively on potato. The institute has played a key role in popularizing potato cultivation and utilization under sub-tropical agro-ecosystem. We believe that potato can play an important role in food and nutritional security of India, while helping the rural poor to rise out of poverty. The institute focuses all its energy to make that belief becomes a reality. The mandate of the institute has been revised accordingly and is given below :

Revised Mandate of ICAR-CPRI, Shimla

- Basic strategic and applied research to enhance sustainable productivity, quality and utilization of potato.
- Repository of genetic resources and scientific information on potato.
- Transfer of technology, capacity building and impact assessment of technologies.
- Disease-free nucleus and breeder seed potato production.
- Coordinate research and validation of technologies through AICRP on potato.

Work of the Institute is being carried out by the six Divisions namely; Crop Improvement; Plant Protection; Crop Production, Crop Physiology, Biochemistry & Post Harvest Technology; Seed Technology and Social Sciences under 10 well defined research programmes and one service project on potato seed production. In addition to regular research programmes, a total of 12 externally funded research projects sponsored by different agencies viz. ICAR, DBT, PPV & FRA, CIP, IASRI, NASF, NEC 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 31.03.2017 was 396 including 67 scientific, 138 technical, 74 administrative and 117 supporting staff. The expenditure of the institute for the year (Plan & Non Plan) was Rs 58.3 crores and receipts Rs. 6.35 crores. The ICAR-CPRI generated some parts of its total budget from its own resources i.e. from the sale of seed, farm produce, consultancy, etc. Revolving fund scheme alone generated an income of Rs 4.8 crores during 2016-17. During the year, 6 scientists joined the institute, 3 retired, 9 were transferred from the institute and 3 were promoted from Sr. Scientist to Principal Scientist. In technical category, 11 technical staff were promoted, 3 retired and 1 was transferred. Under administrative category, 6 persons were promoted, 3 retired and 2 were transferred within institute. In skilled supporting staff, 5 got probation confirmation and 9 retired.

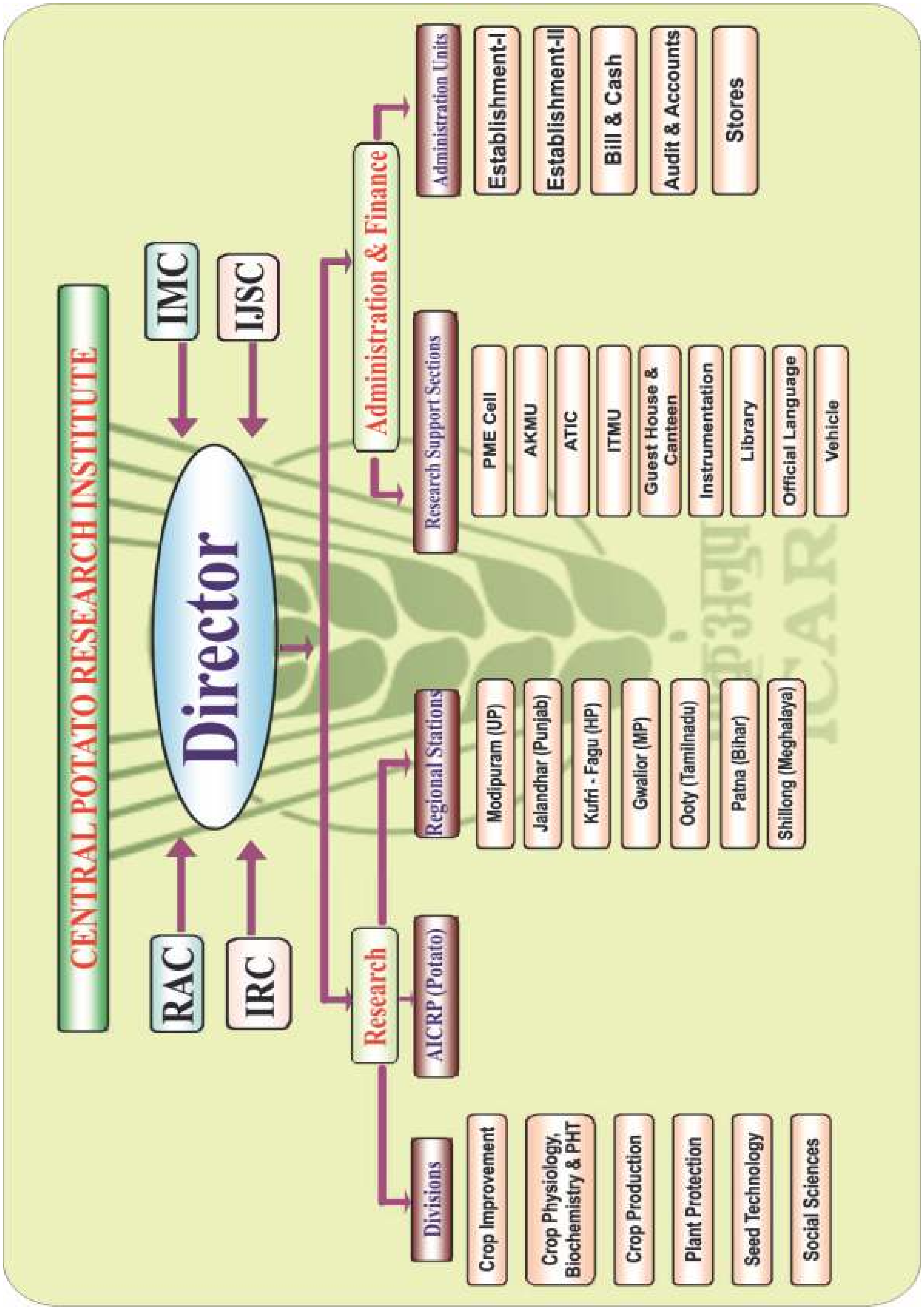
Facilities

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.

This year, a new instrument Ultra-microtome was procured for sectioning of samples for using in Electron Microscope. In CPB & PHT division Dynamic Mechanical Analyzer (DMA) was purchased for analysis of starch rheology & strength of packaging films along with Liquid Chromatography Mass Spectrophotometer (LCMS) for quantification of low concentration compounds. For Analysis of Nano particles, Zeta sizer was procured in Crop Production Lab.

The institute has 521 ha farm lands distributed over 15 units for conducting field experiments and undertaking breeders' seed production. Recently, Aeroponic facility was created in CPRI, Shimla, CPRS, Modipuram, CPRS, Patna and CPRS, Shillong and CPRS, Jalandhar 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.



The Organogram of ICAR-CPRI

Executive Summary

Division of Crop Improvement

The hybridization programme resulted production of 4,14,235 true potato seeds from 273 crosses involving superior parents for yield, quality and resistance/tolerance to biotic and abiotic stresses. In all, 10,812 selections were made from 1,28,026 F_1 seedling raised from 4,31,272 true potato seeds of 242 crosses made last year. In initial clonal generation, 2,471 clones were selected from 9,298 clones evaluated. In advanced stage hybrids trials, 65 hybrids were selected from the 170 hybrids assessed in 20 trials for yield, quality and resistance/tolerance to biotic and abiotic stresses. Based on consistently good performance over the years, seven advanced hybrids namely J/9-141, MS/11-664, PS/10-2 and PS/10-10 (table purposes); MP/10-172 (chips) and HT/11-3 (heat stress) have been identified. Advanced hybrids MS/10-1529 (table purpose), MP/9-28 (Chips) and HT/7-1329 (heat tolerance) were introduced in AICRP for multi-location testing. Molecular profiling of 64 progenies of specialty potato cross Bareilly Red × CP3770 for flesh colour, revealed molecular divergence among the progenies. Advanced hybrid MS/5-1543 was released and notified as potato variety Kufri Mohan by the Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi in its 24th meeting held on 22nd Sep, 2016. Among the 69 genotypes assessed for late blight at Modipuram, all showed lower AUDPC than susceptible variety Kufri Bahar. Optimum NPK requirement (kg/ha) of varieties/advanced hybrid namely Kufri Mohan (220 N, 40 P, 80K), MS/6-1947 (280N, 40P, 100K) and WS/5-146 (180N, 100K) were worked out. Crop geometry of 60x25cm was found optimum for the newly released variety Kufri Mohan. Analysis of processing quality of 12 genotypes during storage at 10-12oC with CIPC at Jalandhar, identified MP/9-36 having lowest reducing sugars (122-158mg/100g fresh weight), sucrose (178-270 mg/100 g fresh weight), acceptable chip colour and French fry colour throughout the storage period of 180 days. Preliminary investigation on seedling establishment and clonal evaluation under tropical agro-climatic condition at Thiruvananthapuram, Kerala showed encouraging results. Kufri Surya invested more biomass in stem and leaves as compared to Kufri Bahar under early and main planting conditions.

Management and enhancement of potato germplasm is the basic programme of the division aimed at collection, conservation, evaluation and documentation of germplasm and its genetic enhancement through pre-breeding. During the year, germplasm collection was augmented by adding 14 accessions and the present collection in the national repository at ICAR-CPRI has more than 4,300 accessions. These are being conserved in field genebanks, in vitro repository and also as true seeds. The collection was evaluated for a number of important biotic and abiotic stresses, keeping quality, processing attributes and also adaptability to various thermo-photoperiods and promising accessions were identified. The information generated has been added to electronic databases. Two elite germplasm stocks have been registered by ICAR-NBPGR germplasm registration committee.

In biotechnology programme, Genome sequencing and analysis was done for *Fusarium sambucinum* (potato dry rot pathogen) and four strains of potato bacterial wilt pathogen *Ralstonia solanacearum.* Similarly, mitochondrial genome of potato late blight pathogen *Phytophthora infestans* A_2 mating type was sequenced and mapped. RNA-sequencing of wild potato species *Solanum demissum* was done for identifying novel late blight resistance genes. RNAi approach was followed to confer resistance to *Phytophthora infestans* using a multi-genes cassette. Stability and functionality of RB gene in late blight resistant transgenic potato was confirmed. Gene expression analysis was carried out to identify candidate genes associated with potato tuberization, resistance to potato apical leaf curl disease caused by a variant of tomato leaf curl (New Delhi) virus -potato (ToLCNDV-Potato), late blight resistance, and nitrogen use efficiency. Complete coding sequence of eIF (iso) 4E gene, a promising candidate for conferring resistance to ToLCNDV, was cloned and sequenced. Molecular characterization of interspecific somatic hybrids was carried out using AFLP markers. Late blight resistance as well as breeding potential of potato somatic hybrids were also determined. An efficient method based on aeroponics has been standardized for carrying out research on nitrogen use efficiency (NUE) in potato.

Division of Plant Protection

Late blight severity was insignificant this year. Isolates of *Phytophthora infestans* were found to be sensitive to new molecules (cymoxanil, dimethomorph and fenamidone). Generated 238 Mb data of P. infestans A_2 (Ibmt DNA haplotype) using Ion Torrent (NGS) technology and Ilumina platform for comparative analyses. Besides, complete genome of ToLCNDV-potato isolate from Kanpur has been determined which shows 96-96.8% (DNA A) and 93.4% (DNA B) identities to ToLCNDV isolate from pumpkin and ash gourd. Developed loop mediated isothermal amplification (LAMP) assay for detection of PVX and PVS; simplified nucleic acid release protocol for RT-PCR based detection of potato viruses, quantum dots for detection and localization of PVX, Q-dot DAS-ELISA for detection of PVX, and recombinant antibody production system for PVY. Various rabi weeds and crops were sampled and tested for common potato viruses in Punjab. Most of the samples tested positive for ToLCNDV (44.59 %) followed by PVA (13.01%), PLRV (8.94%) and PVYN (7.31 %) and were suspected to play an important role in the epidemiology of the viruses. The Indo-Blightcast model developed previously for prediction of appearance of late blight has been embedded in the DSS that will enable the farmers to decide the number of sprays as well as the interval between sprays and the fungicide to be used based on the DSVs of 15 days prior to the selected date. Results of microarray analysis performed to identify differentially regulated genes during P. infestans infection in a resistant (Kufri Girdhari) and susceptible (Kufri Bahar) cultivars revealed expression differences in the category of signal transduction, transcription factors and hormone signalling genes. Similarly, 16 differentially expressed genes, including genes encoding LRR protein, F-box proteins, cell division control 20, Mads box protein and translation initiation factors, involved in ToLCNDV-potato infection, have been selected for validation. Event PCR for confirmation of integration of T-DNA in the chromosomes of ToLCNDV-potato transgenic plants was performed. Application of ametoctradin + dimethomorph (0.2%), famoxadone + cymoxanil (0.1%), cymoxanil + mancozeb (0.3%), and dimethomorph + mancozeb (0.3%) was found effective against late blight. In preliminary studies, application of zinc has shown promising results for inhibition of ToLCNDV-potato under in vitro conditions. Some bacterial endophytes have shown promising results against *P. infestans* and *Ralstonia solanacearum* under pot experiments.

Aphids, whiteflies, leafhoppers, thrips, mites, defoliators and soil pests were monitored at Gwalior, Jalandhar, Modipuram, and Shimla (summer crop) on potato and other hosts during 2016-17 and efforts were made to manage different insect pests by integrated approaches. Among aphids, most important vector and generalist feeder *Myzus persicae* crossed critical level at Jalandhar in third week of December (20.12.16) and at Modipuram on 4th January 2017 but *Aphis gossypii* being hardy, survived through winter months at Jalandhar and Modipuram. Viruliferous nature of another aphid, *Aulacorthum solani*, with respect to predominant viruses, PVY and PLRV was confirmed by the transmission studies. Considering its significance as a vector de novo whole genome of *A. solani* was sequenced using Illumina platform. Being polyphagous, whiteflies *(Bemisia tabaci)* were found on number of plants throughout the year and were recorded on *Ficus sp*. (ornamental) in March and April; on cucumber from May to mid-June; on brinjal (*Solanum melongena*), moong (*Vigna radiata*) and tinda (*Citrullus vulgaris*) in 1st & 2nd week of June; a very high populations of whiteflies (more than 100 per leaf) were also recorded on tulsi (*Ocimum sanctum*) and urdbean (*Vigna mungo*) during July and August in Uttar Pradesh. The results of within-plant distribution of *B. tabaci* eggs, nymphs and adults indicated highest proportion of nymphs on leaf number 2 to 5 with minimum CV which represented around 70% of the assemblage on those particular leaves. For the management of whitefly and aphids, white oil @0.5% with equal amount of soap solution was found effective and results were comparable to summer oil. Thrips recorded on potato at Shimla hills and Hassan was identified as Haplothrips and all found to carry GBNV. Results of gene silencing of flp 32(c) to manage the PCN revealed that Gp-flp-32 (c) expresses an inhibitory neuropeptide which when silenced, induces locomotor activity. Maximum reduction in PCN cyst population with lowest Rf value of 0.83 was obtained with trap cropping in all three seasons at Ooty (Tamil Nadu). With regards to biofumigation, the lowest Rf value of 0.53 was recorded in biofumigation with mustard followed by Dazomet (0.62) although the maximum yield was obtained in biofumigation with cabbage (11.60 t/ha) and was found to be on par with radish, mustard, Dazomet and Carbofuran. Experiment on compatibility of insecticides and fungicides against population build-up of sucking pests and late blight incidence on potato showed that all the combinations of mancozeb, metalaxyl & cymoxanil with imidacloprid were effective.

Division of Crop Production

Impact of climate change on potato productivity in Gujarat was assessed using the WOFOST (WOrldFOodSTudies) crop growth model. Under the combined effect of CO_2 and temperature, the model predicted the highest decline of 10.9 % in productivity of Kufri Pukhraj followed by 9.7 % in Kufri Jyoti and 7.6 % Kufri Badshah in 2020, with corresponding figures of 25.2, 22.1 and 19.5 % in 2055. From the simulation studies, it appears that Kufri Badshah has greater resilience against climate change and can be more suitable cultivar in the future climates than Kufri Jyoti and Kufri Pukhraj in Gujarat. WOFOST model was calibrated and validated for medium maturing, high yielding table purpose variety Kufri Garima and early maturing variety Kufri Khyati in Uttar Pradesh using time course data on potato crop growth.

At Modipuram, mulching with paddy straw @ 5t/ha gave significantly higher total tuber yield than chemical CH-1 and CH-2 both under flood and sprinkler irrigation. At Jalandhar, plant height of Kufri Badshah increased linearly from emergence till 70 days while tuber yield increased by 20.3 percent under elevated (600 ppm) CO_2 levels. Preliminary results from the study on effect of CO_2 concentration on rubiscoactivase (RAC) in potato leaves of Kufri Badshah grown at ambient CO_2 (350 ppm) and high CO_2 (550 ppm) concentration showed that elevated Co_2 enhanced expression of Rub79 isoform of RAC with a concomitant increase in the net photosynthesis rate.

A Decision Support System "Nutrient Recommendation for Raising Potato in Uttar Pradesh (NRRPUP)" has been developed to give recommendations on NPK application in potato in different districts of Uttar Pradesh based on the output derived from QUEFTS model. For optimising site specific nutrient fertilizer doses an experiment was conducted on Kufri Jyoti variety using omission plot technique at CPRS, Jalandhar and N was found the only limiting nutrient. For Real time N management by fine tuning top dressing using leaf SPAD value, experiments were conducted at Gwalior and Meerut. It was concluded that top dressing of 10 or 20 % recommended N at 90 % of reference SPAD value after 1/3rd basal and 1/3rdat earthingup was the best treatment. Reducing P application by 60% at Gwalior and even skipping P at Meerut in High P soil had no significant reduction in potato yield. All potato varieties produced significantly higher tuber yields and numbers at higher moisture level when irrigations were applied at 2.5 IW:CPE ratio in comparison to low and medium irrigation levels.

Two promising potato hybrids, *viz.* N/9-42 and N/10-74 gave maximum nutrient use efficiency as well as yield in a replicated field trial at Patna while two genotypes *viz.* J 93-58 & J.92-167 showed significantly better tuber yield and water use efficiency.

Soil application of 5.0 kg Zn/ha as zinc sulphate increased the Zn content in potato peel by 9 ppm and soil application of 5.0 kg Fe/ha as iron sulphate increased the Fe content in peel by 20 ppm on dry weight basis. The Fe content in tuber flesh of 46 accessions ranged from 25.63 to 35.23 mg/kg (dry weight basis) and Zn content ranged from 13.08 to 23.63 mg/kg (weight basis).

Influence of benzyl amino purine (BAP) and chloro choline chloride (CCC) on in vitro tuberization showed that BAP provided effective results with respect to microtuber size, weight and lower driage. Evaluation of seed from different plant sources for K. Bahar proved that this variety was most sensitive in tissue culture. At Ooty, seed multiplication under in vitro conditions was done for cv. K. Himalini, K. Girdhari, K. Jyoti and K. Swarna. At Shillong, aeroponic minitubers of five cultivars were evaluated in net house and K. Himalini exhibited better tuber yield. Post-harvest handling of these tubers suggested that curing in 24°C temperature with RH (80-100%) for 10 days followed by curing at 16 °C temperature at RH (40-60%) for 10 days resulted in better quality minitubers.

Generation II aeroponic system having improved design of grow boxes was evaluated at Jalandhar. Transplanting of hardened in vitro plants was made possible by developing a new component and performance of two chilling units installed for cooling nutrient solution was assessed. For completing two full crop cycles in aeroponic system, two feeder systems were tested for hardening and raising crop for first 20-30 days. An experimental hydroponic unit was developed and compared with two styrofoam box and poly sheet box systems and results indicated that this system can be used for hardening and initial growth of in vitro plants for 20-35 days. A new grading mechanism based on electromagnetic vibrations was designed and improved for variable size (0.2-4.0 g) of aeroponic minitubers. An automatic swinging system was designed to avoid manual intervention in existing tractor operated gun type sprayer. This system was tested in field at a pressure of 30 kg/cm^2 with a forward speed of 2.7 km/h and swath of 7.2 m.

It was observed that soluble fertilizers could easily be used in aeroponic system and cost was about 25% of currently used salts. Two fold use of in vitro plants was attempted there obtaining highest mean tuber number per plant in K. Mohan (69) in aeroponics and K. Gaurav (21) in net house. Two potato crops in net house at Jalandhar could be feasible as total yield for seed tubers was higher by 147.5%. Similarly, two potato crops in aeroponics in one season proved viable and should be recommended. While comparing performance of photoautotrophic microplants (PAM) and tissue culture microplants (TC) in net house, it was observed that PAM were more sturdier exhibiting better survival and did not require hardening during transplanting. Better canopy management of potato crop in net house resulted in higher total tuber weight in double (28.1%) and single (16.7%) system. In improved aeroponic system at Modipuram cv. K. Chipsona-3 attained maximum tuber number per plant (63). Performance of aeroponic minitubers in net house at Modipuram recorded highest tuber yield (197 g/plant) in cv. K. Pukhraj. Planting geometry (30 x 10 cm) of small aeroponic tubers was superior for obtaining 15g progeny tubers, whereas, for more than 20g tubers, planting was better at 40 x 10cm at Fagu. At Gwalior, highest seed yield was recorded in 31st October planting.

Crop geometry and fertilizer was also optimized for higher production of seed size tubers. At Patna, spacing of 30x10 cm with 120:60:100 NPK kg/ha was most suitable for production of maximum tuber number and yield in net house.

In yield gap estimation at Shimla, results revealed that adoption of institute recommendations (mancozeb as prophylactic and curzate/acrobat with triton as sticker; fertilizer on soil test basis and two earthing) resulted in 29.6% higher tuber yield over farmers' practice. At Modipuram, newly released varieties K. Mohan (48.0 t/ha), K. Garima (40.1) and K. Khyati (37.8) were superior in tuber yields in comparison to K. Bahar (29.4) and K. Pukhraj (36.1). Soil test based and institute recommendations were better as cv. K. Bahar recorded 17.1 and 22.5% higher tuber yield, respectively over Agra farmer's practice. At Shimla, cv. K. Jyoti, K. Girdhari and K. Himalini required 150 kg N ha-1 for optimum yield in Indian GAP activity. Tuber shape studies in potato at Modipuram showed that tuber shape was largely a genotypic trait.

Conclusions of three year organic farming trials at Modipuram suggested that K. Khyati (28.4 t/ha), K. Mohan (28.3), hybrid MS/0-3808 (27.8) and K. Garima (27.0) are promising genotypes for table potatoes over popular varieties K. Bahar (20.5) and K. Pukhraj (21.2). K. Himsona (21.5 t/ha), K. Chipsona-3 (20.3) and French fry hybrid MP-04/578 (21.3) were better genotypes for processing. In vegetable and food grain based systems, organic system (crop residue recycling) and organic system (integrated approach) were markedly better. At Patna, 100% RDN- vermi-compost treatment recorded highest cumulative yield (46.5 t/ha) among all crop sequences. In another trial, treatment of 50% RDF+50% RDN-FYM was comparable to 100% RDF-fertilizer for productivity in all sequences. At Gwalior, yield of kharif pearl millet with cowpea inter-cropping increased by 400 kg over its sole crop yield. At Shillong, potato-cabbage gave highest potato equivalent yield (30.0 t/ha) and 50% RDF+ 25% RDN- FYM+ Azospirillum+ PSB to potato & 50% RDF to subsequent crops treatment recorded highest potato equivalent yield (27.9 t/ha). In sequential planting at Ooty, potato, cabbage and garlic yielded 8.8-19.6, 64.6-94.5 and 4.6-5.9 t/ha, respectively.

In long term plant nutrition studies at Modipuram, application of secondary nutrients along with 100% inorganic slightly increased productivity of all systems over 100% inorganic treatment. System productivity was highest in maize-potato-onion (63.6 t/ha), while soil analysis revealed that crop residue and organics, with or without fertilizers improved the organic carbon content of soil and microbial biomass carbon. Rice-potato-wheat and maize-potato-onion sequence showed higher C stocks in soil. Foliar diseases of potato like Phoma and leaf spot complexes were more in absolute control and organic nutrition in all three systems. Black scurf of potato incidence was highest in organic nutrition, while in potato-wheat-paddy, incidence of apical leaf curl virus was lower in organic treatments. Incidence of powdery mildew of wheat was more in 100% inorganic treatment. Disease incidence of bakane disease in paddy was highest in 100% inorganic+ crop residues (20% DI). In maize, highest incidence of banded sheath blight was observed in 100% organics+ crop residue (53.3% DI). Groundnut crop had fungal disease problem as there was severe attack of *Aspergillus spps*. in all treatments. Population of leafhopper and mite did not build up on potato crop. Whitefly and incidence of PALCV on potato crop did not show significant differences among treatments of all cropping systems. Population of thrips on groundnut, stem borer damage in maize, and leaf folder and stem borer damage in rice did not show any significant difference among various treatments.

In Kharif crop at Hassan,K. Himalini (15.8 t/ha) and K. Jyoti (10.6 t/ha) recorded highest yield at 100 kg N/ha, while K. Surya (12.4 t/ha) had maximum productivity at 150 kg N/ha. K. Himalini (16.5 t/ha) and K. Jyoti (12.5 t/ha) recorded highest yield at 120 kg P_2O_5/ha, whereas, K. Surya (14.8 t/ha) had highest productivity at 160 kg P_2O_5/ha. K. Himalini (22.9 t/ha) recorded highest yield at 100 kg K_2O/ha and K. Surya (21.4 t/ha) at 150 kg K_2O/ha, whereas, K. Jyoti (16.8 t/ha) had maximum yield at 200 kg K_2O/ha.

Total damage indices of cv. K. Pukhraj remained non-significant with increase in tractor's forward speed (2.0, 2.6 and 3.2 km/hr, respectively), while total damage indices of K. Gaurav had downward trend with increase in tractor's forward speed. In grading of K. Jyoti with a square wire mesh type grader, total damage index was 20.6. Slight and severe type bruising in K. Gaurav during harvest with a potato elevator digger were minimum as 8 and 2%, respectively at 2.6 km/h speed of operation. Simulation of mechanical damage caused by all tumbling and dropping during harvest and handling recorded highest external damages of 40 and 30%, respectively, in K. Gaurav and K. Pukhraj with drop height of 120 cm. Two row tractor operated potato combine harvester (Prototype I) having provision for side conveying of tubers in trolley was improved for better separation and less tuber bruising. Potato combine harvester (Prototype II) having provision for collection of tubers in bunker hopper was also improved and run at no load condition to synchronize the speeds of different sub-systems.

Division of Seed Technology

During 2015-16, a total no. of 8562 samples of indexed tubers in stage-1 and standing crop of different commercial potato varieties were tested. Overall health status of Modipuram, Jalandhar, Gwalior, Patna and Kufri recorded during tuber indexing was 96.76, 88.0, 94.72, 90.14 and 98.02 %, while in stage-I, it was 97.87, 66.93, 93.76, 89.97 and 99.26%, respectively. During 2015-16, a total production of 3063.97 metric tonnes of nucleus and breeder seed was achieved from an area of 153.63 ha in plains, out of which 2327.36 tonnes from 116.56 ha was through conventional system and 736.61 tonnes from 37.072 ha through hi-tech system respectively. A total 2472.96 tonnes of breeder seed was supplied to various government and private agencies, from plains. A total no. of 22 varieties was tested with ELISA/PCR against 29 viruses. Out of these, only 12 varieties were found free from all the tested viruses. Later, K. Pukhraj, K. Khyati, K. Frysona, K. Surya and K. Badshah were made free from viruses by carrying out series of testing through PCR/ELISA by a taskforce and were included in the microplants multiplication and supply chain. At Ooty, total quality seed production of four varieties was 88.53 tonnes from 9.76 ha area during summer, autumn and spring season. At Shillong, total quality seed production of seven varieties was 46.25 tonnes from 7.46 ha area through conventional/high-tech system.

Uniform cutting of haulms in the crops raised from aeroponic tubers may limit the harnessing of full production potential of the crops. It is, therefore, suggested that in seed potato production, the duration of crop raised from micro-propagation based systems needs to be re-visited to exploit the full yielding potential of such seed tubers. For improving the size of extremely small sized aeroponic tubers for making them worth planting under field conditions, one time multiplication during the autumn season under protected conditions in high hills can be successfully practised. The size of progeny tubers will improve to 15g and beyond. It was found that in-spite of differences in tuber weight and number of sprouts per tuber at planting, the plant vigour and production potential of the aeroponic tubers from three different harvests didn't vary significantly. To maintain the originality of K. Bahar, it should be multiplied through conventional system and reasons of its sensitivity under tissue culture needs to be studied on priority. Planting of two crops under net–house in Jalandhar revealed the scope of getting higher productivity per unit area over single crop.

Division of Crop Physiology, Biochemistry and Post-harvest Technology

The assessment of physiological and pathological losses was done in potatoes during different stages from harvesting to storage under different storage systems (2-4°C, 10-12°C and non-refrigerated storage). Mean total losses of 2.75 and 6.13% were recorded during harvesting and at curing, sorting, grading and packaging stages, respectively. Mean losses during storage in heaps following the farmers' practice without CIPC treatment up to 90 days (12-31°C, 58-78 % RH) were higher (21.05%) due to prevailing high temperatures and low humidity. Losses were the minimum (3.77%) when potatoes were stored at 10-12°C up to three months followed by 5.28% at 2-4°C up to 6 months of storage. While mean total losses of 11.61% were recorded after 6 months of storage at 10-12°C. The PHL's were similar to the losses reported by survey with farmers and traders. The results also confirmed that potatoes treated with CIPC may result in lower losses even during transportation and marketing. Large scale studies to evaluate volatile compounds for sprout suppression in potatoes revealed that 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. In a study of keeping quality, positive and significant correlation (0.6656) was observed between respiration rates of damaged tubers at day 0 and total weight loss at 60 days of storage, besides, a significant negative correlation could be established between thickness of phellem and total weight loss at 60 and 90 days. Among the antidiabetic agents, biguanides and related compounds reduce hyperglycaemia by increasing insulin sensitivity and decrease glucose absorption. Therefore, biguanide related compounds (BRCs) were studied in several fruits and vegetables and results revealed that the vegetables or fruits which we consume in our daily routine not only provide us nutrition but also have antidiabetic effect on our body. Presence of individual biguanide related compound (BRCs) was also checked in potato peel and flesh through HPLC and potato peel was found to contain higher concentration of these compounds compared to flesh. The concentration of BRCs varied from 0.47 mg/g FW to 1.90 mg/g FW in peel. Microwaved chips were prepared from different processing and non-processing/table varieties varying in sugar content. Along with good appearance, the chips prepared from K. Bahar contained high concentration of flavouring compounds, which makes it possible to use such high sugar varieties also in preparation of chips using microwave. Potato chips were prepared in six different frying oils and stored in ziplocks and in presence of nitrogen for 3 months and were analyzed for the flavouring compounds (AMP+GMP). The results revealed that out of the six tested frying medium, rizol rice bran oil is superior as far as flavor is concerned. Nitrogen flushing not only protected the chips from rancidity, but also helped in flavor retention. For faster detection of glucose from potato tubers, dipsticks were developed. The developed method is highly sensitive (can detect glucose upto 50 ppm concentration), quick (2-5 min.) and simple (anyone can perform). Further, the developed dipsticks were checked for their stability and shelf life and were found to give promising results up to one year. To explore the potential of potato flour as humectant/anti staling agent in bakery products (muffins), an experiment was planned to utilize eight variants of potato flour prepared from processing grade (K. Chipsona-1) and table purpose potato variety (K. Lauvkar). The internal texture and colour of products remained unaffected by incorporation of potato flour. Potato starch based films were prepared with varying concentrations of antimicrobial agents and results showed that potato starch can not only be used for film making, but can also be utilized as replacement of polypropylene due to its higher strength. Under breeding for development of nutrient rich potato varieties, hybrid MSP/15-51 may be selected for high anthocyanins and hybrid MSP/15-26 for high total carotenoids.

Division of Social Sciences

During this year, a survey of 25 farmers of Shimla and 10 each of wholesalers and retailers in Chandigarh was conducted to estimate price spread in potato marketed from Shimla during off season. The results revealed that Retailer's sale price/consumer's purchase price was Rs 2110.00/q whileProducer's sale price / Wholesaler's purchase price was Rs 1705.50/q and the price spread among different components was Rs 714.10/q. Net price received by producer was 66.15% of consumer price.

Another survey was conducted in Jalandhar, Hoshiarpur and Ludhiana district of Punjab covering 135 farmers to assess varietal adoption pattern and cost of cultivation. It was observed that Kufri Pukhraj was the most popular variety occupying more than half of area in both Jalandhar (50%) and Hoshiarpur (76%) district. But, in case of Ludhiana due to contract farming, processing varieties from private companies like Pepsico viz. Lady Rosetta, FC-3 and FC-5 were popular among farmers. While CPRI varieties like Kufri Chipsona-1 and Kufri Chipsona-3 were also having significant area under potato. Cost of cultivation of potato was also worked out in these three districts of Punjab. On an average, cost of potato cultivation in Punjab was found to be Rs 1,22,054/ ha with highest contribution of seed cost (56.7%) followed by human labour (23.8%) and fertilizers (11.9%). In another study, economic impact of Kufri Khyati was assessed by survey of farmers in UP. The cost of cultivation and Gross as well as Net return were calculated for Kufri Khyati and was compared with prevailing variety Kufri Pukhraj to assess its economic impact. The variable cost of cultivation of K. Khyati (Rs 1,47,738/ha) was higher than Kufri Pukhraj (Rs 1,38,155/ha). But, due to higher yield and higher selling price of Kufri Khyati, gross as well as net return was higher for K. Khyati. Net return of Kufri Khyati was Rs. 1,51,623/ha which was nearly Rs.32000/ha higher than that of Kufri Pukhraj. Cost of cultivation study in Nalanda and Patna districts of Bihar was also studied. It was observed that on an average, variable cost of potato cultivation in Nalanda was Rs 131852/ha with highest contribution of seed cost (42.9%) followed by human labour (29.6%) and machine labour (10.5%). In case of Patna, the variable cost of cultivation was estimated to be Rs 106215.20/ha in which maximum contribution was that of human labour (35.5%) followed by seed cost (25.7%) and fertilizers and manure (13.9%). Higher cost of cultivation in Nalanda can be attributed to its high seed rate and use of good quality seed at a higher price. Variable cost of cultivation of potato was worked out in Hooghly and Bardwan districts of West Bengal through survey method covering 130 farmers. Results revealed that, on an average, variable cost of potato cultivation in both Hooghly and Bardwan was Rs 143593/ha. The highest contribution was that of seed (39.7%).

Moreover, a total of 49 demonstrations were carried out of which 20 in Shimla district of HP, 19 in East Champaran district of Bihar and 10 in different parts of Uttar Pradesh. The demonstrated varieties like Kufri Himalini and Kufri Girdhari in Shimla, Kufri Garima in UP and Kufri Khyati, K. Lalit and K. Sindhuri in Bihar out yielded local verities of that region. Enhancement in yield was recorded from 16 to 62% over local check. During this period, we also conducted 10 trainings programmes of different durations at ICAR-CPRI, Shimla and several 1 to 5 days trainings at its regional stations to train farmers in improved methods of potato cultivation. Many *kisan gosthies* were organized at Shimla and regional centres under *Mera Gaon, Mera Gaurav* Programme during 2016-17. The experts from institute also took part in 12 live phone-in programmes/agricultural talk on Shimla Doordarshan.

Research Programmes

Research Programmes, Programmes Leaders and Associates

1.	Management and enhancement of potato germplasm HORTCPRICIL201500100129	**PI: Dr. Vinod Kumar. Associates:** Drs. Vinay Bhardwaj, Rajinder Singh, JK Tiwari, Dalamu, G Vanishree, Tanuja Buckseth, Raj Kumar, R. Sudha, Ashiv Mehta, Ratna Preeti Kaur, SK Luthra, Shambhu Kumar, Name Singh, Bandana, S Roy, Kamlesh Malik, Sanjeev Sharma, Jeevalatha A, Baswaraj R, Ravinder Kumar, Aarti Bairwa, Jagdev Sharma, SomDutt, EP Venkatasalem, Divya K Lekshmanan, Anil Gupta, KR Naik, Kiran Kumar, Shruti Gupta, Kameshwar Sen and Vineet Kumar.
2	Breeding to evolve trait specific varieties for resistance to biotic and abiotic stresses, productivity, quality and adoptability. HORTCPRICIL201500200130	**PI: Dr. SK Luthra. Associates:** Drs. VK Gupta,Raj Kumar, JK Tiwari, RP Kaur, Shambhu Kumar, Mehi Lal, Sanjay Rawal, Vinay Bhardwarj, Bandana, Dalamu, G Vanishree, Ashiv Mehta, Rajinder Singh , R. Sudha, J.S. Minhas, Sanjeev Sharma, S Sundaresha, Baswaraj Raigond, Jeevalatha, Aarti Bairwa, Brajesh Singh, Devendra Kumar, Name Singh, Som Dutt, Raja Shankar, Vinod Kumar, EP Venkatasalam, Sarla Yadav, Babita Chaudhary, Maharishi Tomar and Divya K Lekshmanan
3	Genetic enhancement of potato through molecular and genomic tools. HORTCPRICIL201500300131	**PI: Dr. JageshKumar Tiwari. Associates:** Drs. VK Dua, Som Dutt, VU Patil, S Sundaresha, Vinay Bhardwaj, Raja Shankar, Hemant Kardile, Ashiv Mehta, Rajinder Singh , R. Sudha, J.S. Minhas, Brajesh Singh, Shashi Rawat, Raj Kumar, SK Luthra, Dalamu, Pinky Raigond, Baswaraj Raigond, A Jeevalatha, Sanjeev Sharma, Clarissa Challam, Vinay Sagar, Aarti Bairwa, EP Venkatasalem and Priyank Mhatre.
4	Impact, Adaptation & Management Strategics for climate resilient potato production HORTCPRICIL201600100139	**PI: Dr. VK Dua. Associates:** Drs. RK Singh Devendra Kumar, Jagdev Sharma, Shashi Rawat, Sanjay Rawal, SP Singh, Sanjeev Sharma, J S Minhas, S.K. Yadav, Mehi Lal, Kamlesh Malik, Anuj Bhatnagar, VK Gupta, Vinay Sagar, Som Dutt, Prince Kumar, Hemant Kardile, Mohd. Abbas Shah, Sushil Kumar, Islam Ahmad, Yogesh Gupta, Vijay Paul (IARI), Subhash Chander (IARI) and Parimal Sinha (IARI).

5	Integrated nutrient and water management for improved productivity of potato HORTCPRICIL201500500133	**PI: Dr. Manoj Kumar, Associates:** Drs. VK Dua, Name Singh, Jagdev Sharma, Raj Kumar, M.A. Khan, S.K. Yadav, Prince Kumar, SP Singh, Bapi Das, Shashi Rawat, Pooja Chaukhande, Dalamu, VU Patil,Sarla Yadav, Sushil Kumar and Yogesh.
6	Biology, epidemiology, modeling and management of insect pests, vectors and cyst nematodes of potato. HORTCPRICIL201500600134	**PI: Dr. (Mrs.) Kamlesh Malik, Associates:** Drs. Anuj Bhatnagar, Sridhar Jandrajupalli, Aarti Bairwa, JeevalathaArjunan, Baswaraj Raigond, Ravinder Kumar, S Sundaresha, JK Tiwari, VK Dua, Raja Shankar, Vinod Kumar, Murlidhar Sadawarti, Sanjeev Sharma, EP Venkatasalem, Shashi Rawat, Vinay Sagar, Vinay Bhardwaj, Kapil Kumar Sharma, Mohamad Abas Shah and Priyank Matre.
7	Re-defining epidemiological parameters and management approaches for potato pathogens. HORTCPRICIL201500800136	**PI: Dr. Sanjeev Sharma. Associates :** Drs. Vinay Sagar, A Jeevalatha, Baswaraj R, S. Sundaresha, Ravinder Kumar, S Roy, Mehi Lal, Rahul Bakade, Shashi Rawat, Anuj Bhatnagar,Vinay Bhardwaj, Aarti Bairwa, EP Venkatasalam, VU Patil, J Sridhar, Kamlesh Malik, Prince Kumar, MJ Sadawarti, Pinky Raigond, Mohamad Abas Shah, Priyank Matre, Murari Lal, Subhash Chand, Islam Ahmad and YP Singh.
8	Post harvest management and nutritional enhancement of potatoes HORTCPRICIL201500800136	**PI: Dr. Brajesh Singh. Associates:** Drs. Jagdev Sharma, SK Luthra, Vinay Bhardwaj, Vinay Sagar, Som Dutt, Pinky Raigond, Baswaraj Raigond, Bandana, S Sundaresha, Ratna Preeti Kaur, Dalamu, Dhiraj K Singh, Sanjay Rawal, Hemant Kardile, Pynbianglang Kharumunid, Sushil Kumar, Maharishi Tomar, Abhijit Kar, Vineet Sharma, Yogesh Gupta and Shelly Chopra.
9	Resource optimization in potato based cropping system HORTCPRICIL201500900137	**PI: Dr. Sanjay Rawal. Associates:** Drs RK Singh, VK Dua, Devendra Kumar, Kamlesh Malik, Jagdev Sharma, Vinay Singh, Sunil Gulati, Sukhwinder Singh, Anuj Bhatnagar, Dhruv Kumar, SP Singh, Ashwani Kumar Sharma, Shashi Rawat, EP Venkatasalem, Dhiraj Kumar Singh, Murlidhar Sadawarti, Mehi Lal, RP Kaur, Bandana, Tanuja Buckseth, Pooja Chaukhande, Prince Kumar, Clarissa Challam, Pynbiangland Kharumnuid, Divya K Lekshmanan, Brajesh Nare, Priyank

		Mhatre, Bapi Das, Harvir Singh, KP Singh, RK Samadhiya, Sanjay Sharma and TJ Purakayastha.
10	Assessment of potato technologies and its transfer to stakeholders for improving potato production HORTCPRICIL201501000138	**PI: Dr. NK Pandey. Associates:** Drs. RK Singh, Dhiraj K Singh, Pynbiangland Kharumnuid and Ashok Chauhan.
11	Production of breeder seed of potato through conventional and hi-tech system HORTCPRICIL201501100132	**PI: Dr. RK Singh. Associates:** Drs Devendra Kumar, Tanuja Buckseth, Vinod Kumar, Ashwani Kumar, Vinay Singh, Dhruv Kumar, Prince, Ratna Preeti Kaur, S Roy, SP Singh, MJ Sadawarti, Manoj Kumar, RK Singh, Rahul Bakade, EP Venkatasalem, Parvesh Jassal, Sumita Sharma, RK Verma, Balak Ram, KP Singh, Harveer Singh, NK Sood, Jasvir Singh, Santosh Kumar, Pushpender Kumar, Satinder Kumar, Kapil Kumar Sharma, Akhilesh, Arun Kumar Singh, YP Singh, RK Samadhiya and Sanjay Sharma.

Division of Crop Improvement

Programme: Management and enhancement of potato germplasm

1. Collection: Efforts were continued to augment the potato germplasm collection at CPRI, which is the designated National Repository for Potato germplasm. During the year under report, 4 accessions were imported from The Netherlands and 10 from USA. In total 14 accessions were imported from 2 countries and 4 accessions were added to cultivated germplasm collection after quarantine clearance. The present germplasm collection at CPRI consists of more than 4300 accessions of cultivated and wild species from 30 countries **(Table 1)**.

Table 1. Potato germplasm holding at CPRI, Shimla

Material	No. of accessions				No. of donor countries
	Tuber	*In vitro*	True seed	Total	
a) Tuberosum (Cultivars / parental lines) **Indian**					
Cultivars bred at CPRI	50	50		50	
Advanced hybrids	86	50	-	96	
Indigenous varieties	51	22	-	56	
Indigenous samples	97	43		97	
Exotic	1837	2500	-	2500	30
b) Andigena	770	77	-	770	5
c) Wild/ semi-cultivated sps.	112 (34 species)	51 (15 species)	972 (104 species)	1082 (118 species)	5
Total germplasm				4311	

2. Conservation:

a) Field conservation: One thousand five hundred and fifty-two Tuberosum accessions, 762 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, 499 clones of 142 accessions of 54 Solanum species were maintained in tuber form in glasshouse/ polyhouse whereas, 340 accessions of 71 species were maintained in TPS form. In total, 482 accessions (both in tuber and TPS forms) of 125 species were conserved at CPRI, Shimla.

b) *In-vitro* conservation: Nearly 2500 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. Mericlones of different hybrids and varieties were developed and tested for their freedom from all viruses. The results were quite encouraging as 14 varieties namely K. Megha, K. Khyati (Modipuram clone), K. Ashoka, K. Khyati, K. Himalini, K. Jyoti, K. Badshah, K. Frysona, K. Bahar, K. Lauvkar, K.

Chipsona-1, K. Pukhraj, K. Chipsona-3 and K. Surya, besides 8 advanced hybrids viz., MS/08-1148, P/05-75, HT/05-1105, WS/05-146, P/02-14, MS/06-1947, MS/08-1565 and MS/07-645 were found free from all viruses.

c) Cryopreservation of potato germplasm: Pollen of six potato varieties namely Kufri Garima, Kufri Chipsona 3, Kufri Lalit, Kufri Khyati and Kufri Gaurav were cryopreserved after packing in gelusil capsules, kept in cryo-vials and immersed in liquid nitrogen cryocan **(Fig. 1)** for future use. The pollen viability of cryopreserved pollen grains was tested after 24 hrs of cryopreservation using in vitro germination of pollen grains. The germination percentages and percentages of non-germinated viable and inviable pollen grains for different treatments were statistically analysed. The **Fig. 2** depicts the occurrence of the three observable pollen types in potato based on percentage out of total. The proportion of the viable pollen types varied in fresh pollen samples of varieties varieties with 13.53 in K. Khyati, 13.632% in K. Chipsona-3, 6.18% in Kufri Lalit, 11% in K. Garima and 6.38 in K. Gaurav.

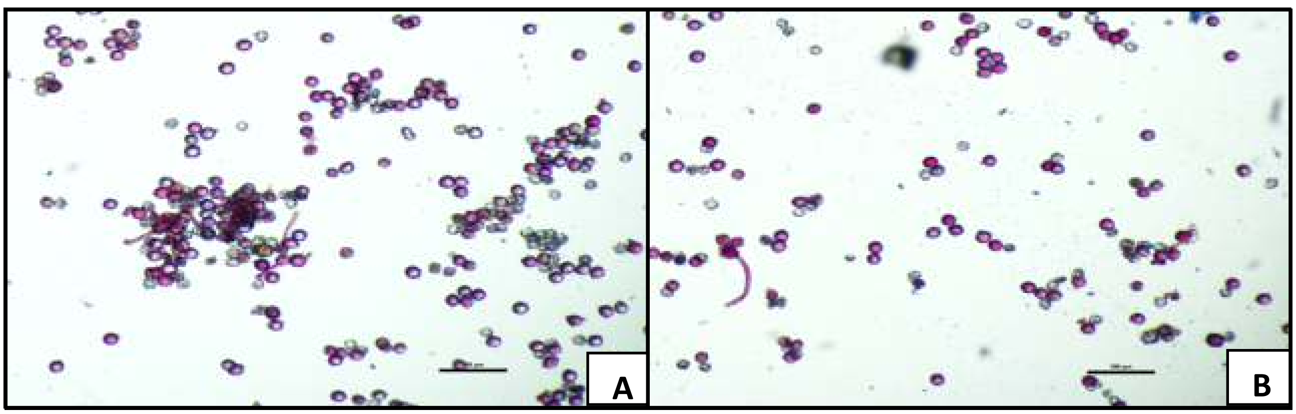


Fig. 1. Comparison of A: Fresh pollen of K. Gaurav B: Cryopreserved pollen after 24 hrs of cryopreservation

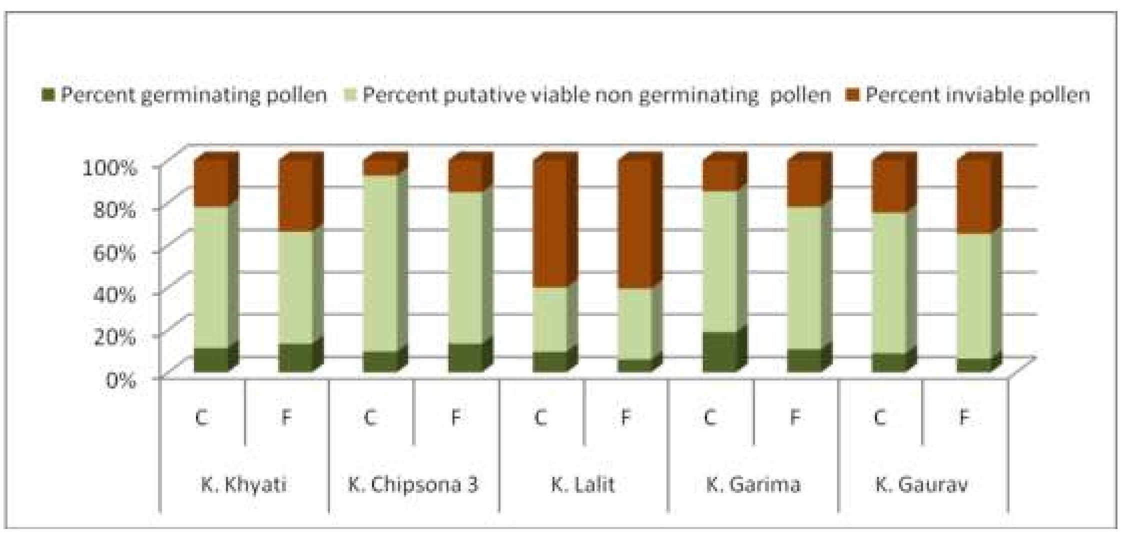


Fig. 2. Percentage pollen types observed in different varieties and pollen status (germinating pollen, putative viable non-germinating pollen and visibly in viable pollen) where C is Cryopreserved pollen and F is fresh pollen.

3. Evaluation: As in previous years, a large number of accessions were evaluated for various biotic and abiotic stresses and also for adaptability and physcio-biochemical qualities. Promising accessions identified in these evaluations are listed in **Table 2**.

Table 2. Evaluation of potato germplasm

Character	Location	No. of accessions evaluated	Promising accessions*
Adaptability	Kufri	160	CP Nos.3094, 3116, 3159, 4387 and 4430
	Jalandhar Spring	100	None out yielded the best control Kufri Jyoti (380 g/plant)
	Modipuram Autumn (early)	59	CP 4238, CP 4283, MP/91-132, MP/98-42 and K. Arun
	Autumn (Main)	51	K. Garima, J/95 -242, K. Sadabahar, K. Pukhraj, J/95-227, K. Kyati, MP/98-42, K. Surya and MS/95-4904
Late blight Foliage	Kufri (field)	115	10-HR; 10-R; 34-MR (Promising CP Nos: 3087, 3183, 3197, 3204, 3505, 4387, 4401, 4428, 4429 and 4430)
	Kufri, Shillong & Ooty (field)	94	Six accessions (CP Nos. 1187, 1398, 3470, 3787, 4051 and 4118 were promising at all the three locations)
	Shimla(Lab)	56	3-HR(CP 3983, CP 4188 & CP 4363); 17-R and 17-MR
Tuber	Shimla(Lab)	57	14-HR (CP Nos:1328, 1652, 1696, 1875, 2059, 2392, 3167, 3388, 3987, 4133, 4406, 4408, 4428 & 4430)
Viruses PVX & PVY	Shimla	45	3- R (CP 3767, CP 3872 & CP 4368 to PVX & PVY) ;19-R (PVY); 8-R (PVX)
PSTVd	Shimla	300	38 accessions were infected.
Leaf hopper and Mites	Modipuram	86	18 accessions(CP Nos.3605, 3618, 3619, 3627, 3631, 3639, 3641, 3641, 3647, 3651, 3655, 3671, 3672, 3677, 3681, 3689, 3715 and 3754,) had below 5% damage to both pest.
Cyst nematodes	Ooty	67	4 accessions viz., CP Nos.1302, 3179, 4406 and 4408 were resistant to both the species of PCN.
Keeping quality	Jalandhar	123	12- Best keepers(CP 4139, CP 4143, CP 4164 and JEX/A Nos. 164, 189, 316, 380, 595, 715, 717, 807 & 1126); 42-Good Keepers.
Chipping	Jalandhar	75	6 accessions viz. CP Nos. 4082, 4096, 4139, 4242, 4311 and 4313 were found to be suitable for chipping.
Vitamin C	Modipuram	75	CP Nos1817, 1829, 1836, 1873, 1875, 1881, 1890, 1897, 1905, 1915, 1920, 1933, 1940 and 1945 (> 31 mg/100 g fr.wt.) were promising.
Micro nutrients (Zinc & Iron)	Shimla	13	For Zinc content Rajendra II & P/6-24 For Iron content P/6-24 & Rajendra- II
Protein Content	Shimla	100	CP Nos.1706, 2339, 3625, 3763, 4096, 4149 and JEX/A 275 (> 0.8% soluble protein)
Water use efficiency	Modipuram	26	6 accessions viz., CP 1316, CP 1330, CP 1937, CP 2013, CP 2148 and CP 2340 were promising.
Foliage maturity	Patna	338	15 accessions (CP Nos. 1162, 1163, 1289, 1385, 1386, 1388, 1465, 1547, 1553, 1607, 1753, 1769, 1815, 1822 and 2054) were early maturing having > 80% foliage maturity at 70 days after planting

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

a) Evaluation of wild potato species for foliar blight resistance: In detached leaf assay, 173 clones of 77 accessions of 32 different wild potato species were screened for foliar late blight resistance at Shimla. 19 clones of 10 species were highly resistant {lesion area (cm2) ≤1} while 107 clones of 25 species were resistant (lesion area 1.1-2.5) (Table 1). 33 clones of 10 species were moderately resistant (lesion area 2.51-6.0). Remaining only 14 clones (8% of total clones evaluated) were susceptible (lesion area >6.0). Highly resistant clones were: 1767-08 *(S. ambosinum)*, 2178-04 *(S. bulbocastanum ssp. bulbocastanum)*, 1825-03 *(S. cardiophyllum ssp. cardiophyllum)*, 2694-0 *(S. demissum)*, 2741-02, 2741-05 *(S. kurtzianum)*, 2609-19, 2610-03, 2612-05 *(S. microdontum)*, 2616-07, 2658-01 *(S. pinnatisectunm)*, 2710-18, 2713-07 *(S. stoloniferum ssp. stoloniferum)*, 3124-0 , 3124-01, 3125-04 *(S. trifidum)*, 2781-14, 2788-05, 2792-26 *(S. tuberosum ssp. andigena)*.

Under natural epiphytotic conditions at Shimla, 112 clones of 42 accessions of 24 different wild potato species were screened for foliar late blight resistance. Based on late blight data collected 3 times over a time interval of 10 days followed by 9 days after first disease symptom appearance in the control, and there after AUDPC calculation, 9 clones of 4 species were highly resistant (AUDPC≤100) while 7 clones of 2 species *viz., S. microdontum* and *S. tuberosum ssp.* andigena were resistant (AUDPC101-200) (Table 2). 13 clones of 5 species were moderately resistant (AUDPC 200-300). Remaining 83 clones (74% of total clones evaluated) were susceptible (AUDPC >300).

Table 3. Screening of wild potato species for foliar blight resistance in open condition

Level of resistance	Promising Clones (Species)
Highly resistant	2625-0 *(S. berthoultii)*, 2635-02 *(S. demissum)*, 2610-01, 2610-02, 2610-05, 2610-07, 2610-08, 2610-09 *(S. microdontum)*, 2615-08 *(S. pinnatisectum)*
Resistant	2610-06 *(S. microdontum)*, 2686-0, 2781-09, 2781-19, 2781-24, 2781-26, 2781-27 *(S. tuberosum ssp. andigena)*
Moderately resistant	2609-19, 2610-10, 2610-15 *(S. microdontum)*, 2614-01, 2614-02 *(S. pampasense)*, 2657-0 *(S. pinnatisectum)*, 2710-12, 2710-15 *(S. stoloniferum)*, 2686-01, 2781-03, 2781-20, 2781-22, 2781-29 *(S. tuberosum ssp. andigena)*

b) Genetic enhancement of Tuberosum

With the objective to select early maturing late blight resistant clones, 144 F1C3 clones were evaluated for late blight at Kufri and for foliage maturity at Modipuram. Clones viz., TE 6, TE 36, TE 39, TE 41, TE 42, TE 44, TE 45, TE 47, TE 53, TE 58, TE 91, TE 92 and TE 122 were found to have resistance to late blight and early foliage maturity.

c) Mapping population and hybridization programme of wild species: A total 33 diploid wild species/accessions were used to develop mapping population for late blight resistance. These species were screened previously for resistance/susceptibility by challenge inoculation of P. infestans under controlled conditions. The diploid wild species resistant to late blight were used as male parent namely *S. cardiophyllum* (1 acc), *S. berthaultii* (2 acc.), *S. iopetalum* (1 acc.), *S. microdontum* (2 acc.), *S. pinnatisectum* (2 acc.), *S. polyadenium* (5 acc.), *S. polytrichon* (1 acc.), *S. trifidum* (3 acc.), and *S. verrucosum* (4 acc.). Whereas late blight susceptible parents were used as female parents *S. vernei* (1 acc.), *S. acauli* (1 acc.), *S. commersonii* (1 acc.), *S. polytrichon* (3 acc.) and *S. tuberosum* dihaploid C-13. Flower dropping was observed maximum after the pollination. Overview of flowering behaviour and crossing of few wild species under the glass-house conditions are shown in Figs. 3 and 4.

S. *iopetalum* S. *microdontum* S. *polyadenium* S. *commersonii*

S. *berthaultii* S. *vernei*

Fig. 3. Flowering behaviour of wild species planted in the glass house under Kufri conditions.

4. Documentation:

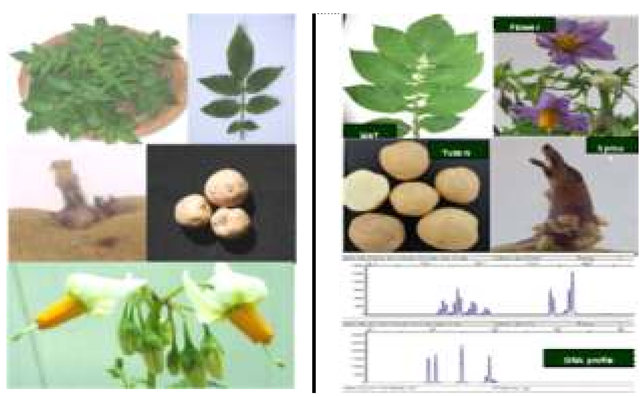
Computer databases of cultivated as well as wild species were updated by incorporating the evaluation data for various accessions. Databases of availability of various accessions at different conservation sites were also updated.

5. Germplasm registration:

Following 2 elite germplasm stocks were registered with NBPGR, N. Delhi (Fig. 4)

i. SM/00-120 **(INGR16022)**: A photo-insensitive high yielding hybrid with high resistance to late blight both in hills and subtropical plains.

ii. SS 1652-09 **(INGR16023)**: a clone of wild potato species *Solanum jamesti;* highly resistant to late blight; low cold induced sweetening after 6 months cold storage.



SS 1652 - 09 **SM/00 - 120**

Fig. 4. Registration of potato germplasm

Programme : 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, 2,01,762 true potato seeds were obtained from 128 crosses at Jalandhar, Modipuram and Patna.

Seedling stage: A total of 95,326 seedlings were raised in field from sowing of 2,56,460 true potato seeds of 164 crosses. At harvest, 9,772 promising clones were selected including 359 selections from specialty potato crosses. Crosses with CP4242 either as female or male parent produced progenies having red or purple skin/flesh colour.

Initial clonal stages: In initial clonal stages (F1C1, F1C2 and F1C3), 7,362 clones were evaluated at 60/75/90 days. At harvest 2152 promising clones were selected including 386 clones of specialty potato crosses. From 19 clones of specialty potato cross Bareilly Red x CP3770 (F1C2 stage), eight clones namely MSP/15-11 (dark yellow flesh colour), MSP/15-12 (dark yellow flesh colour), MSP/15-26, MSP/15-44, MSP/15-48, MSP/15-51 (red purple flesh colour), MSP/15- 56 (red vascular bundle) and MSP/15-60 were retained based on tuber attributes **(Fig. 1)** and nutritional components. Among these, MSP/15-26 (627 g/plant) and MSP/15-48 (573 g/plant) also produced high tuber yield than leading variety Kufri Bahar (559 g/plant). Clone MSP/15-51 possessed high anthocyanin (9.82 µg/g FW), ascorbic acid (30.08 mg/g FW) and manganese (51.85 g/kg), however it possessed moderate level of carotenoids (11.92 µg/g FW), zinc (16.32 mg/kg), iron (55.9 mg/kg and copper (8.55 mg/kg)

Fig. 1. Tubers of promising clone of specialty potato cross Bareilly Red x CP3770

Replicated yield trials: In all, 110 advanced stage hybrids were evaluated in 14 yield trials at 60/75/90 DAP at Jalandhar, Modipuram and Patna, and 37 promising hybrids were selected. In seven preliminary yield trials, 21 promising hybrids namely J/11-156, J/11-174, J/11-40, J/11-61, J/11-129, J/11-30, J/11-126, J/11-130 (Jalandhar), MS/11-664, MCIP/11-163, MS/13-110, MS/13-148, MS/13-168, MS/13-391, MS/13-518, MS/13-527 (Modipuram), KPT-29C1, KPT-36C1, PRT-4C1, PT/12-80, PT/12-8C2 (Patna) were selected from 67 hybrids evaluated. Interestingly MS13-148 (Fig. 2), produced high tuber yield with desirable tuber traits, high tuber dry matter and acceptable chip colour score (at 75 and 90 days). In four confirmatory yield trials, eleven promising hybrids namely J/10-91, J/10-127, J/10-148 (Jalandhar), MP/12-415, MS/12-935, MS12-1283, MS12-2116 (Modipuram),

Fig. 2. Tubers and chips advanced stage hybrid MS / 13-148

PS/11-31, PS/11-47, PS/11-84, PS/11-86 (Patna) were selected from 30 hybrids evaluated. In three final yield trial, five advanced hybrids namely J/9-141 (Jalandhar), MCIP/10-15, MP11-472 (Modipuram) and PS/10-02, PS/10-10 (Patna) were selected from 13 hybrids evaluated.

Promising advanced stage hybrids identified: Based on consistent good performance over the years, four hybrids namely J/9-141, MS/11-664, PS/10-02 and PS/10-10 were identified (Table 1, 2, 3, Fig. 3).

J/9-141: The hybrid with tuber yield of 28 and 38 t/ha gave 16.5 % and 10.3% higher yield over control Kufri Khyati at 60 and 75 days harvests, respectively. It possessed 16.7 % tuber dry matter. It produces yellow ovoid tubers with shallow eyes and cream yellow flesh (Table 1, Fig. 3).

MS/11-664 (Kufri Kanchan x Kufri Khyati): The hybrid with total tuber yield of 32.2 t/ha (75 days) and 42.8 t/ha (90 days) showed superiority of 13% and 10% over best control Kufri Arun (28.6 t/ha) at 75 days and Kufri Lalit (38.8 t/ha) at 90 days. The hybrid produces attractive red ovoid tubers with shallow eyes and cream flesh (Table 2, Fig. 3). The hybrid possesses 15% tuber dry matter and very good keeping quality. MS/11-664 showed some resistance to late blight under field and through detached leaf test.

PS/10-02 (Kufri Lalima x CP 1207): The hybrid with tuber yield of 27.8 and 34.8 t/ha showed advantage of 26 and 8% at 75 and 90 days respectively than best control Kufri Lalit (22.1 and 32.3 t/ha t/ha). The hybrid (Table 3, Fig. 3) produces red round tubers with shallow medium eyes and light yellow flesh having 18% tuber dry matter, medium dormancy and moderate level of resistance to late blight.

PS/10-10 (JEX/A-98-103 x CP2340): The hybrid with tuber yield of 32.8 and 38.7 t/ha showed advantage of 15 and 8% at 75 and 90 days than Kufri Pukhraj (28.5 and 35.9 t/ha t/ha). The hybrid (Table 3, Fig. 3) produces white round tubers with shallow eyes and white flesh having 18.5% tuber dry matter, medium dormancy and moderate level of resistance to late blight.

Fig. 3. Tubers of J/9-141 (A), MS/11-664 (B), PS/10-2 (C) and PS/10-10 (D)

Table 1. Promising advanced hybrid identified at Jalandhar

Genotypes	Total tuber yield (t/ha)							
	2014-15		2015-2016		2016-2017		Average	
	60 days	75 days	60 days	75 days	60 days	75 days	60 days	75 days
J/9-141	34.9	41.9	26.8	35.5	23.2	35.2	28.3	37.5
Kufri Pukhraj	26.3	38.6	23.1	33.0	23..3	30.5	24.2	34.0
Kufri Khyati	26.6	38.4	23.4	33.0	22.9	30.7	24.3	34.0
CD (0.05)	2.07	3.27	2.00	2.58	2.01	2.07		

Table 2. Promising advanced hybrid identified at Modipuram

Genotypes	Total tuber yield (t/ha)							
	2014-15		2015-2016		2016-2017		Pooled average	
	75 days	90 days	75 days	90 days	75 days	90 days	75 days	90 days
MS/11-664	26.5	37.6	34.7	43.8	35.5	46.9	32.2	42.8
Kufri Arun	20.4	32.1	32.9	41.1	32.6	41.3	28.6	38.2
Kufri Lalima	23.7	30	30.6	40.2	29.8	36.8	28.1	35.7
KufriLalit	26.3	32.8	29.9	43.7	27.6	39.7	27.9	38.8
Kufri Sindhuri	22.9	29.2	25.6	41.8	30.4	37.1	26.3	36.0
CD (0.05)	2	2.34	2.65	1.84	2.09	1.8	2.18	1.59

Table 3. Promising advanced hybrid identified at Patna

Genotype	Total tuber yield (t/ha)							
	2013-14	2014-15	2015-16		2016-17		Average	
	75 Days	75 Days	75 Days	90 Days	75 Days	90 Days	75 Days	90 Days
PS/10-02	28.9	25.3	28.3	37.6	28.7	32.0	27.8	34.8
Kufri Lalit	-	15.5	26.2	35.4	24.6	29.1	22.1	32.3
Kufri Lalima	27.0	15.2	11.0	20.3	20.1	24.5	18.3	22.4
PS/10-10	29.2	34.2	34.6	39.3	33.1	38.1	32.8	38.7
Kufri Khyati	26.1	28.7	17.1	17.3	30.6	33.0	25.7	25.1
Kufri Pukhraj	29.5	23.9	27.2	37.0	33.4	34.8	28.5	35.9
CD (0.05)	1.85	1.95	2.11	2.19	2.07	2.05	-	-

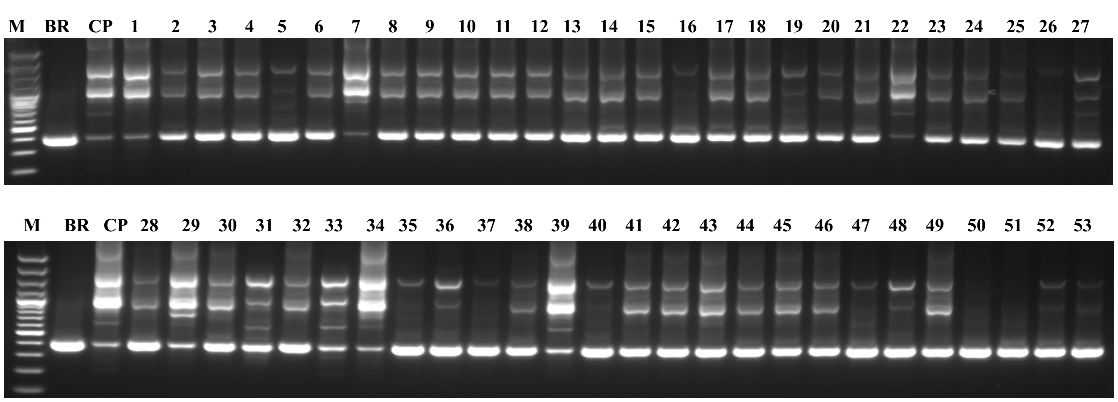
Advanced hybrids introduced in AICRP: Introduced advanced hybrid namely MS/10-1529 in AICRP for multi-location testing. MS/10-1529 (46 t/ha) produced 36, 8, 8 & 17% high total tuber yield than Kufri Bahar (34 t/ha), Kufri Garima (43 t/ha), Kufri Pukhraj (43 t/ha) and Kufri Sadabahar (40 t/ha) respectively at 90 days. It produces white-cream, round-ovoid tubers (8-

10), with medium eyes and cream flesh (Fig.4). MS/10-1529 possesses long tuber dormancy and excellent keeping quality under ambient temperature. It has mealy texture, good flavour with good taste and free from discolouration after cooking. MS/10-1529 possesses 17% dry matter content. It is moderately resistant (AUDPC:379) to late blight than Kufri Bahar (AUDPC:802) under Modipuram conditions.

Fig. 4. MS/10-1529- Leaf, flowers, tubers and sprout

Notification of new potato variety: Advanced hybrid MS/5-1543 was released and notified as potato variety Kufri Mohan by the Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, Department of Agriculture and Co-operation, Government of India, New Delhi in 24th meeting held on 22.09.2016. It 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 Kufri Bahar in northern plains and Kufri 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.

Molecular profile of progenies of cross Bareilly Red × CP3770 for flesh colour: Sixty four segregating progenies a cross between Bareilly Red and CP3770 (contrasting parents for potato flesh colour) were used to search for polymorphic markers. Sixty four progenies were profiled using 24 ISSR markers, of which only seven were polymorphic markers (ISSR2, ISSR5, ISSR10, ISSR2105, ISSRMC1, ISSRMC2 and ISSR872). These polymorphic markers showed distinct profile differentiation between two parents. Molecular profile of 64 progenies generated by a polymorphic marker ISSR2105 on 1% agarose gel is shown in Fig. 5. Dendrogram created based on the seven ISSR data as shown in Fig. 6 that shows molecular divergence among the progenies with compared to the parents.



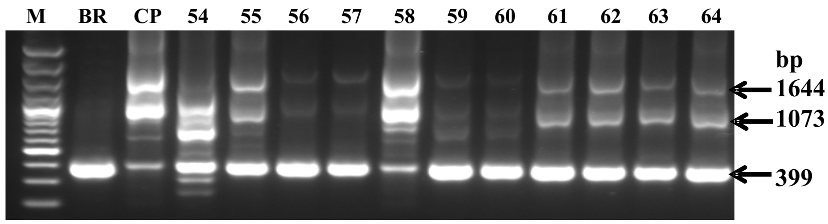


Fig. 5. Molecular profile of 64 progenies of cross Bareilly Red × CP3770 for flesh colour potato generated by a polymorphic ISSR marker (ISSR2105) on 1% agarose gel; SN 1-64 denotes samples MSP/14-1 to MSP/14-64; M=100 bp DNA ladder; Parents are denoted as: BR=Bareilly Red and CP=CP3770.

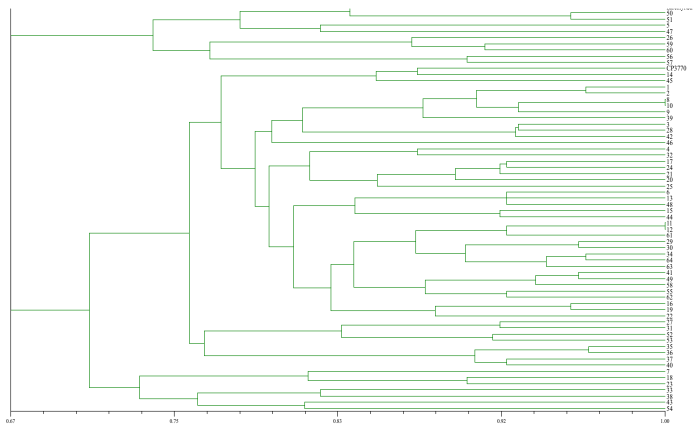


Fig. 6. Diversity among 64 progenies based on the seven polymorphic ISSR data. Dendgrogam created based on the Jaccard's similarity coefficient using UPGMA clustering method.

Optimizing agro-technology for variety Kufri Mohan: Three year investigation for optimizing fertilizer requirement of Kufri Mohan for a crop period of 90 days suggested application of 220 kg nitrogen and 80 kg potassium per hectare. Lower response to phosphorous suggested that 40 kg phosphorous per hectare is sufficient for optimum tuber yield. Increase in plant spacing from 15 cm to 30 cm does not influences marketable tuber yield significantly. So planting may be done at 60 cm row spacing, while plant to plant spacing may be increased from 20 cm to at least 25 cm (Fig. 7).

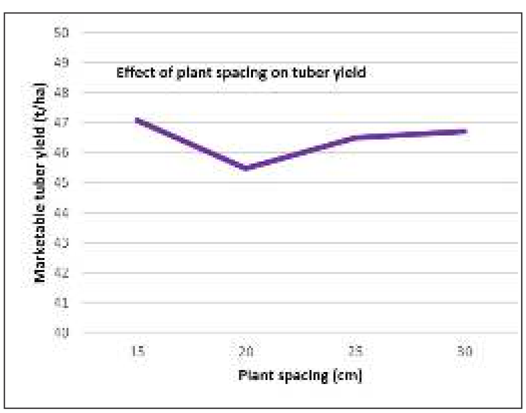


Fig. 7. Effect of plant spacing on tuber yield

Optimizing nitrogen, phosphorous and potassium requirement for advanced hybrid MS/6-1947: Nitrogen level of 280 kg/ha had significantly better marketable tuber yield (44.0 t/ha) over control (27.0 t/ha) remaining comparable to higher levels (45.4- 46.1 t/ha). This hybrid did not respond to phosphorous application and marketable tuber yields hovered between 44.1-46.5 t/ha at different doses including control. Potassium (K_2O) level of 100 kg/ha increased marketable tuber yield (43.4 t/ha) significantly over control (35.8 t/ha) and 50 kg (39.1 t/ha), while remained comparable to higher levels (Fig. 8).

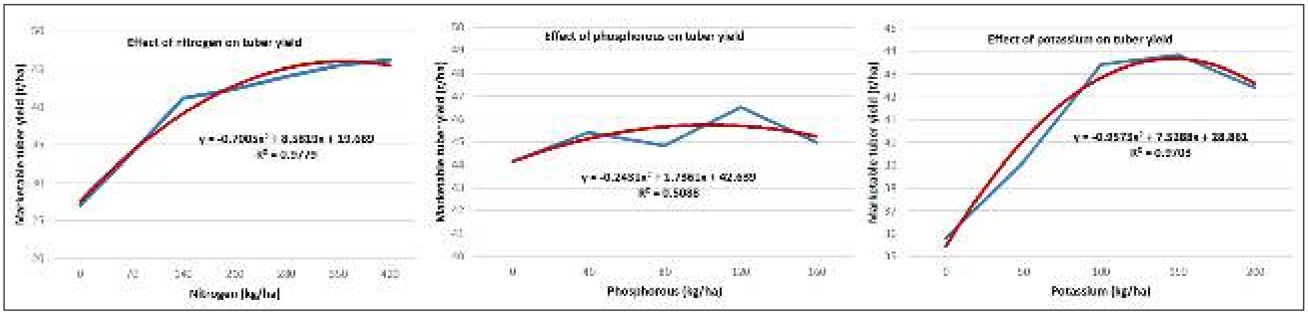


Fig. 8. Effect of nitrogen, phosphorus and potassium on tuber yield

Evaluation of advanced stage hybrids for late blight resistance at Modipuram: Results on screening for late blight on sixty nine advanced stage hybrids along with 13 varieties in field (74, 81, 88, 96 & 103 days) and lab condition revealed that all the hybrids possessed less Area Under Disease progress Curve (AUDPC) than highly susceptible variety Kufri Bahar (1099.2). Among 69 advanced stage hybrids, CPH, Card 6, Card 10 and Card 16 were devoid of late blight symptoms. In remaining genotypes, minimum AUDPC was recorded in CP4401 (7.2), MP/12-209 (30.5), CP4386 (55.3), MS/13-540 (80.8) CP4403 (101.4), MS/13-527 (116.2), MCIP/12-185 (116.9), MP/12-57 (194.3) as compared to standard cv. Kufri Bahar (1099.17). These advanced hybrids also showed less rAUDPC. By detach leaf method five hybrids viz, CPH, Card 6, Card 10, Card 16 and CP4386 were found highly resistant (HR) and four (C13, CP4403, MCIP/10-15, MCIP/12-185) were found resistant and 13 moderately resistant (CP4393, CP4401, CP4404, MCIP/12-286, MCIP/13-64, MP/12-209, MS/11-1123, MS/12-935, MS/13-401, MS/13-518, MS/13-527, MS/13-529, MS/13-540) and remaining 40 were susceptible.

Research activity 2: Breeding for processing varieties

Hybridization A total of 1,18,107 true potato seeds of 53 crosses were produced at Kufri and Modipuram.

Seedlings stage: In all, 1,18,107 TPS of 53 crosses were sown for seedling raising and at harvest, 591 clones were selected from 23,895 seedlings transplanted at Modipuram.

Initial clonal evaluation: A total of 1,108 clones were evaluated in initial clonal stages (F1C2, F1C2, F1C3 stage) and 161 promising clones were retained based on tuber characters and chip colour. In F1C4 stage, seven advanced stage hybrids namely MP/12-70, MP/12-105, MP/12-118, MP/12-126, MP/12-223, MP/12-313 and MP/12-543 were selected from the 15 hybrids tested at 75 and 90 days.

Advanced clonal evaluation: Fourteen advanced stage hybrids along with six control varieties were evaluated at 75, 90 and 110 days in two trials and on the basis of total tuber yield, processing grade yield, chip colour and tuber dry matter, eight hybrids MP/9-45, MP/10-172, MP/11-30, MP/11-34, MP/11-37, MP/11-112 and MP/11-221 were selected for chips/French fries.

Evaluation of advanced hybrids at Burdwan (West Bengal): Among the 15 genotypes evaluated at 90 days, MP/9-73 (63 t/ha), MP/11-34 (59 t/ha), MP/10-172 (57 t/ha) and MP/11-142 (54 t/ha) were found to be superior on the basis of tuber yield and processing attributes.

Performance of advanced hybrids at Jalandhar: Among 11 genotypes evaluated at 90 days, maximum total tuber yield was recorded in

MP/9-73 (41 t/ha) followed by MP/10-172 (40 t/ha). All hybrids recorded > 20% DM at harvest. Reducing sugar (RS) contents remained within acceptable limits (<150mg/100g fr wt) in all the hybrids except MP/9-73 and MP/10-172. Minimum sucrose contents were recorded in MP/8-82 (218.2 mg/100g fresh weight). Acceptable colour French fries were produced from MP/9-22, MP/9-45, MP/9-73, MP/9-82, MP/10-86 and MP/10-172 at harvest. However, acceptable chip colour was found in MP/9-82.

Performance of advanced processing hybrids at Kufri: In 1st trial, among 15 processing genotypes tested for for yield and late blight resistance, five advanced hybrids namely MP/8-214, MP/8-328, MP/8-329, MP/8-466, MP/8-1467 out yielded the best control besides either low or statistically at par late blight resistance with Kufri Himsona. In 2nd trial, among 11 processing genotypes evaluated for yield and late blight resistance, three hybrids namely MP/9-28, MP/9-45 and MP/9-82 yielded higher or at par with control for total tuber yield. Among the 51 parents being used in breeding for processing, highly resistant parents were viz., CP2011 and CP2350.

Identification of promising advanced stage hybrid: Based on consistence performance for tuber yield and processing attributes during last three years, advanced hybrid MP/10-172 (Kufri Chipsona 1 x CP3771) for chipping has been identified (Fig. 9). MP/10-172 produced 6.4 % higher mean processing (26 t/ha) and 8.4 % higher total (35 t/ha) tuber yields than Kufri Chipsona-3 (24 and 32 t/ha). It produces attractive white cream, ovoid tubers with shallow eyes and cream flesh. The hybrids possess 20% dry matter, acceptable chip colour score (2.6) and good keeping quality.

Fig. 9. Tubers and chips of MP/10-172

Advanced hybrid introduced into AICRP: Based on consistence performance during 2013-2016 for yield and processing attributes, advanced hybrid MP/9-28 (Kufri Chipsona-1 x CP1911) for chipping was introduced in AICRP for multi-location trials. MP/9-28 produced 19% higher mean processing (29 t/ha) and 10 % higher total (34 t/ha) tuber yields than Kufri Chipsona-4 (24 and 30 t/ha) and Kufri Chipsona-3 (24 and 31 t/ha). It produces attractive white cream, ovoid tubers with shallow eyes and cream flesh **(Fig 10)**. The hybrids possess 22% dry matter and acceptable chip colour score (2.2) and good keeping quality.

Fig. 10. Leaf, Flower, Sprouts and tubers of MP/9-28

Processing quality of genotypes during storage at 10-12°C with CIPC at Jalandhar: Among 12 genotypes, all hybrids (except MP/06-39) recorded more than 20% DM at 0 day and during storage. MP/9-36 showed lowest reducing sugars (122-158mg/100g fr. wt) and sucrose (178-270 mg/100 fr wt), acceptable chip colour (2.62-3.62) and French fry colour (1.62-2.62) throughout the storage period of 180 days. Fry colour remained acceptable in all genotypes namely MP/9-28, MP/9-36, MP/6-39, MP10-82, MP/4-578, MP/4-816 and MP/8-1900 up to 180 days of storage.

Optimizing crop geometry for advanced French fry hybrid MP/04-578: Advanced stage hybrid, MP/04-578 in row spacing of 66 cm., recorded highest and significantly better French fry grade (20.1 t/ha) and total tuber yield (36.4 t/ha) with plant spacing of 20 cm in comparison to 15, 25 and 30 cm. Proportion of French fry grade tubers (55.3%) was also comparable to wider spacing (Fig.11). Quality parameters i.e. specific gravity and French fry colour were not affected by different plant spacing.

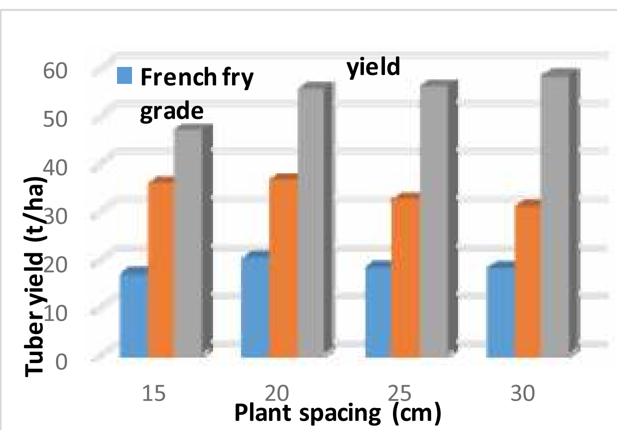


Fig. 11. Effect of plant spacing on tuber

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

Hybridization: At Shimla, out of 65 successful crosses, 84,474 hybrid seeds were extracted. It includes, about 24000 hybrid TPS were obtained to stack multiple disease resistance genes in a common host background. At Shillong, about 7,000 hybrid seeds were extracted while at Ooty about 1 lakh hybrid TPS were produced involving selected late blight and potato cyst nematode resistant parents.

Evaluation of advanced hill hybrids under sub-tropical plains to identify photo-insensitive/ day-neutral hybrids

HR 09-04

Two trials were conducted for adaptability along with controls in the plains at CPRIC, Modipuram to evaluate eighteen late blight resistant hybrids. The results revealed that hybrids, SM/00-42, VMT 5-1, LBY-2, HR 7-5 and HR 9-4 yielded significantly higher than the most prominent cultivar of the country, K. Jyoti while HR 9-4 yielded statistically higher than K. Bahar (Table 9). All these hybrids are resistant to late blight as well. The performance of the hybrid HR/9-4 is constant during two years, therefore it will be proposed for introduction in AICRP (P) multi-location trials.

Evaluation of medium maturing late blight resistant hybrids

Four late blight resistant hybrids along with three controls i.e. Kufri Jyoti (both sprayed and unsprayed), Kufri Himalini and Kufri Girdhari were evaluated in a replicated trial in F1C7 generation at Kufri. Hybrid, SM/03-23 yielded significantly higher than the best control Kufri Girdhari. The early maturing hybrid, LBY-18 possesses combined resistance to both late blight and Potato Virus Y and is a very promising parental line.

SM/03-23

4. Seedling raising and screening for resistance to late blight

A total of 15,950 seedlings of forty crosses were screened under controlled conditions against complex races of Phytophthora infestans and a total of 1945 resistant seedlings were obtained (Fig. 12). At harvest, 506 clones obtained from the resistant seedlings were advanced at CPRIC, Modipuram and 104 F_1C_2 clones were selected for evaluation to late blight/ agronomic traits at Kufri in the coming crop season.

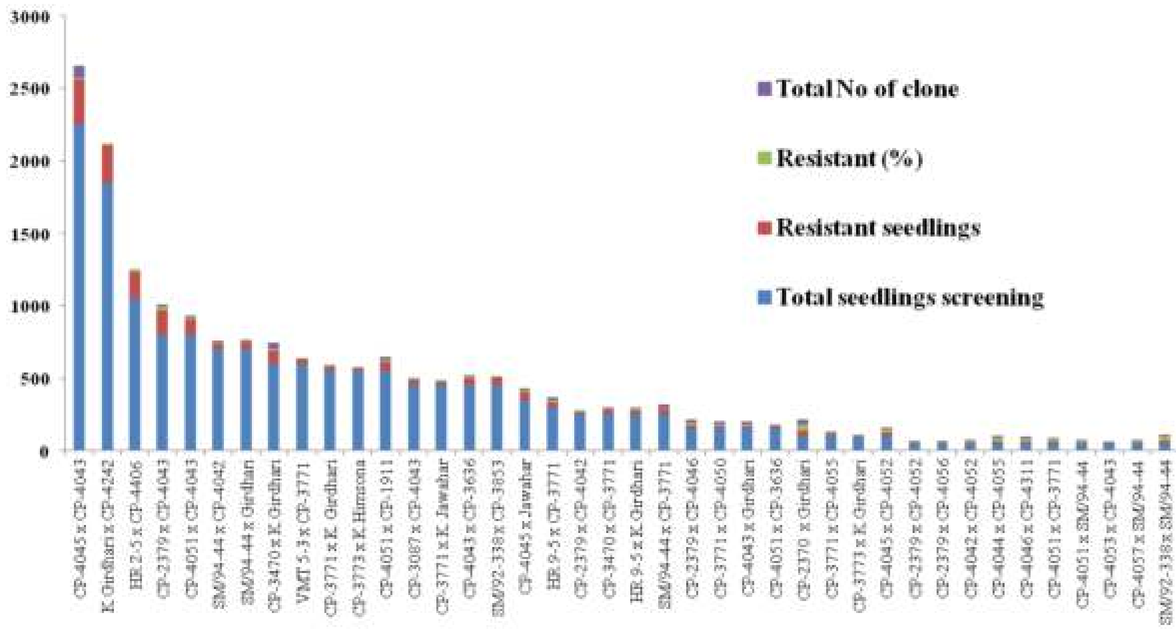


Fig. 12. Details of seedlings screened under controlled condition against complex races of *Phytophthora infestans*

Initial evaluations of hybrids

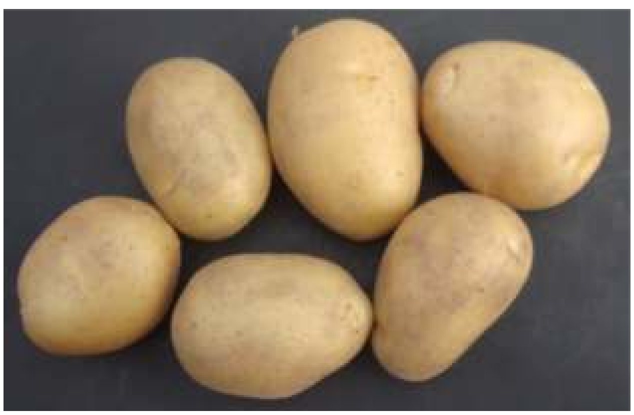
In the initial stages (F_1C_1 to F_1C_4), 155 clones were selected based on late blight resistance and tuber characteristics from 595 genotypes under natural field conditions at Kufri. Similarly, at Shillong 162 promising clones were selected. These will be evaluated in the next season for the yield and late blight resistance.

Evaluation of advanced generation hybrids

Seventeen F_1C_5 hybrids (10, 7) were evaluated in two different Randomized Block Design (RBD) trials with three replications along with Kufri Jyoti (sprayed and non-sprayed), Kufri Girdhari and Kufri Himalini as controls. Eleven late blight resistant hybrids in two trials were selected for further evaluation during the next year. In F_1C_6 generation, two hybrids, SM/10-139 and SM/09-163 yielded significantly better than the best control, K. Girdhari and 2 other hybrids, SM/08-01 and SM/09-10 which were better than the best control for yield in replicated trial were selected for further evaluation during the next year. In F_1C_7 generation SM/08-12 and SM/08-11 yielded significantly higher than the best control Kufri Himalini and their late blight resistance was also at par with the best control, Kufri Girdhari in replicated trial. At Ootacamund, OS/07-14 recorded highest yield followed by OS/08-8 while Kufri Girdhari was the best control. All the hybrids were found resistant to both species of potato cyst nematodes and field resistant to late blight. At Shillong, out of ten advanced hybrids, five promising advanced hybrids namely, SS/10-107, SS/10-187, SS/10-711, SS/09-36 and SS/09-122 were selected based on the tuber characteristics, dry matter (%), AUDPC and yield.

Multiplication & screening of advanced hybrids

Among the 3 late blight resistant advanced hybrids, SM/00-42 has performed well across locations and was further multiplied. The tuber material was supplied to all hill and kharif centres for identifying a day neutral hybrid over locations during next cropping season. These hybrids also possessed moderate to high tolerance against PVY. The results will be confirmed during next crop season.



SM/00-42

Molecular Breeding

Hybridization and early evaluations: Hybridization was done to pyramid multiple resistance genes in a common genotypic background mainly for late blight *(R1* and *R3a)*, PVY *(Ryadg, Rysto)* and potato cyst nematodes *(H1, HC_QRL* and *Gro1-4)* resistance using molecular assisted selection. A total of 23,835 hybrid TPS were extracted from 13 successful crosses.

Characterization of tuberosum core set for resistance genes: A total of 95 genotypes from the core set were screened for presence of late blight *(R1, R2, R3a, R3b)*, PVY *(Ryadg, Rysto)* and PCN *(H1)* resistance genes with reported molecular markers. Results revealed that six genotypes viz., CP 2399, CP 3917, CP 3636, CP 2314, CP 3625 and CP 3639 possessed the combination of 3 genes for late blight resistance. Similarly, genotypes with genes for resistance to Potato Virus Y and PCN were also obtained.

Characterization of parental lines for multiple virus resistance: A total of 100 genotypes including parental lines, cultivars and advanced hybrids were screened for multiple virus resistance using tightly linked molecular markers viz., GM 339, GM 637 and SPUD 237 for PVX, GP 250 for PVM, SCG17321 for PVS and NI1127 for PLRV resistance. All the 100 genotypes were tested for DAS-ELISA to detect virus PVX, PVS and PVM infection from the samples. Out of 100 samples 40 were found to be free from all the viruses. The same genotypes were also found to have virus resistant genes (Fig. 13).

Population structure analysis among cultivated and indigenous potato cultivars using microsatellite markers: Population structure analysis of 150 potato lines including cultivated, indigenous, exotic and UPOV varieties with 24 microsatellite markers (2 per chromosome) depicted the presence of two populations. In population I (green bars), 20 while in population II 29 genotypes were almost pure while all other had admixture of alleles (Fig 14).

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

Breeding for heat tolerance

Hybridization: A total of 52,011 TPS were obtained from 47 successful crosses at Kufri /Modipuram involving parents having earliness and heat tolerance.

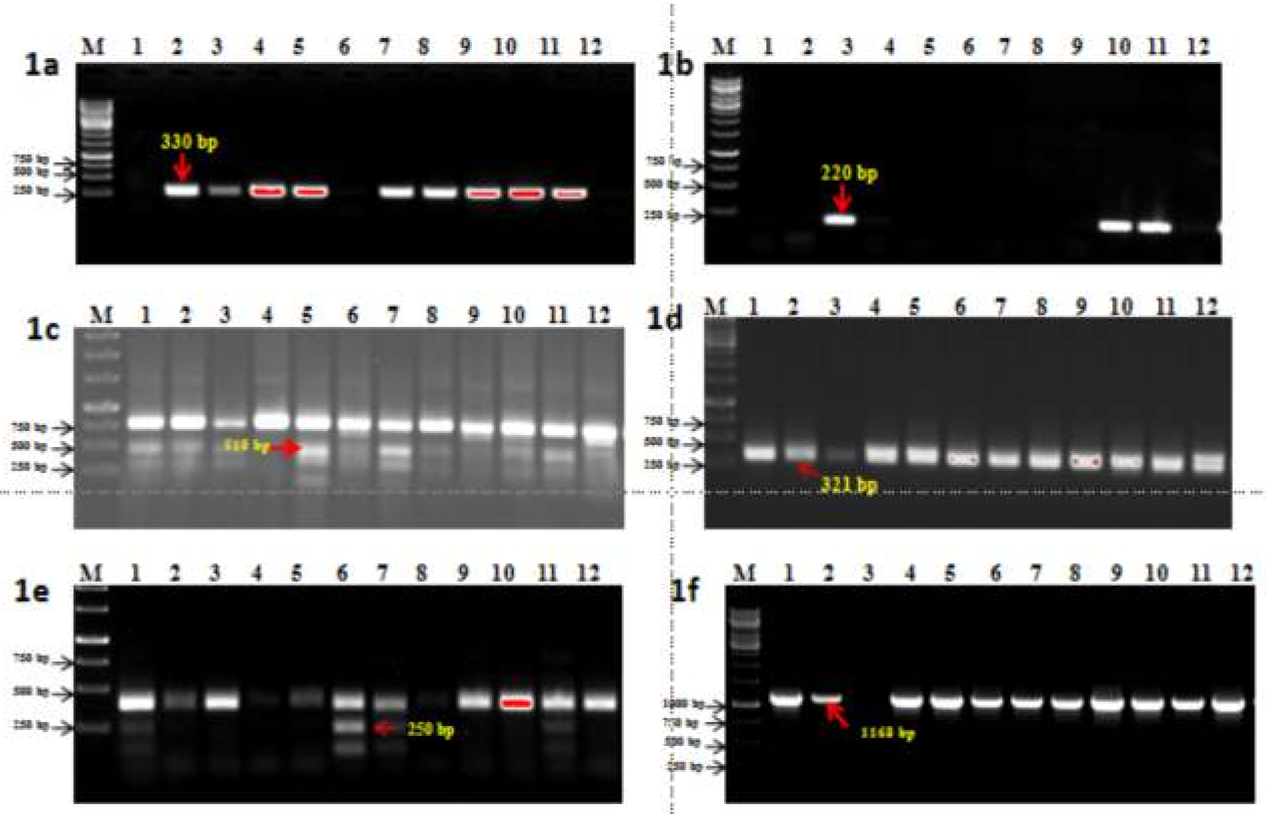


Fig. 13. Agarose gel electrophoretic pattern of selected potato germplasm accessions generated using virus resistance linked molecular markers (1a) GM 339 (PVX, PVXNb gene), (1b) GM 637 (PVX, PVXNb gene), (1c) GP 250 (PVM, Rm gene), (1d) SCG 321 (PVS, PVSNs gene), (1e) SPUD 237 (PVX, PVXNb gene), (1f) NI1127 (PLRV, Plrv.1 gene).

Fig 14: Population structure analysis of 150 potato lines using 24 SSR markers

Seedling stage: In all 5,980 seedlings were recovered from 19,705 TPS of 14 crosses and at harvest 308 selections were made.

Initial clonal stages: In all 377 clones of F1C1, F1C2 & F1C3 were multiplied and evaluated at Modipuram in winter season and 83 clones were retained at harvest.

Evaluation of advanced hybrids at Modipuram: Twenty seven advanced stage hybrids were evaluated in early crop at 75 days. In confirmatory yield trial, two hybrid namely HT/13-68 and HT/13-109 were selected from the nine hybrids evaluated. In final yield trial nine promising hybrids namely HT/10-1554, HT/10-1559, HT/10-2002, HT/10-2816, HT/11-3, HT/12-043, HT/12-116, HT/12-725, HT/12-751, HT/12-830 and HT/12-834 were retained from the 18 hybrids evaluated.

Promising advanced stage hybrids identified: Based on three year consistence performance during early planting season (2014-2017), advanced stage hybrid HT/11-3 (Kufri Khyati x Kufri Surya) produced 18% and 24% higher marketable (13.9 t/ha) and total tuber yields (15.9 t/ha) at Modipuram (Table 12). Respectively over the best control Kufri Surya (11.8 and 12.8 t/ha). It possesses white cream, oval tubers, shallow eyes and light yellow flesh. The hybrid showed less hopper and mite burn as compared to Kufri Surya. The hybrid possesses 17% dry matter, long dormancy period and very good keeping quality under country store.

Evaluation of advanced hybrids at Bhubaneswar and Ladol: Among the 11 genotypes evaluated at 90 days, hybrids HT/10-1559 (23.1 t/ha) and HT/10-2002 (19.3 t/ha) produced higher total tuber yield as compared to Kufri Lauvkar (15.7 t/ha) and Kufri Surya (17.4 t/ha) at Bhubaneswar. At Ladol (Gujarat) among eight genotypes evaluated in early rabi at 90 days, hybrids HT/10-1559 (631 t/ha), HT/10-1554 (50.3 t/ha) and HT/10-2002 (48.0 t/ha) performed superior as compared to best control Kufri Badshah (47.4 t/ha) and Kufri Surya (43.7 t/ha).

Evaluation of advanced hybrids and TPS crosses at CTCRI, Thiruvananthpuram: In all 1,851 seedlings recovered from 19,915 TPS of 16 crosses were transplanted and at harvest, 24 selections were made. Maximum selection were obtained from cross K Pukhraj x HT/13-3 (8) followed by HT/10-1554 x CP1971 (7). In preliminary screening, among six advanced stage hybrids evaluated in 15 tuber trial during rabi season, hybrids HT/7-1329 and HT/10-2002 produced higher tuber yield as compared to Kufri Surya at 90 days (Table 4, Fig.15).

Table 4. Performance of advanced heat tolerant hybrids at CTCRI, Thiruvananthpuram, Kerala

Genotypes	Tuber yield (kg/plot)		Tuber yield g/plant	Tubers/plot (1.8m^2	Tubers /Plant	Projected yield (t/ha)	
	Marketable	Total				Marketable	Total
HT/7-1329	3.75	4.95	330	112	7.5	20.83	27.50
HT/10-1554	0.80	2.15	143	78	5.2	4.44	11.94
HT/10-1559	0.63	2.93	195	76	5.1	3.47	16.25
HT/10-2002	3.28	4.48	298	76	5.1	18.19	24.86
HT/10-2816	2.50	3.30	220	75	5.0	13.89	18.33
Kufri Lauvkar	0.35	0.95	63	69	4.6	1.94	5.28
Kufri Surya	2.65	3.58	238	120	8.0	14.72	19.86

Fig.15. Evaluation of heat tolerant advanced hybrids and TPS seedlings at CTCRI,

Advanced hybrid Introduced into AICRP: Based on two year consistence performance during early planting season (2014-2016) at Modipuram, Ladol (Gujarat) and Pune (Maharashtra) advanced stage hybrid, HT/07-1329 (LT-9 x CP1748) has been introduced into AICRP for multi-location testing. It produced 6%, 12% and 23% higher total tuber yields at Modipuram, Pune and Ladol respectively over the best control Kufri Surya. The hybrid produces white cream oval tubers with shallow eyes and light yellow flesh **(Fig.16)**. The hybrid possessed 20% dry matter, medium dormancy period and very good keeping quality under country store.

Fig. 16. Leaf, flower, tuber and sprout HT/7- 1329

Screening against leafhopper burn and mite damage at Modipuram: Amongst the 29 advanced hybrid and nine varieties screened under moderate pest pressure genotypes, HT/10-1559, HT/7-1329, HT/11-3, HT/11-2912, HT/12-830 and HT/13-68 had ≤ 15.0 % mite burn and hopper burn ranged from 0 to 1.7%. Kufri Lauvkar had the highest damage due to mite (38.3%) and hopper burn (20.0%).

Screening of seedling in heated glasshouse: Forty days aged 1190 Seedlings of 8 crosses were exposed to high temperature (Day: 35-380C; Night: 22-240C). 1st and 2nd screening for tuber formation was done 45 and 60 days of high temperature exposure and seedling showing tuber formation were allowed to grow/bulk under ambient temperature. In all, 104 and 183 seedlings showed tuberization after 45 days and 60 days respectively.

Tuberization efficiency of advanced hybrids at high night temperature: Two sets of single leaf bud cutting (4th, 5th and 6th) from 30 days plant of 10 heat tolerant hybrids were exposed to 24/24°C and 24/22^{0}C day/night temperature for knowing their tuberization efficiency. Result recorded after 21 days, showed good capability of tuberization in genotypes HT/7-1329 and HT/10-1554 at 22^{0}C and HT/7-1329, HT/10-2816 and HT/12-751 at 24^{0}C.

Quantification of biomass allocation with reference to growing degree days: Biomass investigation was done in Kufri Bahar and Kufri Surya in early (22/09/16 planting) and main winter crop (20/10/16 planting). 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: $[\{(T_{max} + T_{min})/2\}-8]$ with the temperature data starting from the day of seed withdrawn from cold store. In early crop at around 1066 GDD (Fig. 17), Kufri Surya had higher biomass (29.2 g/plant) and showed its distinct growth pattern investing more biomass in stem (5.3 g/plant) and leaves (14.7 g/plant) as compared to Kufri Bahar (3.0 and 6.7 g/plant respectively). However in main winter crop season, at higher GDD 1577 accumulated in 75 days crop, Kufri Bahar showed higher biomass 70.7 g/plant as against 59.0 g/plant in Kufri Surya. However, Kufri Surya, invested more biomass in stem (5.3 g/plant) and leaves (12.5 g/plant) as compared to Kufri Bahar (2.6 and 9.0 g/plant, respectively).

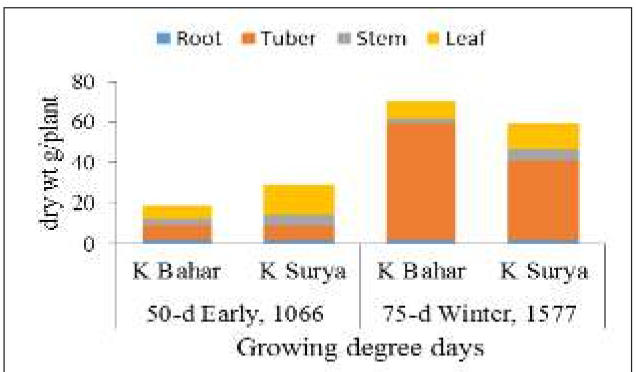


Fig. 17. Effect of growing degree days (GDD) on total biomass and its distribution pattern in potato varieties

Complete coding sequence (CDS) of eIF(iso)4E gene was cloned and sequenced: Complete Open Reading Frame (ORF) of the cloned eIF(iso)4E gene contained 603 nucleotides

```
atggccaccgaagcaccggtagaggcgacggagattccgccggtcgcggcggcggagtcg
 M  A  T  E  A  P  V  E  A  T  E  I  P  P  V  A  A  A  E  S
gtggagaagcaaccgcataagctagagaggaagtggacgttctggttcgataaccagtct
 V  E  K  Q  P  H  K  L  E  R  K  W  T  F  W  F  D  N  Q  S
aaaccgaaacagggcgccgcttggggaagttctcttcgaaaagcttatacttttgaaact
 K  P  K  Q  G  A  A  W  G  S  S  L  R  K  A  Y  T  F  E  T
gttgaggaattctggagtttatatgatcagatattcaagcccagcaagttgactgttaat
 V  E  E  F  W  S  L  Y  D  Q  I  F  K  P  S  K  L  T  V  N
gcggactttcatttgttcaaagctgggattgagcccaaatgggaagatcctgagtgtgcc
 A  D  F  H  L  F  K  A  G  I  E  P  K  W  E  D  P  E  C  A
aatggtggcaagtggactgctacaagcagcagagaggctaatctcgagactatgtggctt
 N  G  G  K  W  T  A  T  S  S  R  E  A  N  L  E  T  M  W  L
gaaacactgatggcattggttggcgagcaattcgatgagtcagaagatatatgtggagtg
 E  T  L  M  A  L  V  G  E  Q  F  D  E  S  E  D  I  C  G  V
gttgctagtgtgcgtaggagtcaagataaactttccttgtggactaagactgccaccaat
 V  A  S  V  R  R  S  Q  D  K  L  S  L  W  T  K  T  A  T  N
gaagcagctcagatgggcattggtaggaagtggaaggagatcattgataccgaaaagata
 E  A  A  Q  M  G  I  G  R  K  W  K  E  I  I  D  T  E  K  I
tcctatagtttccatgatgattctaaaagggagaggtcagctaagagccgatatactgtg
 S  Y  S  F  H  D  D  S  K  R  E  R  S  A  K  S  R  Y  T  V
tga
 -
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Fig. 18. Complete ORF & deduced amino acid sequences of eIF (iso) 4E

encoding 200 amino acids (Fig. 18). The cloned eIF(iso)4E sequence was submitted to NCBI GenBank and has been assigned accession number KX380989. The cloned eIF(iso)4E gene sequence showed allelic variations for two nucleotides (at 334th and 493rd nucleotide positions) when compared with the most identical sequence (99 % identity) of eIF(iso)4E available in NCBI GenBank (accession number FN666437). Comparison with the second most identical sequence (98 % identity) of eIF(iso)4E available in GenBank (accession number NM001288204) revealed the allelic variations for 10 nucleotides (at 74th, 132nd, 149th, 324th, 334th, 345th, 381st, 393rd, 444th and 518th nucleotide positions).

Breeding for drought tolerance

Seedling stage: In all, 4,825 seedlings were recovered from 37,000 TPS of 11 crosses and at harvest 141 selections were made.

Evaluation in Initial clonal stages: In all 451 clones of F1C1, F1C2, F1C3 and F1C4 were multiplied and evaluated at Modipuram and 75 clones were retained.

Performance of advanced stage hybrids in yield trial: Four advanced stage hybrids were assessed under normal (4 irrigations) and water stress (three irrigations) conditions along with Kufri Bahar and Kufri Pukhraj. Irrigations were regulated to be in equal quantity of water, using Parshall Flume. Besides, a winter rain (30.0 mm) was received just after last irrigation on 7 Jan 2017. Based on net photosynthesis rate, SPAD value at 72 DAP, total yield (Table 5, Fig. 19) and tuber characters under water stress conditions, hybrids WS/9-605 and WS/9-609 were selected.

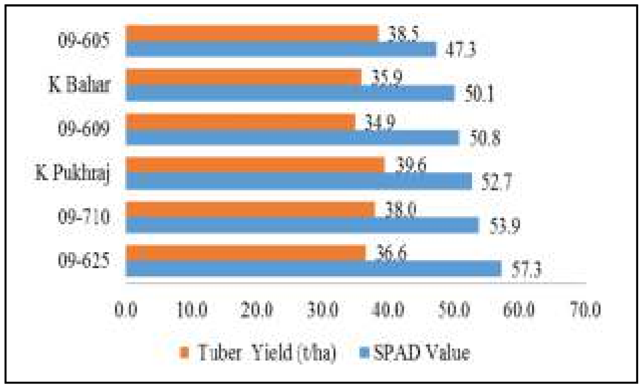


Fig. 19. Total tuber yield (90 days) and SPAD value (72 DAP) in potato genotypes under water deficit stress in winter crop. (Watering was withheld at 62 DAP)

Table. 5 Net photosynthesis and associated traits in potato genotypes screened under water deficit stress at 72 DAP in winter crop. (Watering was withheld at 62 DAP)

Genotypes	Net photosynthesis rate (μ mol $CO_2m^{-2}s^{-1}$)			Stomat conductance (s. cm^{-1})		
	Control	Stress	Mean	Control	Stress	Mean
WS/09-605	24.2	19.9	22.1	0.48	0.27	0.38
WS/09-609	25.2	17.6	21.4	0.58	0.23	0.40
WS/09-625	24.9	17.8	21.4	0.59	0.23	0.41
WS/09-710	24.5	21.1	22.8	0.65	0.43	0.54
K. Bahar	26.1	19.6	22.9	0.54	0.32	0.43
K. Pukhraj	22.4	20.2	21.3	0.47	0.29	0.38
Mean	24.6	19.4	--	0.55	0.30	--
CD (0.05)	V=NS	T=1.72	VxT= NS	V=0.08	T=0.04	VxT=NS
Genotypes	Transpiration rate (μ mol $H_2Om^{-2}s^{-1}$)			Leaf temperature (^0C)		
WS/09-605	2.32	0.98	1.65	18.7	15.2	16.9
WS/09-609	2.05	0.96	1.50	16.8	16.0	16.4
WS/09-625	2.57	0.84	1.71	18.6	14.8	16.7
WS/09-710	2.34	1.36	1.85	17.6	15.5	16.6
K. Bahar	2.44	1.08	1.76	18.5	14.3	16.4
K. Pukhraj	1.72	1.16	1.44	16.4	16.1	16.2
Mean	2.24	1.06	--	17.8	15.3	--
CD (0.05)	V=0.21	T=0.12	VxT=0.29	V=0.23	T=0.13	VxT=0.23

Evaluation of advanced hybrids for higher yield and water use efficiency: In all six advanced hybrids along with Kufri Bahar & Kufri Pukhraj were tested 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. 297, 247 & 197 mm under wet, moist & semi-dry regime, respectively during 90 days winter crop. Hybrids WS/09-605 and WS/09-625 produced significantly higher marketable and total tuber yield than than Kufri Bahar and Kufri Pukhraj at all soil moisture regimes. Hybrids WS/09-605 and WS/09-625 (1.87 & 1.81 q/ha-mm, respectively) also showed high water use efficiency specifically under semi-dry regime as compared to control varieties (<1.60).

Optimizing NPK requirement of advanced drought tolerant hybrid: The drought tolerant hybrid, WS/5-146 at 90 days revealed that nitrogen (180 kg/a) had significantly better marketable tuber yield (27.7 t/ha) as compared to control (10.8 t/a) and lower N levels (22.1- 24.1 t/ha), while it was at par with higher N levels of 240 and 300 kg ha-1 (27.1- 27.6 t/ha) (Fig. 20). WS/5-146 showed no response towards P_2O_5 application which may be due to medium to high soil available P_2O_5content. Potassium (K2O) @100 kg/ha application improved yield in WS/5-146 as this dose recorded statistically superior marketable tuber yield (27.8 t/ha) over control (21.9 t/ha) and 50 kg K_2O dose (24.9 t/ha) while remaining at par with the level of 150 kg K_2O (28.1 t/ha).

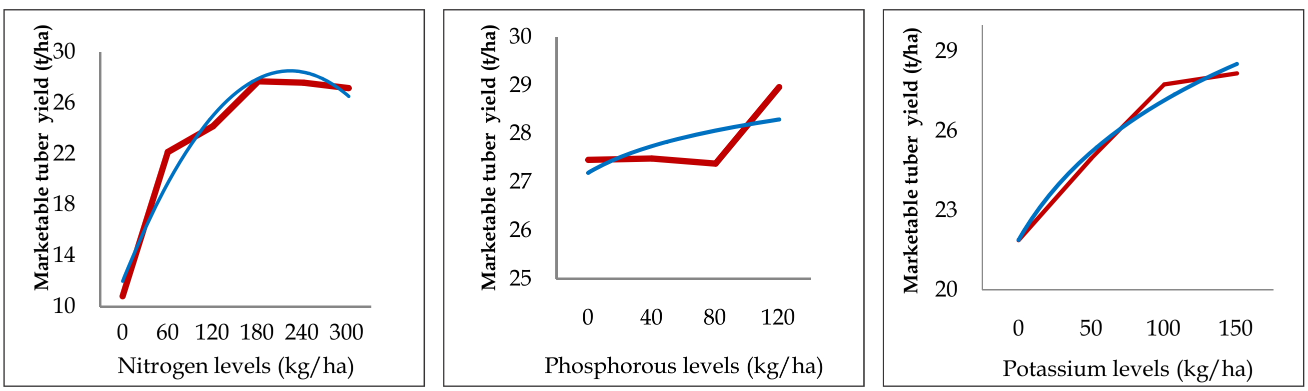


Fig. 20. Effect of NPK levels on tuber yield under water stress in WS/5-146

Evaluation of dwarf transgenic lines for morphological traits and tuber yield: Among the six dwarf transgenic lines of Kufri Surya yielded better than control with KS-13 giving the highest yield of 504 g/plant followed by KS-8 (375 g/plant), KS-11 (292 g/plant) and KS-1 (242 g/plant) compared to Kufri Surya (271 g /plant). Among the two dwarf transgenic lines of Kufri Himalini, KH-45 yielded highest (605 g/plant) followed by KH-44 (408 g/plant) compared Kufri Himalini (554 g/plant).

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.

Programme: Genetic enhancement of potato through molecular and genomic tools

Complete genome analysis of potato dry rot pathogen (*Fusarium sambucinum*): *De novo* sequenced compete genome of *F. sambucinum* strain F-4 using the Roche 454 GS (FLX Titanium) pyrosequencing platform. Shotgun sequencing yielded high quality 2,396,357 reads amounting to 919,493,539 bases and 18-fold coverage of its estimated 50 Mb genome. The GS De Novo Assembler (version 2.5.3) yielded 697 contigs (over 500 bp) with an average contig size of 54.1 kb, N50 contig size of 109 Kb and largest contig of 1044.1 kb (NCBI Bioproject PRJNA274729). The draft genome of strain F-4 has G-C content of 47.81%, and annotation revealed a total of 12,845 protein coding regions (CDSs) with 12,478 (97.14%) coding longer than 100 amino acids. Fig. 1 shows classification of the predicted F. sambucinum proteins based on biological process of the GO annotation.

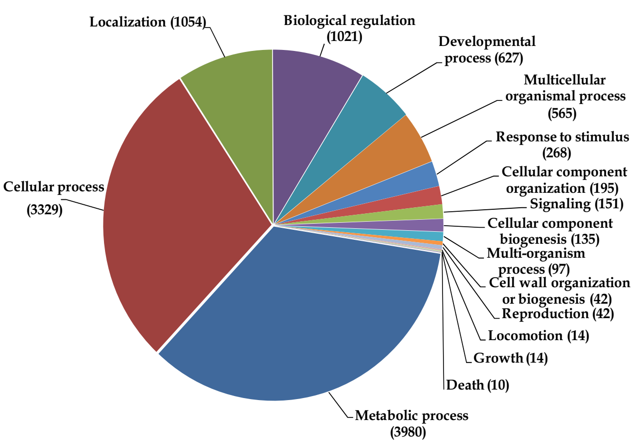


Fig. 1. Classification of the predicted F. sambucinum proteins based on GO annotation (biological process).

Complete genome analysis of potato bacterial wilt pathogen *Ralstonia solanacearum*: Sequenced genome of four strains of R. solanacearum using the above Roche 454 platform. Shotgun sequencing runs yielded 2.88 million reads (>500bp) of which nearly 99.5% reads were of high quality with genome coverage ranged from 18X (RS48) to 76X (RS75). High quality reads were mapped on to publically available reference genomes, GMI1000 (RS25 & RS48), Po82 (RS2) and PSI07 (RS75) using gsMapper with optimized mapping parameters and variants were called. The chromosomes carried higher portion (60% to 70%) of the repeat elements than megaplsmids in all the four strains **(Table 1)**.

Table1. Feature and distribution of genes in R. solanacearum strains (Rs2, Rs25, Rs48 and Rs75)

Strain	Origin	Phylotype	Sequence status	Genome size (Kb)			GC%	CDS	rRNA	tRNA
				CHR	MPL	Total				
RS-2	Indore (MP), India	IIB(1)	Draft	3,481	1,608	4,768	57.36	4,590	2	53
RS-25	Shimla (HP), India	I(45)	Draft	3,065	1,950	5,232	60.11	4,732	3	57
RS-48	Shimla (HP), India	I(30)	Draft	3,065	1,727	5,300	60.10	4,817	3	57
RS-75	Shillong (Meghalaya), India	IV(8)	Draft	2,903	1,720	5,045	60.06	4,867	2	54

CHR-Chromosome, MLP-Megaplsmid

Mapping of complete mitochondrial genome of potato late blight pathogen (*Phytophthora infestans* A_2 mating type): Sequencing of mitochondrial genome if *P. infestans* (HP10-31)-belonging to haplotype-Ia and A2 mating type-using gsFLX Titanium (Roche 454) resulted 40Mb data with coverage of 100X. Data was assembled using GS DeNova Assember and GS Ref Mapper (Roche, Diagnostics) with mitochondrial genome of Ia as reference, yielding single mega scaffold of 37,767bp covering entire genome with 22.38% GC content. A total of 55 protein-coding genes were predicted including 26 tRNA, 16 ribosomal proteins, 18 respiratory proteins, and an import protein Sec-Y (independent transport protein). The phylogenetic tree depicting genome-wide comparative studies of A2 mating type with A1 mating types *P. ramorum*, *P. sojae* and *P. andina* using average nucleotide identity (Fig. 2).

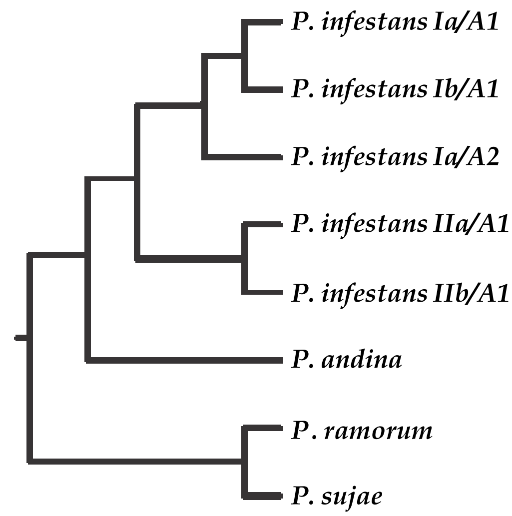


Fig. 2. Phylogeny based on pair-wise comparison of *Phytophthora* spp.

Silencing of *Phytophthora infestans* multi-genes in potato using single RNAi construct: Silencing of *P. infestans* effector Avr3a gene have been well demonstrated and proven that silencing of single gene imparts partial / moderate type of resistance. An established way to knockdown gene expression in plants is expressing a hairpin-RNAi construct, eventually leading to degradation of a specifically targeted mRNA. Accordingly, eight *P. infestans* genes encoding biochemical regulatory pathway were selected including housekeeping genes also in order to reduce the metabolic activity of the pathogen. Four constructs labelled as A, B, C and D each has two different essential genes of *P. infestans* stacked together in each the sense and antisense orientations having each pair 1000 bp for transgenic development **(Fig. 3)**.

EcoRI-HF Kpn-HF ApaI MluI BamHI HindIII
pCAMBIA1300 - Promoter+ TEV - antisense genes - Intron - sense genes - Terminator – pCAMBIA1300
35Sx2e+ TEV PIV2 Intron 35S terminator
Approximate size (bp) 760 1000 200 1000 400 8960

Fig. 3. The pCAMBIA 1300 T-DNA map of RNAi construct carrying Phytophthora infestans genes.

Stability and functionality of RB gene in late blight resistant transgenic potato: A total of 2827 *P. infestans*-responsive genes were identified in transgenic lines after challenge inoculation through cDNA microarray. To validate the basal defense genes and few unigenes with reference to potato genome sequence homology were selected and quantitative PCR analysis was performed. The analysis showed that 1.5 fold expression of SKP1, subtilase and HSP90 genes and hypersensitive responsive SOD genes showed 5.5 to 7 fold expressions in RB transgenic (KJ65) and parent SP951 lines compared to the control Kufri Jyoti at 24 h interval samples.

Separately, to confirm the R gene analogues (RGAs) in transgenic (KJ65) expression of R2 and TIR genes revealed 2.8 fold expression compared to the control. Further, PCR amplification cum sequencing revealed 99% identity with S. tuberosum disease resistance protein RPP13. Study demonstrates that RGAs in genetic background of Kufri Jyoti enhances late blight resistance by interacting with host protein complexes (Fig. 4).

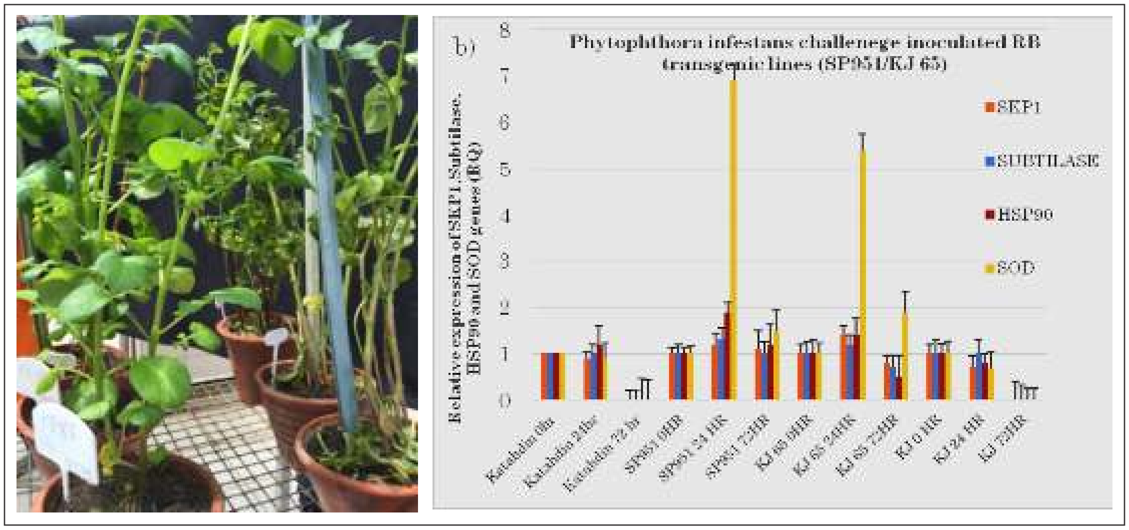


Fig. 4. Late blight resistant RB transgenic (KJ65) showed 90% resistance after challenge inoculation with the pathogen (left). Real-time PCR analysis of genes in KJ65 at different time interval (right).

RNA-sequencing of wild potato species *Solanum demissum* for late blight resistance: RNA-sequencing of *S. demissum* revealed a strong induction of Auxin signalling F-box proteins and its interacting defense proteins for inducing resistance mechanism. At different time points i.e. 24, 48 and 96 h post-inoculation (hpi) 651, 989 and 926 transcripts were differentially expressed. KEGG pathway construct depicts, the involvement of

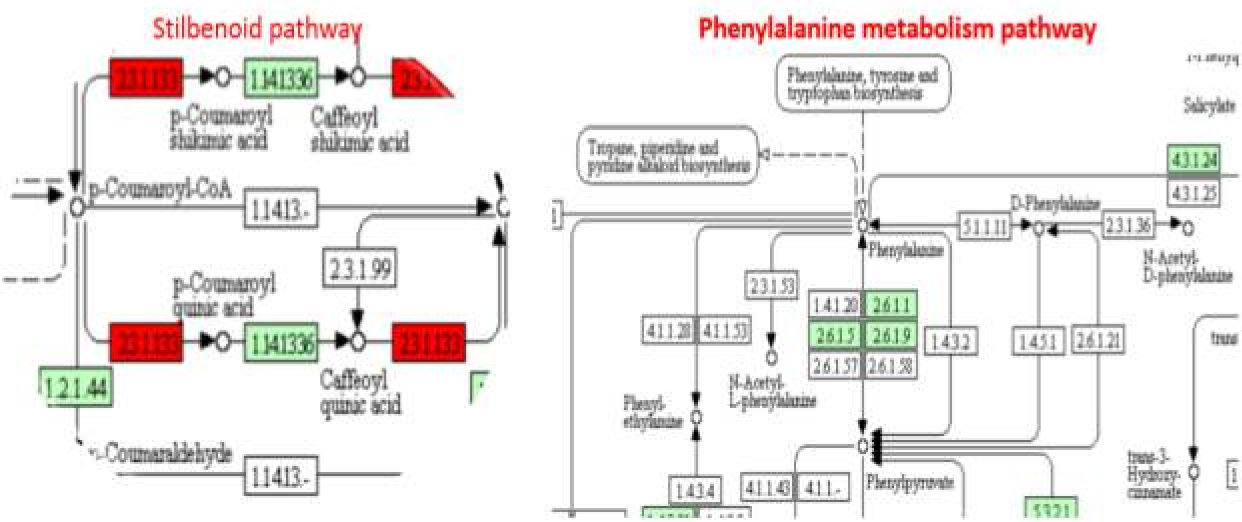


Fig. 5. Representative KEGG pathway depicts involvement of defence-responsive metabolites (flavonoids, caffeoyl shikimic acid, tyrosine and tryptohpan) in regulating auxin/ABA signalling pathway for *P. infestans* resistance in *S. demissum.*

phenylpropanoid, flavonoids, secondary metabolites, resistance related metabolites and stilbinoids for inducing late blight resistance mechanism via activating defense signalling pathways. Representative metabolism pathway involved in biosynthesis of flavonoids and resistance related metabolites involved in ABA/Auxin metabolism **(Fig 5).** Most of the highly up regulated genes belong to auxin signalling genes and ubiquitin mediated F-box proteins that might activate downstream signalling process involved in defense mechanism.

Gene expression analysis of cyclic dependent gene for potato tuberization: Development of potato varieties independent of the photoperiodic day length is a major challenging task. Cycling dependent DNA with one finger transcription factor circadian gene family underlies a major QTL for tuber initiation and well demonstrated in short-day Andigena population. Two allelic forms of CDF (CDF1.1 and CDF1.2) were investigated by PCR cycling sequencing method in short-day and long-day varieties. The strongest expression was detected at early morning (1.8 fold) followed by afternoon (1.5 fold) and declined (1.2 fold) at late evening drawn K. Surya sample compared to declined (less than 1 fold) expression in K. Chandramukhi sample. Finding indicates that CDF acts intermediate between tuberisation and plant life cycle length. Further, ten genes were used for cloning into tobacco rattle virus (TRV)-based virus-induced gene silencing (VIGS) vector **(Fig. 6)** for Agroinoculation into thermo-tolerant Kufri Surya and thermo-sensitive Kufri Chandramukhi varieties for understanding the functionality of the selected genes for tuberization.

Identification of PALCV (potato apical leaf curl virus) resistance genes in potato: Potato apical leaf curl disease caused by PALCV, transmitted by white fly, has emerged as a new problem in potato seed crop. These two varieties Kufri Bahar (resistant) and Kufri Pukhraj (susceptible) were examined to identify genes involved in PALCV resistance. Pelota and Permease I transmebranal protein gene reported to be involved in TYLCV (tomato leaf curl virus) resistance. Homologous genes were identified in potato and sequence analyzed. A single nucleotide polymorphism (SNP) was observed in pelota gene that might makes potato susceptible. Transversion is observed i.e. A to T resulting in a Glutamic acid to Aspartic acid substitution in Kufri Pukhraj.

Molecular diversity in the potato association mapping panel: A panel consisting of 304 diverse potato accessions were analyzed for genetic diversity using 25 potato SSRs markers (Fig. 7). Whole set of accessions was divided into two major clusters (I & II), and cluster #II had four

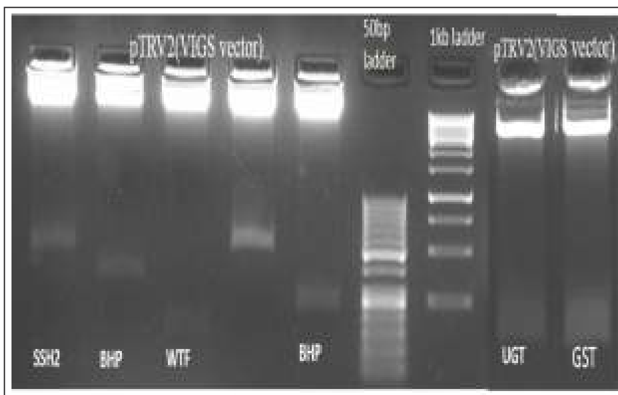


Fig. 6. Restriction digestion to confirm cloning in VIGS vector.

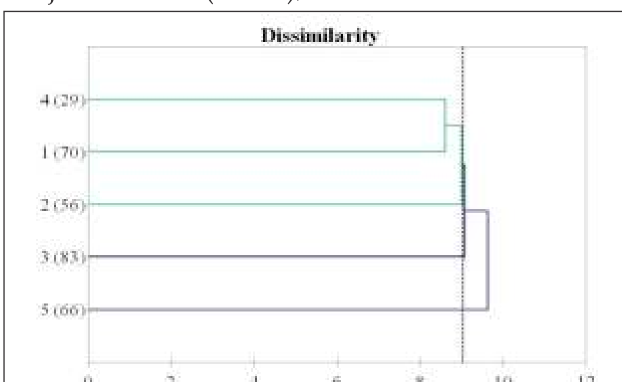


Fig. 7. Diversity in the association mapping panel of 304 accessions using 25 SSRs markers.

sub-clusters (#i-iv). The major cluster #I comprised of 70 accessions, while major cluster #II possessed 56 (#i), 83 (#ii), 29 (#iii) and 66 (#iv) accessions. All the released varieties clustered together except Kufri Alankar. It was interesting to note that all the released varieties were grouped together in the same cluster probably because of the similarity in the breeding methodology followed for their development resulting in somewhat similar genetic constitution. The association mapping panel is being used for evaluation for various traits such as micronutrients Zn (6.8-102 mg/kg), B (7-354 mg/kg) and Cu (1.6-28 mg/kg) contents.

Somatic hybridization

Molecular characterizations of interspecific somatic hybrids using AFLP markers: Interspecific potato somatic hybrid (Solanum tuberosum dihaploid C-13 + S. cardiophyllum) clones Crd6, Crd10, Crd 16 and Crd23 and the parents (C-13 and wild S. cardiophyllum) were profiled using AFLP markers. Protocols was followed according to the original protocol of EcoRI+MseI enzymatic combinations following manufacturer's instructions of the AFLP® plant mapping kit manual for the "3500 Genetic Analyzer" (ABI). Somatic hybrids were confirmed by 30 AFLP primer-pair combinations and all markers confirmed the hybridity. In AFLP analysis there were several fragments identified in somatic hybrids that distinguished the two parents **(Fig. 8)**. Dendrogram constructed using Jaccard's coefficient by unweighted pair-group method (UPGMA) clustering method with the program NTSYS-PC 2.21 showed clear differences in somatic hybrids **(Fig. 9)**.

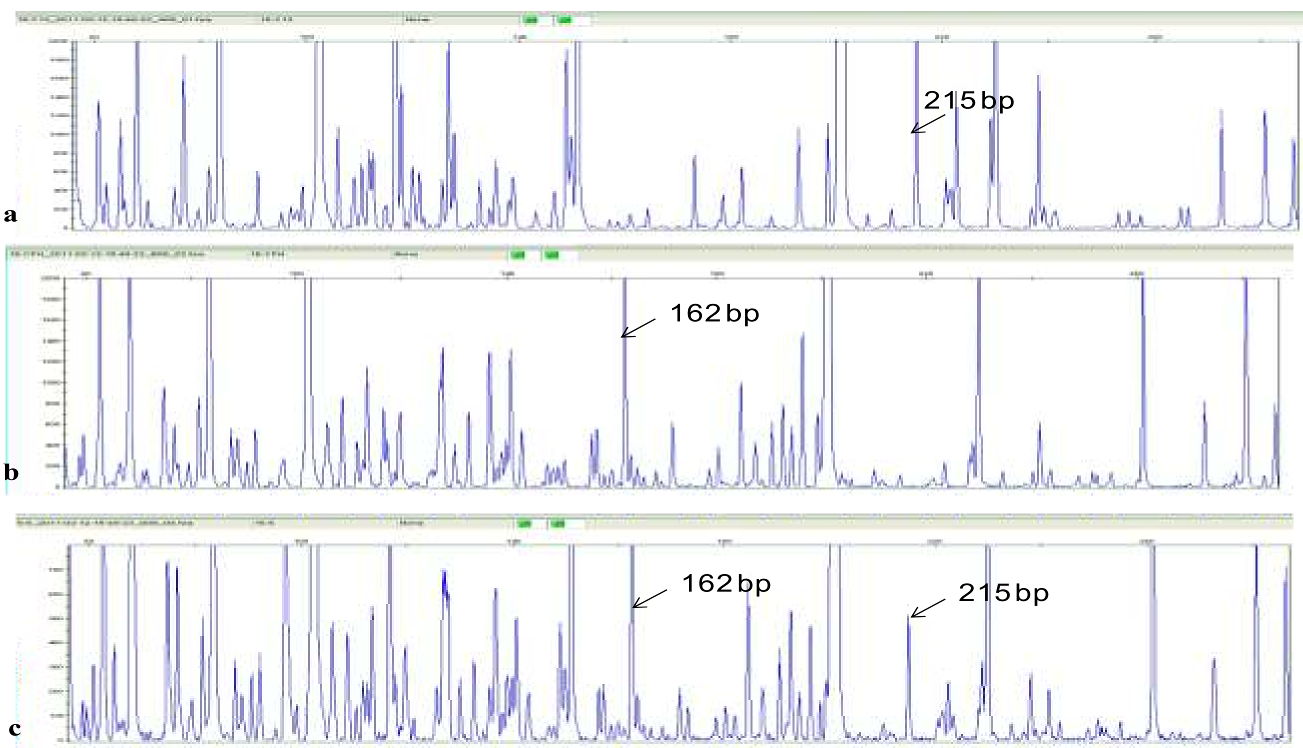


Fig. 8. AFLP primer pairs combination (*Eco*RIACA+*Mse*ICTG) confirmed hybridity of the potato somatic hybrids C-13 (+) *S. cardiophyllum* possessing parental bands. (a) C-13, (b) *S. cardiophyllum,* and (c) somatic hybrid, analyzed on the "3500 Genetic Analyzer".

Late blight resistance assay: Somatic hybrids plants (in duplicate) were evaluated for late blight resistance by challenge inoculation of *P. infestans* under controlled conditions at Shimla. Somatic hybrids and wild parent S. cardiophyllum were highly resistant (HR) (AUDPC = 0) in comparison to the susceptible control (Kufri Jyoti; AUDPC = 180-190) and susceptible cultivated parent C-13 (130-150). Plants were categorized based on the area under disease progress curve (AUDPC) value: HR (<50), R (50–100), MR (100–150), and S (>150) (HR=highly resistant, R=resistant, MR= moderately resistant and S=susceptible) (Fig. 10).

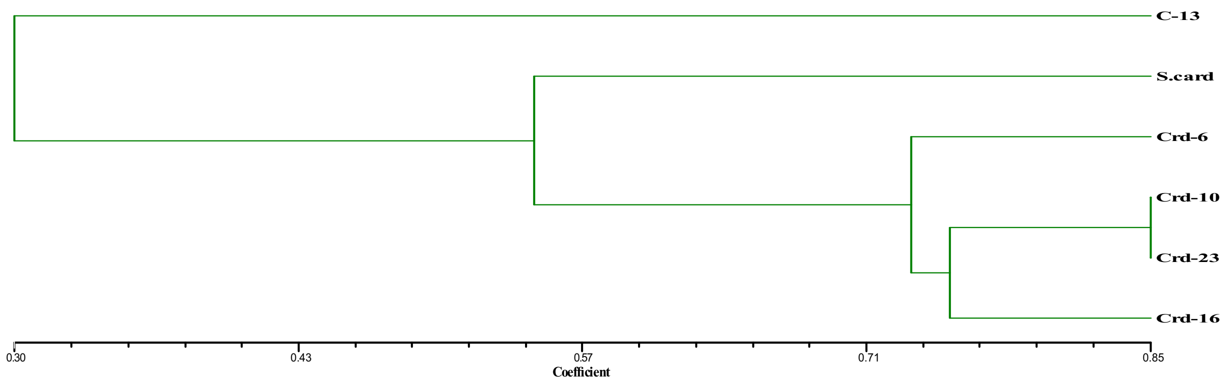


Fig. 9. Dendrogram showing divergence among the somatic hybrids *(Solanum tuberosum* dihaploid C-13 + S. *cardiophyllum)* clones Crd6, Crd10, Crd 16 ansd Crd23 with respect to the parents (C-13 and wild S. card).

Somatic hybrids **S. cardiophyllum** **C-13**

Fig. 10. Screening of somatic hybrids (Crd6, Crd 10 and Crd 16) and parents (C-13 and *S. cardiophyllum*) for late blight resistance by challenge inoculation under controlled conditions.

Breeding potential of potato somatic hybrids: Ten potato somatic hybrids (C-13 + *S. pinnatisectum*) were evaluated for adaptability, tuber traits, late blight resistance and keeping quality attributes (dormancy, sprouting, weight loss and appearance after 75 days of storage) under the sub-tropical plains of India. Most of the somatic hybrids possessed higher tuber dry matter content, resistance to late blight and better keeping quality attributes than the standard controls. Notably, the tubers of somatic hybrids showed a tendency for colour change from white to purple on exposure to the sunlight. Breeding potential of somatic hybrids was further assessed by crossing them with commonly grown local potato varieties for the development of backcross (BC1) progenies. Based on our study, the somatic hybrids P4, P8 and P10 can be utilized for the introgression traits into common potato via breeding methods for varietal development in the sub-tropical plains of India **(Fig. 11)**.

Molecular profiling of segregating progenies of somatic hybrids developed by crossing with potato varieties: Hybrid progenies were developed by crossing interspecific potato somatic hybrids with potato varieties and analyzed by using SSR and ISSR markers. In total, seven cross-combinations were characterized using 24 ISSR and 60 SSR markers. Besides, TPS (nos. 10,744) were developed for different cross combinations by crossing somatic hybrids (C-13 + *S. pinnatisectum*) and (C-13 + *S. cardiophyllum*) groups with potato varieties Kufri Jyoti, Kufri Garima, Kufr Gaurav and some selfed progenies of somatic hybrids itself to study geentics and segregation pattern **(Fig. 12)**.

Fig. 11. Tubers of some promising somatic hybrids and Kufri Bahar the most popular variety of the region.

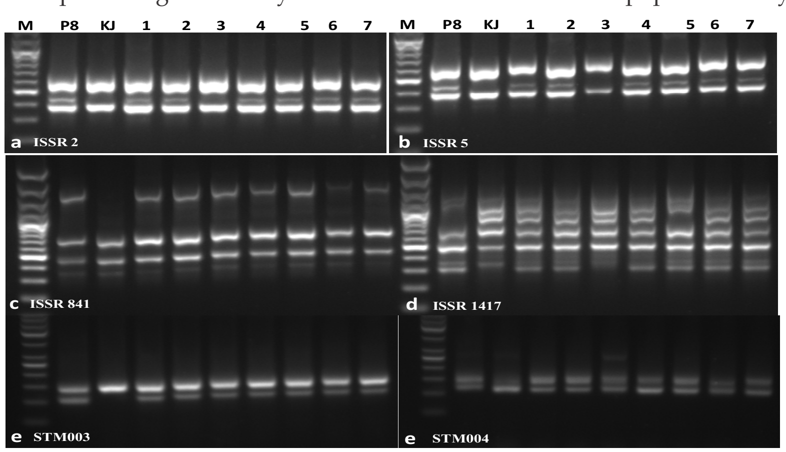


Fig. 12. Selected polymorphic ISSR markers (a. ISSR2, b. ISSR5, c. ISSR841, and d. ISSR1417) and SSR markers (e. STM003 and f. STM004) showing banding profiles in the hybrid progenies developed by crossing between somatic hybrid (*S. tuberosum* + *S. pinnatisectum)* P8 and popular cv. Kufri Jyoti (KJ). Progenies (SN 1-7): MSH/14-112, -113, -114, -115, -116, -122, -123.

Evaluation in F_1C_3 segregation population: Seventeen (17) F_1C_3 clones of 4 crosses (developed using somatic hybrids (C13 + *S. pinnectisectum*) as parent in combination with indigenous varieties were evaluated in multiple row trial (120 tubers) at 90 days crop duration. At harvest 3 clones namely MSH/14-7 (Kufri Garima x Mix pollen of somatic hybrids), MSH/14-129 and MSH/14-131 (Kufri Gaurav x P2) were identified as promising advanced hybrid (Fig. 13) for next year evaluation in F_1C_4 stage (replicated trial). MSH/14-7, MSH/14-129 and MSH/14-131 produced 25, 32 and 4% high total tuber yield when compared to Kufri Bahar, the most popular variety of the region. In addition five clones namely MSH/14-112, MSH/14-113, MSH/14-115, MSH/14-122, MSH/14-123 (Fig. 14) from the cross P8 x Kufri Jyoti showing improvement for late blight resistance, yield and tuber traits over somatic hybrid parents were identified as elite genetic material.

Fig. 13. Promising clones identified as advanced hybrid from F1C3 stage of crosses between somatic hybrids (C13 + *S. pinnectisectum*) and indigenous varieties) at Modipuram (2016-2017)

Evaluation of somatic hybrids under field conditions: Somatic hybrids namely Crd 6, Crd 10, Crd 16 and Crd 23 derived from interspecific symmetric somatic hybridization between androgenic dihaploid of C13 (+) wild species *S. cardiophyllum* were evaluated along with both parents and control varieties under field conditions in replicated yield trial at 105 days after planting. Somatic hybrid namely Crd 6 (12 tubers/plant), Crd 10 (16 tubers/plant), Crd 16 (13 tubers/plant) produced significantly high total tubers/plant than both the parents (C13 (14 tubers/plant) and *S. cardiophyllum* (10 tubers/plant) and control varieties namely Kufri

Fig. 14. Promising clones identified as elite genetic material from F1C3 stage of cross (P8 x Kufri Jyoti) between somatic hybrids (C13 + S. pinnectisectum) and indigenous varieties) at Modipuram (2016-17)

Bahar (11 tubers/plant) and Kufri Garima (10 tubers/plant). None of somatic hybrid could produce higher total tuber yield than parent C13 (25.31 t/ha), however Card 6 (8.99 t/ha), Card 10 (9.10 t/ha) and Card 16 (7.41 t/ha) produced significantly higher total tuber yield than wild parent *S. cardiophyllum* (2.58 t/ha) **(Fig. 15)**. It is to pertinent to mention that somatic hybrid namely Card 6, Card 10, Card 16 and Card 23 possessed significantly high tuber dry matter (above 24%) than both the parents and control varieties.

Fig. 15. Somatic hybrids of C13 (androgenic dihaploid of S. tuberosum) (+) S. cardiophyllum

Nitrogen use efficiency

Enhancing nitrogen use efficiency (NUE) in potato crop through genomics approaches: Increasing global food production is a serious challenge to feed the rapid growing population where cultivable land area is limited. Moreover, increasing cost of production with high fertilizer input costs specially N and degrading soil health are the major concerns to enhance the sustainable agricultural food production. Potato, being the major non-cereal food crop globally, is a heavy N fertilizer feeder crop. Several agricultural best management practices have been discussed in the past on N management in potato crop production through intervention of agronomy and soil science. However, unlike advancement in other model plant and cereals, application of molecular genomics tools is lacking in potato, hence it is inevitable to enhance plant genetic potential with better nitrogen use efficiency (NUE). Better N-use efficient plant can be grown with less fertilizer input and also on poor soil. This work highlights an initiative on applications of novel genomics tools to improve NUE in potato through discovery of novel genes and markers for applications in molecular breeding methods and gene manipulation (transgenic) techniques.

Plant growth under aeroponics system to study NUE: Virus-free healthy in vitro plants of cv. Kufri Jyoti were raised for proper plant growth in the aeroponics. Aeropoonics boxes (made up of plastic) is available for potato growth under the aeroponics at the institute. One-week hardened in vitro plantlets were planted in the aeroponic boxes. Based on the experimental design, nutrient solutions were prepared. N starvation (without nitrogen) and N sufficient (7.5 mM NO3-) were used to raise the tissue culture plants while all other nutrients remain same except one or two. Plants were grown for 20 days under normal full nutrient solutions then starvation period was induced with without N solutions. N starvation symptom was clearly visible after a week time.

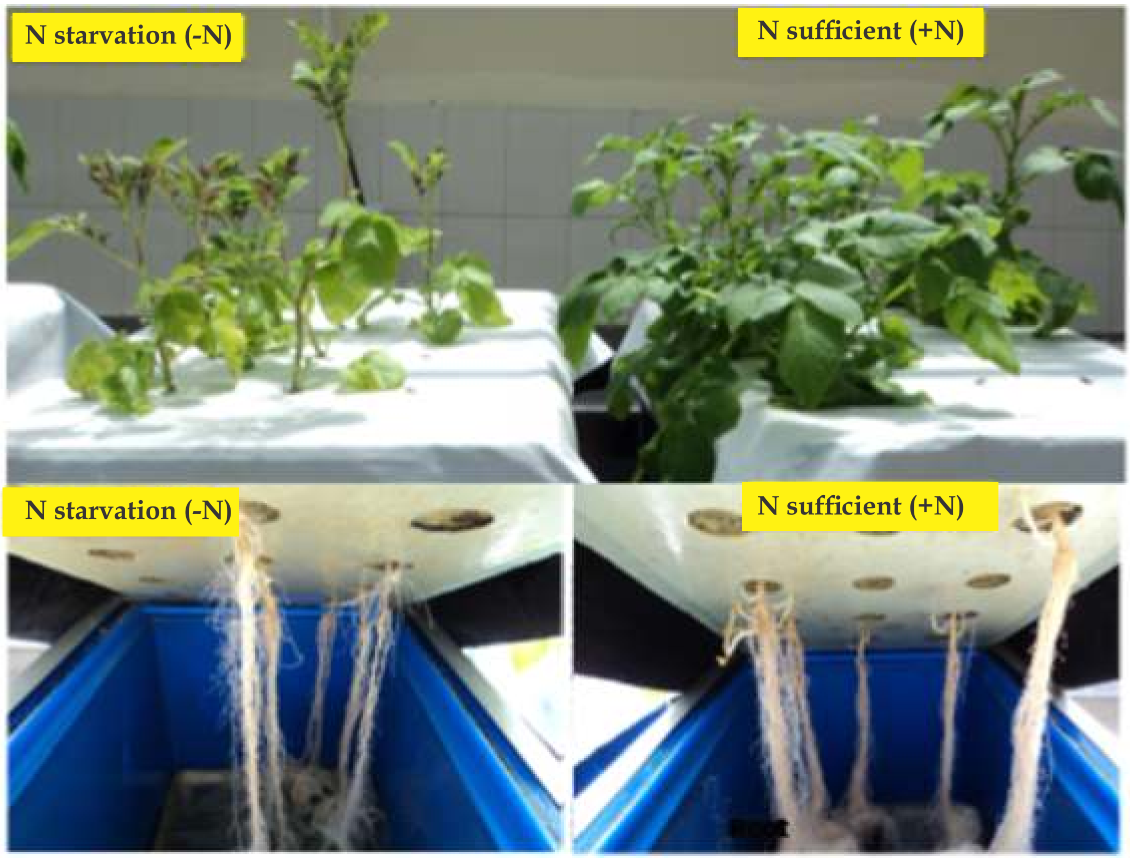
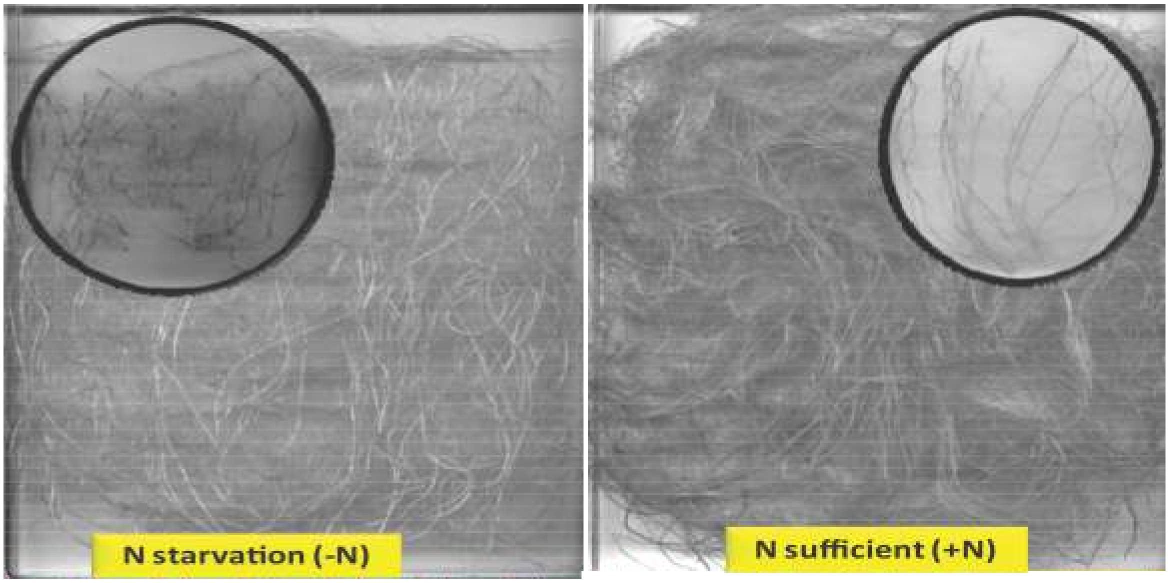


Fig. 16. Plant growth under aeroponic culture system for nitrogen use efficiency in potato cv. Kufri Jyoti.

Stock solutions of all nutrients are prepared and then working solutions are mixed in the growth tanks wherein plant uptakes nutrients in the form of mist or fog lifted via a pump. Fresh nutrient solutions are changed every week and pH is monitored between 6.0-7.0. Temperature for potato tuberization is very crucial and therefore controlled chamber with temp. (< 20 °C) is used to conduct a successful experiment. Plant growth under aeroponics is shown in **Fig. 16.** Plants foliage was clearly visible for symptoms caused by different N treatments. Plant biomass (fresh weight and dry weight) and root scanning **(Fig. 17)** was also performed to study differences caused by the different N treatments.

Transcriptome sequencing (RNA-seq) for NUE: Root and shoot samples of potato variety Kufri Jyoti were collected at different time intervals for two N treatments (N starvation: 0N and N sufficient: 7.5N) to study transcriptome dynamics in potato. Samples were processed for library preparation and followed by total RNA sequencing on Ion Proton (ABI) as per the manufacturer's instructions, as for example shown in Fig. 18.



Traits	N starvation	N sufficient
Root length (m)	125.79 m	246.15
Surface area (cm^2)	4905.44	9267.42
Avg. Diameter (mm)	7.58	18.43
Root volume (cm^3)	155.28	362.87

Fig. 17. Scanning of roots and summay of different root traits of cv. Kufri Jyoti grown under aeroponics with two N treatments (N starvation and N sufficient) to study NUE in potato.

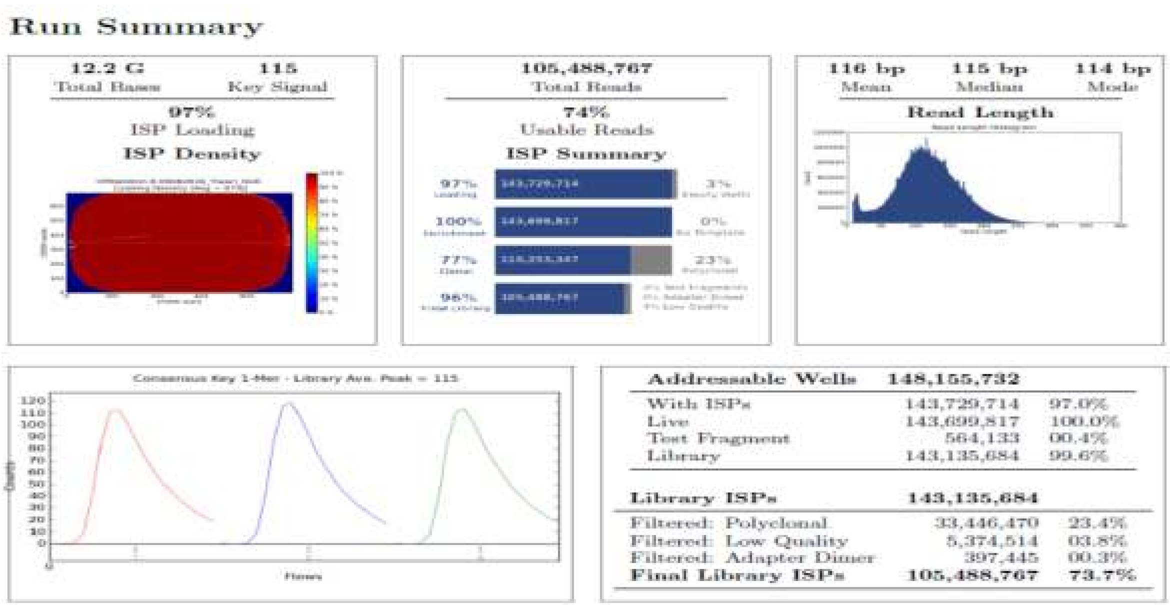


Fig. 18. Image showing summary data generated by transcriptomes sequencing (RNA-Seq.) of potato leaf tissues of aeroponically grown plants with different N treatments (N starvation and N sufficient) to study genes associated in NUE in

Sequence analyses of late blight resistance homologous genes isolated from wild potato species: The selected late blight resistant wild species *S. berthaultii, S. cardiophyllum, S. iopetalum, S. jamesii, S. lesteri, S. microdontum, S. pinnatisectum, S. polyadenium, S. polytrichon, S. trifidum and S. verrucosum* were PCR amplified using gene-specific primers, gel eluted, cloned and sequenced analyzed for homology of R genes in the wild species. 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) were used for allele mining in these wild species. The successfully isolated and sequenced genes were i) Rpi-pta1 (in *S. cardiophyllum* and *S. microdontum*), ii) Rpi-edn1.1 (in S. berthaultii), iii) EDNR2GH7 (in *S. trifidum* and *S. verrucosum*), iv) SNKR2GH5 (in *S. iopetalum* and *S. lesteri*) and v) Rpi-snk1.1 (in *S. jamesii*). The isolated homologous R genes from different wild species are summarized in Table 2.

Table 2. Summary of R gene homologues isolated from the wild potato species.

SN	Isolated R gene homologues	Wild species	Potato R gene (NCBI Acc. No.)
1.	PTA1_CPH62	*S. cardiophyllum*	*Rpi-pta1* (EU884422.1)
2.	PTA1_MCD24	*S. microdontum*	*Rpi-pta1* (EU884422.1)
3.	EDN1.1_BER57	*S. berthaultii*	Rpi-edn1.1 (GU563963.1)
4.	EDNR2_TRF22	*S. trifidum*	EDNR 2GH7(GU563968.1)
5.	EDNR2-VER55	*S. verrucosum*	EDNR 2GH7(GU563968.1)
6.	SNK1.1_JAM07	*S. jamesii*	*Rpi-snk1.1* (GU563975.1)
7.	SNKR2_IOP59	*S. iopetalum*	SNKR2GH5(GU563977.1)
8.	SNKR2_LES34	*S. lesteri*	SNKR2GH5(GU563977.1)

Sequence variations for N-metabolism genes in potato: To unravel the sequence variations among the genes involved in nitrogen metabolism pathways, a total of 20 genes-specific primer pairs were used. 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 and products were separated on agarose gel. Sequence variations and diversity for the genes involved in nitrogen metabolism pathways between the potato cultivars (Kufri Jyoti and Kufri Pukhraj) was observed distinctly.

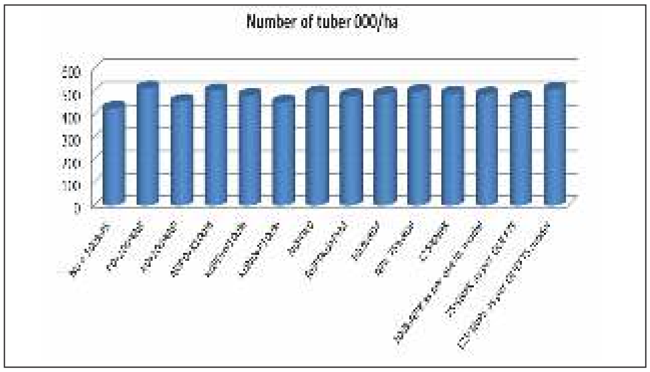
Division of Crop Production

Programme: Integrated nutrient and water management for improved productivity of potato

Developing Decision Support System based on QUEFTS model: Due to lack of site-specific recommendations farmers are often resorting to applying more than the recommended dose of fertilizers. Higher than the recommended application of fertilizers not only result in increased cost of cultivation, but also cause a decline in soil health and environmental pollution over time. Due to imbalanced and over use yield of many crops including potato have already stagnated. Maximizing input use efficiency is the only alternative left to enhance the productivity in a sustainable manner from the limited natural resources without any adverse consequences on soil health and environment. Models can help in making precise fertilizer recommendations and QUEFTS is one such model. It is a site- specific nutrient management approach which describes the quantitative evaluation of the native fertility of tropical soils, using yields and NPK uptake trials. A Decision Support System "Nutrient Recommendation for Raising Potato in Uttar Pradesh (NRRPUP)" has been developed. This decision support tool is developed to give recommendations on NPK application in potato in different districts of Uttar Pradesh (Fig.1).

Fig. 1. Model of Nutrient recommendation for raising potato in Uttar Pradesh (NRRPUP)

Experiments for validation and caliberation of QUEFTS model: Experiments on validation of QUEFTS model was under taken at CPRIC, Modipuram and CPRS Gwalior. At Gwalior application of 100% NK, 100% K, 75% NPK and 125% as per QUEFT model produced higher number of tubers over other treatments. Production of tuber was highest with the application of 75% NPK as per QUEFTS model which was followed by 125% NPK as per QUEFTS model. Lowest tuber yield was recorded with the application of 100% P which shows that there is buildup of phosphorus in the soil which is causing antagonistic effect on crop on its application. Initial soil fertility showed that pH 7.3, EC 0.42 mhos/cm, OC 0.39%, available N 170 kg/ha, available P 42.33 kg/ha and available K 311.36 kg/ha. Tuber numbers and yields are presented below (Table 1, Fig. 2).



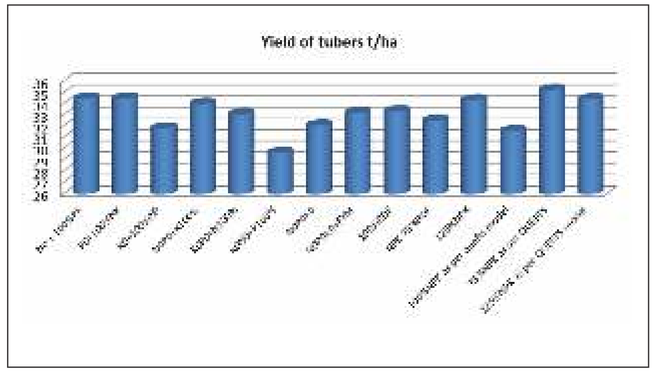


Fig. 2. Effect of NPK levels on tuber numbers and yield of potato as per QUEFT model

Table 1. Validation of QUEFTS Model at Modipuram for cv Kufri Garima

Treatment	N-P-K Doses	Tuber Yield ton/ha				Tuber Number lakh/ha			
		>75 g	25-75 g	<25 g	Total	>75 g	25-75 g	<25 g	Total
T1	0-80-100	0.83	4.34	3.25	8.432	0.14	1.29	2.74	4.17
T2	180-0-100	4.96	13.45	3.87	22.28	0.55	3.50	2.58	6.62
T3	180-80-0	7.47	15.28	3.51	26.28	0.79	2.89	2.34	6.03
T4	0-0-100	0.18	5.86	3.12	9.17	0.41	1.31	2.61	4.33
T5	180-0-0	2.70	13.43	3.75	19.88	0.32	2.93	2.42	5.68
T6	0-80-0	1.01	5.91	3.07	9.99	0.42	1.66	2.62	4.71
T7	0-0-0	0.73	4.34	3.00	8.08	0.11	1.16	2.52	3.80
T8	0-0-0+FYM	1.30	9.05	4.66	15.02	0.16	2.39	2.83	5.39
T9	180-80-100	8.44	15.04	4.09	27.57	0.98	3.36	2.69	7.03
T10	135-60-75	8.24	14.35	4.31	26.90	0.93	2.80	3.32	7.06
T11	225-100-125	9.95	17.90	4.62	32.47	1.10	4.12	3.18	8.40
T12	275-0-95	13.45	13.75	3.89	31.09	1.65	3.16	2.70	7.52
T13	215-0-145	8.86	16.35	3.68	28.89	0.89	3.35	2.78	7.02
T14	360-0-260	10.29	16.47	4.16	30.93	1.22	3.29	3.15	7.68
	CD 0.05	5.39	7.47	NS	10.88	0.64	1.78	NS	2.11

Date of planting-3.11.2016; Date of harvesting-4.03.2017

T_1-Minus N (N0+100% PK); T2-Minus P (P0+100% NK); T3-Minus K (K0+100%NP); T4-Minus NP (N0P0+100%K); T5-Minus PK (P0K0+100%N); T6-Minus NK (N0K0+100%P); T7-Minus NPK (N0P0K0); T8-Minus NPK +FYM ; T_9: 100%NPK as per standard recommendation; T10- 75%NPK as per standard recommendation; T11-125%NPK as per standard recommendation; T12-100%NPK as per QUEFTS model; T13-75%NPK as per QUEFTS model;T14-125%NPK as per QUEFTS model

Omission plot experiment: For optimising site specific nutrient doses, an experiment was conducted on Kufri Jyoti variety using omission plot technique at CPRS, Jalandhar on a soil having 238 kg available N 112 mg/kg, 22.6 mg/kg available P and 128 mg/kg available K and 5.5g/kg organic carbon. Haulm cutting was done at 90 days after planting. Omission of N led to significant decrease in tuber as well as haulm yield in all the treatment combinations. Lowest yield of 17.48 t/ha was obtained without application of any fertilizer (control treatment). Tuber yield was not affected by reducing or increasing the recommended fertilizer dose by 25%. Nitrogen was found the only yield limiting nutrient (Fig. 3).

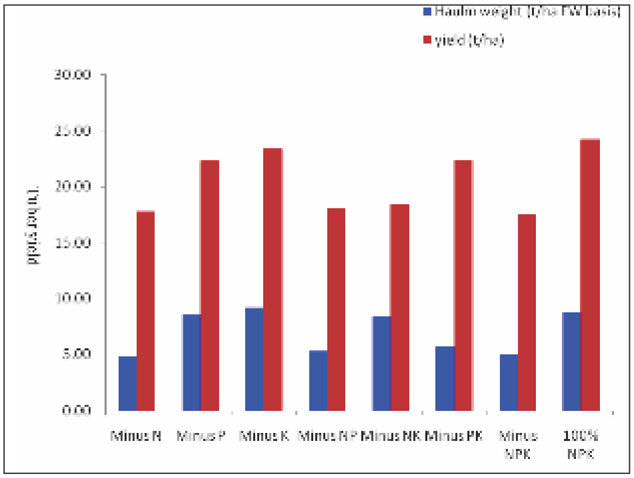


Fig. 3. Omission plot experiment at Jalandhar

Real time N management by fine tuning top dressing using leaf SPAD value: A more environmentally sound and cost effective strategy to improve N-use efficiency would be to apply moderate amounts of N at planting and the remainder as side dressings, as needed, before the last cultivation at hilling. Growers would be more likely to adopt such a strategy if they had a reliable, rapid method to assess N status at the field site. Traditional tissue testing and laboratory analysis for N are often too slow for timely response by growers. Nitrogen was applied in accordance with chlorophyll contents of leaves. There was no any effect of fertilizers on number of tubers due to splitting of nitrogen. Application of 125% NPK (50% at planting + 50% at earthing up) produced highest tuber yield (53 t/ha) which was followed by 1/3rd as basal, 1/3rd at earthing up and 20% at 90% SPAD value (Fig. 4). It shows that splitting of nitrogen at 90% SPAD value was better utilized by crop compared to its 80% SPAD value. All three cultivars showed higher yield when the third split application of N was done on 90% of SPAD value (T5 & T4). Mean tuber yield and SPAD values are presented in Fig. 4 and 5.

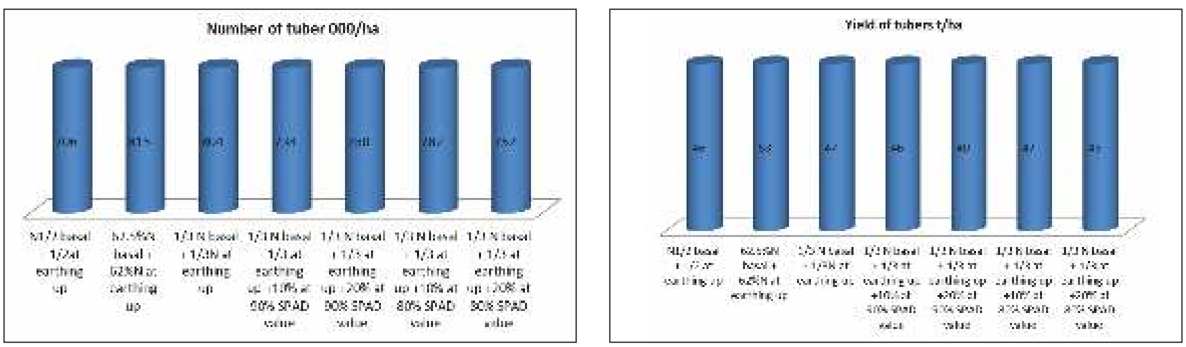


Fig. 4. Effect of nitrogen levels as per SAPD values on tuber number and yield of potato

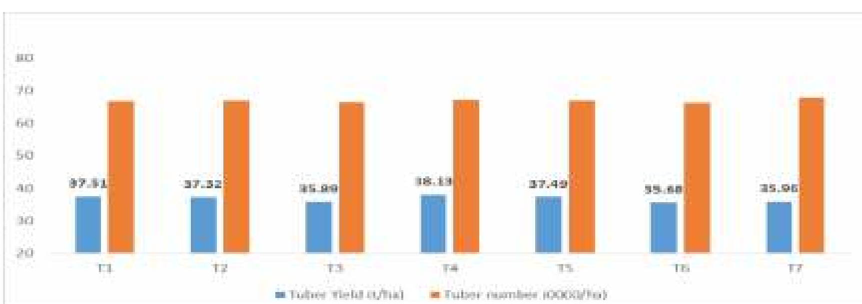


Fig. 5. Potato tuber yield and number as result of N scheduling based on SPAD value

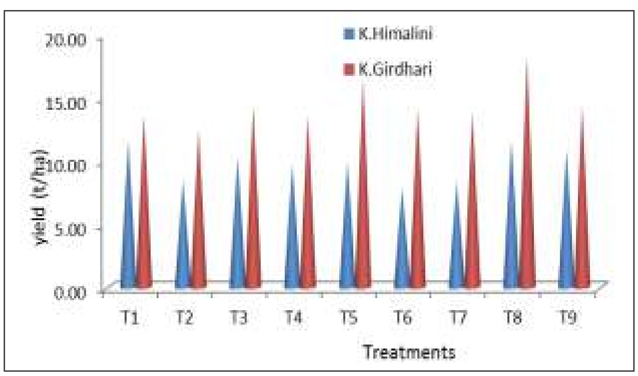
Fig. 5. T1: 50% basal and 50% at earthing up of recommended N; T2: 62.5% basal and 62.5% at earthing up of recommended N; T3: 33.33% basal, 33.33% at earthing up + 33.33% at 80% SPAD value of over fertilized plot(T2); T4: 33.33% basal, 33.33% at earthing up and 10% at 90% SPAD value of over fertilized plot(T2); T5: 33.33% basal, 33.33% at earthing up and 20% at 90% SPAD value of over fertilized plot(T2); T6: 33.33% basal, 33.33% at earthing up and 10% at 80% SPAD value of over fertilized plot(T2); T7: 33.33% basal, 33.33% at earthing up and 10% at 80% SPAD value of over fertilized plot(T2)

Optimization of phosphorus dose in potato: Imbalanced use of fertilizer in potato crop is a growing concern and P is applied at the higher rate than its uptake because of its lower use efficiency. Therefore experiments were undertaken in high P soils with the objective to utilise the applied P more efficiently. At Gwalior stopping or reducing phosphorus application by 60% did not have any adverse effect on yield and tuber number. Application of PSB was found very effective in increasing the yield over control and 10% of the RDF andtuber number per plant. . This shows that there scope for utilization of inherent soil P and saving can be made by reducing use of chemical fertilizers in this region. At modipuram, however, there was no reduction in yield even in plots where no P was applied in soil having available P 111 kg/ha.

Table 2: Effect of integrated nutrient management on potato tuber yield.

Treatment	Total tuber yield (t/ha)
100% RDF	16.68
25% RDF + 75% RDN-FYM	14.67
75% RDF + 25% RDN-FYM	17.06
25% RDF + 75% RDN-FYM + Boron + Azotobacter + PSB + Potash mobilizing bacteria	15.95
75% RDF + 25% RDN-FYM + Boron + Azotobacter + PSB + Potash mobilizing bacteria	19.23
100% RDN-FYM	16.24
Boron	6.01
Azotobacter + PSB + Potash mobilizing bacteria	8.33
Control	5.41
SEm±	1.03
CD (P=0.05)	3.13

Optimizing fertilizer requirement for potato cultivars Kufri Girdhari and Kufri Himalini for southern hill region: Field experiment was conducted for optimizing fertilizer dose for promising cultivars Kufri Girdhari and Kufri Himalini in split plot design (fig 9). The maximum yield for the cultivar Kufri Girdhari (18.23 t/ha) and Kufri Himalini (11.61 t/ha) was observed when fertilizer was applied at the rate of 125% nitrogen, 100% phosphorus and 100% potassium (112.5:135:90 kg/ha NPK).



T1:100% N, P and K; T2: 75% N & P: 100% K; T3: 75% N: 100% P and K; T4: 75% N: 125% P: 100% K; T5: 100% N: 75% P : 100% K ; T6: 75% N: 125% P : 100% K; T7: 125% N: 75% P : 100% K; T8:125% N:100% P & K and T9:125% N:125% P : 100% K.

Fig. 9. Response of potato varieties to different fertilizer levels

Variety specific water and nutrient management schedule under limited water availability: The effect of potato varieties and irrigation levels were significant on total tuber yield and numbers as well as large and medium grade tuber yields and numbers. The potato yield was in the order of Kufri Khyati > Kufri Anand > Kufri Garima > Kufri Sadabahar > Kufri Pukhraj > Kufri Bahar (**Table 3**). The irrigations applied at 2.5 IW:CPE ratio produced significantly higher tuber yield (49.0 t/ha), which was also found statistically superior over other irrigation levels tried. All potato varieties produced significantly maximum tuber yields and numbers at higher moisture level when irrigations were applied at 2.5 IW:CPE ratio in comparison to low and medium irrigation levels (**Tables 3 & 4**).

Nutrient requirement of newly released variety through drip fertigation: Although 100% NPK fertigation produced highest yield the effect of fertigation was non- significant on total tuber yield and numbers as well as grade-wise tuber yield and numbers . The newly released variety Kufri Mohan produced significantly higher total tuber yield (33.8 t/ha) in comparison to popular variety Kufri Bahar which gave 31.1 t/ha, but, the reverse trend was noticed in case of tuber numbers (**Table 5**). The interaction effect of variety and NPK fertigation was non- significant.

Table 3. Total yield and tuber numbers of potato varieties as influenced by different irrigation levels.

Treatment	Total yield (t/ha)							Tuber numbers (ths./ha)						
	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean
2.5 IW:CPE	39.6	48.0	55.4	51.3	48.1	51.5	49.0	678	762	639	663	533	904	713
2.0 IW:CPE	36.1	40.3	47.6	46.2	44.2	47.8	43.7	601	622	604	699	531	863	653
1.5 IW:CPE	37.4	42.4	48.9	44.0	40.7	46.3	43.3	628	693	628	607	473	863	646
Average	37.7	43.6	50.6	47.2	44.3	48.5	-	636	692	623	689	512	877	-
LSD at 5%	Variety (V) 2.0		Irrigation (I) 1.4		V x I NS			Variety (V) 45		Irrigation (I) 32		V x I NS		

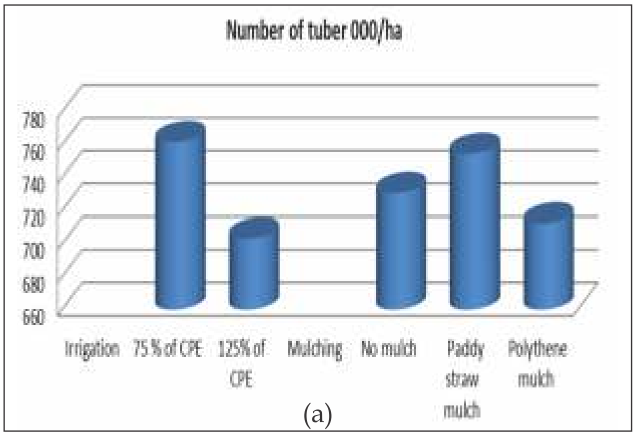
Table 4. Total yield and tuber numbers of potato varieties as influenced by different nitrogen levels.

Treatment	Total yield (t/ha)							Tuber numbers (ths./ha)						
	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean
150 kg N/ha	36.4	42.1	49.6	45.3	41.7	47.0	43.7	626	695	612	675	518	866	664
180 kg N/ha	38.2	43.8	50.4	47.7	46.0	48.1	45.7	623	672	633	679	498	861	661
210 kg N/ha	38.7	44.9	51.8	48.5	45.4	50.5	46.6	658	710	626	714	520	903	687
Average	37.7	43.6	50.6	47.2	44.3	48.5	-	636	692	623	689	512	877	-
LSD at 5%	Variety (V) 2.3		Nitrogen (N) 1.7		V x N NS			Variety (V) 48		Nitrogen (N) NS		V x N NS		

Table 5. Interaction effect of irrigation scheduling and N levels on potato yield and tuber numbers.

Treatment	Total yield (t/ha)			Tuber numbers (ths./ha)		
	Kufri Bahar	Kufri Mohan	Mean	Kufri Bahar	Kufri Mohan	Mean
Drip irrigation	30.5	33.0	31.7	903	662	783
75 % NPK fertigation	29.8	32.5	31.1	884	622	753
100 % NPK fertigation	33.2	35.5	34.3	931	559	746
Mean	31.1	33.8	-	906	615	-
LSD at 5%	Variety (V) 2.5	Fertigation (F) NS	V X F NS	Variety (V) 65	Fertigation (F) NS	V X F NS

Effect of mulch with drip irrigation on potato: Application of 75% CPE recorded higher number of tubers (762 thousand/ha) compared to 125% CPE. Application of paddy straw mulch @ 5 t/ha produced highest number of tubers (755 thousand/ha) which was higher over no mulch and 25 micron plastic mulch (Fig. 7).



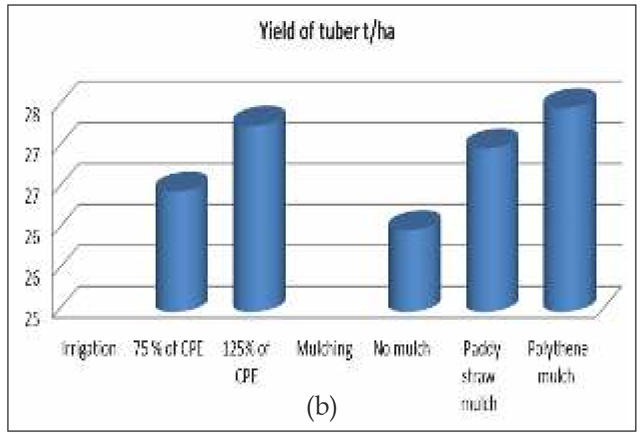


Fig. 7. Effect of mulch and irrigation on tuber number and yield

Developing nutrient and water efficient cultivars

To develop nutrient use efficient varieties hybridization among breeding lines/cultivars was carried out. Botanical seeds were used to raise F_1 generation. F_1C_1, F_1C_2 and F_1C_3 clones were evaluated for tuber characters. Hybrids were evaluated in replicated yield trials at 90 days harvest using Kufri Gaurav and Kufri Pukhraj as controls.

Hybridization: A total of 133458 seeds of 49 crosses were obtained.

Raising of seedlings: A total of 55,656 F_1 seedlings obtained from germination of 182702 seeds, were transplanted in field and 13335 selections were made on the basis of tuber characters such as colour, shape and eye depth.

Evaluation in clonal generations: Six thousand one hundred thirty (6,130) F_1C_1 clones were planted. Based on tuber characters, such as shape, skin colour and eye depths 756 clones were selected. Out of 653 F_1C_2 clones planted, 277 were selected. The yield range of the selected clones was 560 to 1080 g/plant as compared to 540 g/plant of control Kufri Gaurav. Out of 208 F_1C_3 clones planted, 49 were selected. The yield range of the selected clones was 533 to 867 g/plant as compared to 500 g/plant of control Kufri Gaurav.

Evaluation in replicated yield trial: Fourteen hybrids were selected out of 35 hybrids and evaluated in 4 preliminary 90 days yield trials under normal (October) planting condition (Table 3). Selected hybrids were: N/12-12, N/12-25, N/12-30, N/12-32, N/12-39, N/12-40, N/12-42, N/12-45, N/12-46, N/12-48, N/12-51, N/12-57, N/12-92 and N/12-38. Hybrids N/12-12, N/12-25, N/12-30, N/12-32, N/12-39 and N/12-40 in Trial No. 1, hybrids N/12-42, N/12-45, N/12-46, N/12-48, N/12-51 and N/12-57 in Trial No. 2, and hybrids N12-38 in Trial No. 4 gave significantly higher yield than controls. Seven hybrids were selected out of 12 hybrids evaluated in 2 Confirmatory 90 days yield trial under normal (October) planting condition (Table 6).

N-efficiency confirmatory trials – Four germplasm/varieties have been evaluated for tubers yield. At nitrogen deficient condition, CP-2013 produced slightly higher tuber yield than Kufri Gaurav and Kufri Pukhraj but mean tuber yield was maximum in Kufri Pukhraj under all the variable nitrogen levels. In single row experiment twenty germplasm planted with four levels of nitrogen including four control varieties. On the basis of yield, none of the culture could produce more tuber than commercial varieties.

Evaluation of advance hybrid for their efficiency in replicated trials: In order to evaluate advanced hybrids/lines developed for high nutrient efficiency at Jalandhar, a replicated field trial of seven advanced hybrids namely N/9-42, N/9-230 and N/9-260, N/10-15, N/10-74, N/10-91, N/10-96 along with three checks (*viz.*, Kufri Pukhraj, Kufri Jyoti, and Kufri Gaurav) were planted at four N levels (0, 80, 160 & 240 kg/ha) in three replications at Patna. Field observations were recorded for SPAD value of the fourth leaf of randomly selected representative plants at 85 days after planting in the plots. Results are presented in Tables 7, 8 & 9.

Table 6. Performance of nitrogen efficient cultivars as compared to controls at varying N levels (a) tuber numbers ('000/ha).

Hybrids/Controls	Grades of tubers			Total
	Small (< 25g)	Medium (25-75g)	Large (> 75g)	
N/9-42	257.59	276.11	53.98	587.69
N/9-230	237.04	270.09	42.22	549.35
N/9-260	208.98	221.11	45.65	475.74
N/10-15	77.32	129.72	36.39	243.43
N/10-74	216.67	311.02	37.32	565.00
N/10-91	144.63	221.39	36.39	402.41
N/10-96	177.41	301.11	32.78	511.29
Kufri Pukhraj	243.06	286.67	39.17	568.89
Kufri Gaurav.	237.22	257.22	42.78	537.22
Kufri Jyoti	275.83	243.33	32.04	551.20
Nitrogen levels (kg/ha)				
0	198.07	199.70	19.19	416.963
80	212.48	253.93	36.15	502.556
160	219.66	277.96	51.37	549.000
240	200.07	275.52	52.78	528.370
CD (0.05)				
Hybrids	38.717	39.816	10.679	54.716
N levels	N/A	25.182	6.754	34.606
Hybrid x N	N/A	N/A	N/A	N/A

Table 7. Performance of nitrogen efficient hybrids as compared to controls at varying N levels (b) yield (Q/ha)

Hybrids/Controls	Grades of tubers			Total
	Small (< 25g)	Medium (25-75g)	Large (> 75g)	
N/9-42	32.87	147.76	64.53	245.16
N/9-230	27.94	148.53	45.03	221.49
N/9-260	24.05	131.52	62.32	217.88
N/10-15	15.60	109.05	71.45	196.09
N/10-74	32.70	161.12	54.98	248.80
N/10-91	19.56	146.43	61.89	227.89
N/10-96	24.11	172.54	46.35	243.00
Kufri Pukhraj	29.48	141.86	52.00	223.33
Kufri Gaurav	24.72	113.99	57.89	196.59
Kufri Jyoti	28.90	106.29	44.52	179.71
Nitrogen levels (kg/ha)				
0	23.18	87.33	21.69	132.21
80	26.65	134.45	53.86	214.97
160	26.74	160.28	71.36	258.39
240	27.39	169.57	77.47	274.42
CD (0.05)				
Hybrids	5.57	18.67	13.51	23.02
N levels	N/A	11.81	8.55	14.56
Hybrid x N	N/A	N/A	N/A	N/A

Table 8. Yield of nitrogen efficient hybrids as compared to controls at varying N levels (Q/ha)

Hybrids	N levels (kg/ha)				Mean of hybrid
	0	80	160	240	
N/9-42	120.94	241.94	305.65	312.09	245.16
N/9-230	131.86	203.28	256.39	294.45	221.49
N/9-260	128.70	206.55	249.14	287.11	217.88
N/10-15	112.66	178.90	252.12	240.71	196.09
N/10-74	184.96	241.23	287.30	281.72	248.80
N/10-91	138.18	220.82	257.01	295.53	227.89
N/10-96	156.19	251.22	271.76	292.86	243.01
Kufri Pukhraj	133.34	228.52	249.99	281.47	223.33
Kufri Gaurav	106.48	188.29	241.87	249.74	196.59
Kufri Jyoti	108.74	188.90	212.64	208.55	179.71
Mean of N level	132.21	214.97	258.39	274.42	

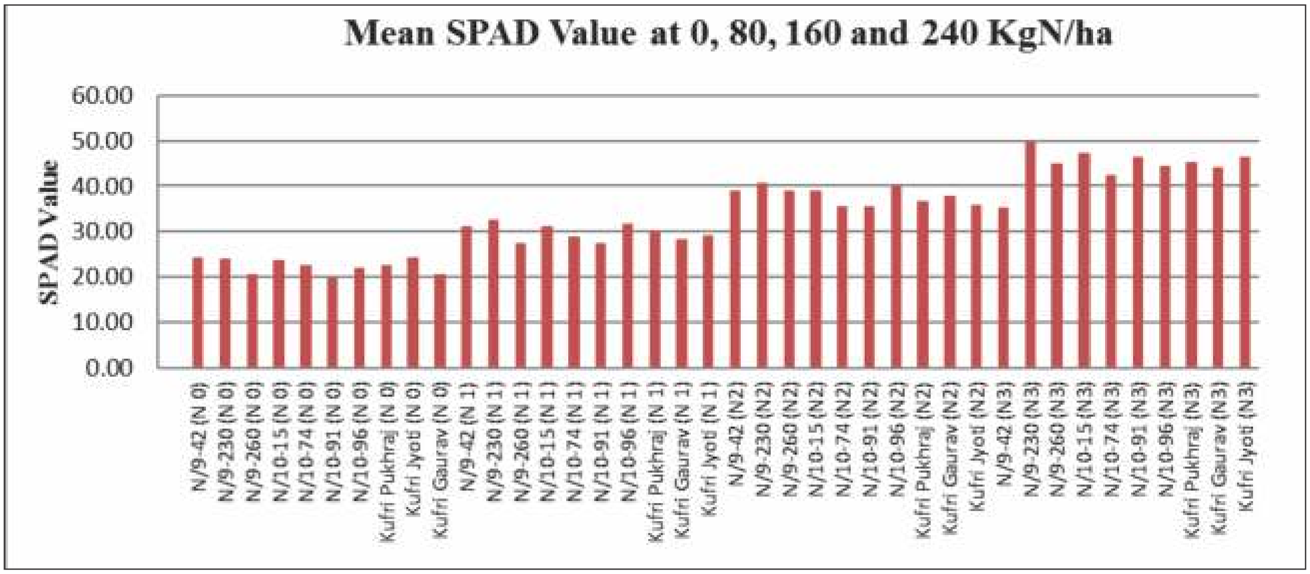


Fig. 8. SPAD Value of leaves of different advanced hybrids with check varieties at varying nitrogen levels at 85 days after planting.

To develop / identify nutrients & water use efficient potato cultivars/ hybrids: Effect of genotypes and moisture regimes was significant on total tuber yield as well as water use efficiency. Both the promising genotypes *viz.* J 93-58 & J.92-167 produced significantly maximum tuber yield (35.7 & 35.3 t/ha, resp.) in comparison to control *var.* Kufri Bahar (30.5 t/ha) and Kufri Pukhraj (33.2 t/ha). The yield of potato genotypes increased with the increas in moisture level from 0.60-0.65, 0.40-0.45 & 0.20-0.25 bars/atm soil moisture tension (Table 9). The similar trend was also noticed in case of water use efficiency (Table 9). The data showed that the water use efficiency was maximum in case of advance genotypes *viz.* J 93-58 and J.92-167 (1.479 & 1.460 q tubers/ha) in comparison to Kufri Bahar (1.257 q tubers/ha).

Table 9. Potato yield and water use efficiency (WUE) of advance genotypes as influenced by irrigation regimes.

Advance Genotypes	Total yield (t/ha)			Mean (t/ha)	Water use efficiency (q/ha-mm)			Mean (q/ha-mm)
	Wet regime (0.20-0.25 bars)	Moist regime (0.40-0.45 bars)	Semi-dry regime (0.60-0.65 bars)		Wet regime (0.20-0.25 bars)	Moist regime (0.40-0.45 bars)	Semi-dry regime (0.60-0.65 bars)	
K. Bahar	33.1	30.2	28.2	30.5	1.115	1.224	1.432	1.257
K. Pukhraj	36.9	32.3	30.7	33.2	1.243	1.309	1.559	1.370
J 93-58	37.2	35.1	34.6	35.7	1.254	1.424	1.758	1.479
J.92-167	36.7	35.6	33.4	35.3	1.236	1.444	1.699	1.460
Average	36.0	33.3	31.7		1.212	1.350	1.612	-
LSD at 5%	Irrigation (I) 2.1	Genotype (G) 2.4	Interaction (I x G) NS		Irrigation (I) 0.095	Genotype (G) 0.110	Interaction (I x G) NS	

Increasing Zn and Fe contents in potato tubers : Two field experiments were conducted at CPRS, Jalandhar during 2015-16 on Kufri Pukhraj using different sources of Zinc and Fe to increase their content in tuber flesh. Soil application of 5.0kg Zn/ha as zinc sulphate increased the Zn content in potato peel by 9 ppm. Similarly, soil application of 5.0 kg Fe/ha as iron sulphate increased the Fe content in peel by 20 ppm dry weight basis also increased significantly by soil application of ferrous sulphate and Fe-EDTA. However there was no significant improvement in both Fe and Zinc contents in tuber flesh. Foliar applications were not effective in increasing the zinc and Fe content of tubers.

Effect of different sources of boron on its availability: Since vertical mobility of the boron is high in soil, it is often subjected to leaching particularly in high rainfall areas. Keeping this in view an experiment was conducted by using colemanite (calcium borate), a less soluble source of boron and compared with borax in laboratory incubation for six weeks and in a pot experiment in a soil from Shimla. Both sources increased the boron content in leaves significantly over control (Fig. 9). However, application of B 5.0 and 7.5 kg/ha from either source caused leaf deformities, chlorosis followed by necrosis and resulted in growth reduction (plant height) significantly. Both laboratory and pot experiment studies showed that it can be used as a slow release source of boron for potatoes. Application of boron @5.0 kg/ha or more from both the sources caused its toxicity (Fig. 10).

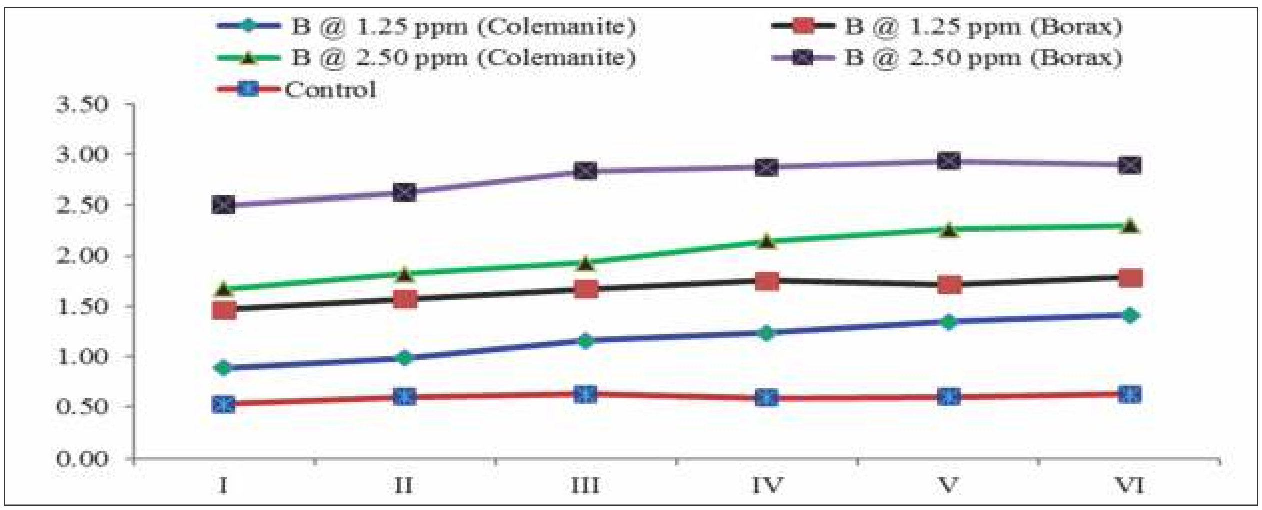
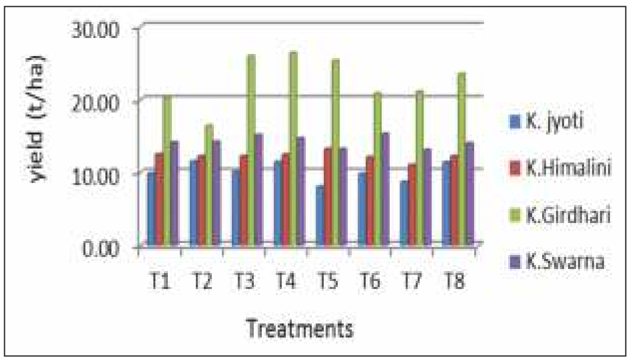


Fig. 9. Boron availability from different sources over time

Fig. 10. Boron toxicity symptoms marginal chlorosis, deformities in leaf shape and marginal necrosis in potato

Response of potato cultivars to foliar application of boron and molybdenum: Field experiment was conducted during 2016-17 for studying the effect of foliar application of boron and molybdenum in popular cultivars viz., Kufri Jyoti, Kufri Himalini, Kufri Girdhari, Kufri Swarna in split plot design at CPRS Ooty. The data showed that foliar application of 1.0 g/L ammonium molybdate significantly increased the total yield in cultivars viz., Kufri Himalini (12.20 t/ha), Kufri Jyoti (11.37 t/ha), Kufri Girdhari (23.52 t/ha), whereas, the cultivar Kufri Swarna gave more yield with foliar application of 0.25g/L ammonium molybdate (Fig. 11).



T1-control,T2-0.5g/L sodium borate, T3-1.0g/L sodium borate, T4-1.5g/L sodium borate, T5-2.0g/L sodium borate, T6-0.25g/L ammonium molybdate, T7-0.5g/L ammonium molybdate, T8-1.0 g/L ammonium molybdate

Fig. 14. Response of different cultivars to foliar application of boron and molybdenum

Breeding for improving micronutrient content in potato tubers: Forty eight 48 varieties and 32 accessions were screened to study the genetic variations in micronutrient content and to select suitable parents for breeding nutrient rich cultivars. Tubers of forty eight 48 varieties were evaluated for micronutrient content for consecutive two years. Iron concentration ranged from 19.96 mg/kg in Kufri Garima to 49.51 mg/kg in Kufri Girdhari with an average (two years) concentration of 28.49 mg/kg in tuber flesh. Highest average concentration of Fe in tuber flesh was found in Kufri Girdhari followed by Kufri Bahar, Kufri Surya and Kufri Red and contained >35 mg/kg Fe in Tuber flesh. A significant amount of Fe (39.87%) followed by Mn (21.71)%, Cu (15.36%) and Zn (12.96%) was present in peel. Zinc concentration ranged from 12.59 in Kufri Arun to 22.85 mg/kg in Kufri Anand with an average content of 17.64 mg/kg (Fig. 12).

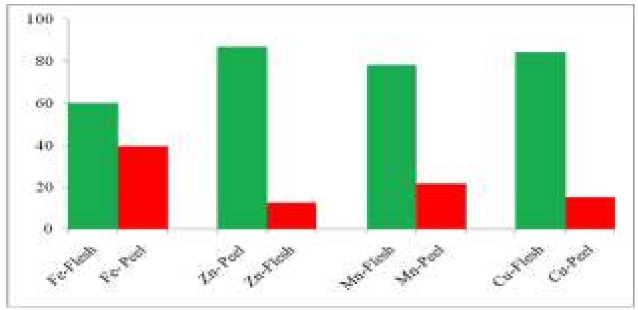


Fig. 12. Partitioning of micronutrient content in tuber flesh and peel (mean of 48 varieties)

Forty six accessions were analysed for Zn and Fe contents. The tubers were raised at Modipuram and CPRS, Kufri under uniform fertility. 13 advanced hybrids from Patna were also analysed for Zn and Fe contents. The Fe content in tuber flesh ranged from 25.63 to 35.23 mg/kg (dry weight basis) and Zn content ranged from 13.08 to 23.63 mg/kg (weight basis). Amongst eleven red skin colored advanced hybrids and varieties grown under uniform conditions at Patna Rajendra-2 contained highest Fe content in tuber flesh followed by P-14 on dry weight basis. Zinc content was highest in P/6-24 hybrid followed by Rajendra-2 (Fig. 13).

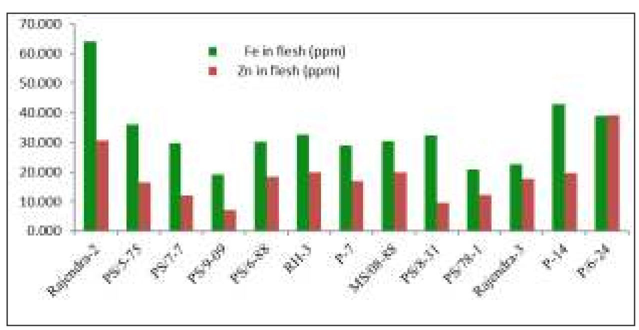


Fig. 13. Response of different cultivars to foliar application of Zn and Fe

Programme: Impact, adaptation and management strategies for climate resilient potato production

Global climate is changing with potentially severe implication for human life if we fail to restrict the global average temperature increase below 2°C. Developed countries have released the overwhelming share of greenhouse gases jeopardising the earth atmosphere and as a consequence of which every strata of the society is affected by the climate change. The concentration of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) has been manifold since from the 17th century due to human domestication activity. In 2015 the concentration of greenhouse gases were 399.5 ppm, 1834 ppb, and 328 ppb, and exceed the pre-industrial levels by about 423%, 154% and 21% respectively. Now the concentration of major greenhouse gas CO_2 has crossed the 400 ppm level. The most important challenge for food security in the 21st century is global climate change. The negative impact of climate change on overall food productivity are now well documented and the impact of climate change on the productivity of major crops in most of the regions have been assessed to some extent. Potato, a temperate region crop being grown in sub-tropical regions of India is threatened by climate change not only in form of productivity but also due to its vulnerability to major diseases and pests in the region.

Climate change impact on potato productivity in Gujarat: Three popular potato cultivars; Kufri Badshah (long duration), Kufri Jyoti (medium duration) and Kufri Pukhraj (short duration) were selected for impact assessment studies. The WOFOST model derived simulation results has shown that there was a great variation in the productivity of potato within the state under the baseline climate scenario (2000). The extrapolated results have shown a baseline productivity of 40.3, 36.1, 37.5 t/ha for these cultivars (Table 1). The distribution of geographical area in Gujarat under different productivity classes for different potato cultivars in 2000 is given (Table 2). The WOFOST simulated potato productivity was highest in northern districts (Fig 1).

In 2055, due to increase in temperature, greater decline is expected in the productivity of all the three cultivars. The mean decline expected in the yield due to temperature for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj is 22.9, 30.1 and 33.9% respectively. On the other hand, the increase in CO_2, which is expected to reach to 590 ppm in 2055 under the A1FI scenario is likely to have positive impact on the productivity. The mean increase of 20.8, 22.9 and 22.5% in the productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj is expected due to positive effect of CO_2 fertilization. However, this positive effect of CO_2 in productivity of these cultivars is not sufficient to compensate fully the negative impact of associated temperature rise on potato and the model has shown a mean decline of 19.9, 23.3 and 25.6% in the productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj respectively when the mean was taken over the 20 locations under study.

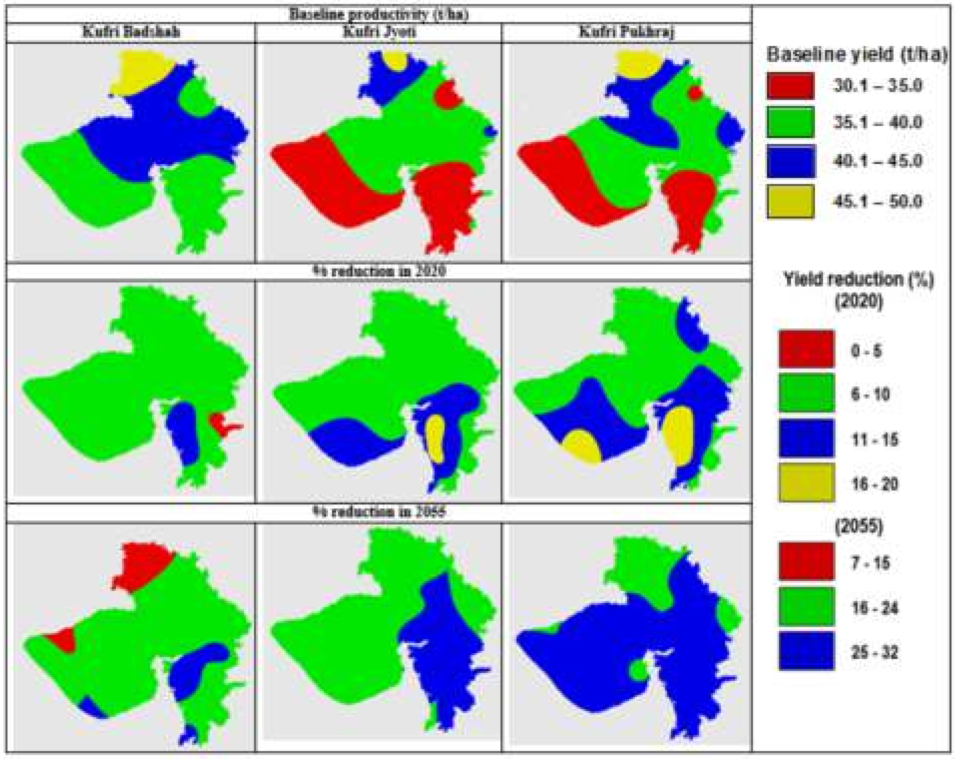


Fig. 1. Potential productivity of different potato cultivars under baseline and changes in future climatic scenario in Gujarat state

Table 1: Productivity of potato cultivars in baseline year and changes thereof in future climates (interpolated results for total geographical area of Gujarat, excluding Kachchh)

	Kufri Badshah	Kufri Jyoti	Kufri Pukhraj
Baseline yield (t/ha)	40.3	36.1	37.5
Overall reduction in yield (%)			
2020	7.6	9.7	10.9
2055	19.5	22.1	25.2
Yield reduction classes (%) in 2020	**% geographical area of Gujarat**		
0-5%	1.7	-	-
6-10%	92.1	72.5	53.8
11-15%	6.2	24.4	36.2
16-20%	-	3.1	10.0
Yield reduction (%)classes in 2055			
7-15%	10.2	-	-
16-24%	79.9	70.4	19.8
25-32%	9.9	29.6	80.2

Table 2. Geographical area of Gujarat (excl. Kachchh) (%) under different yield classes in 2000

Potential productivity (t/ha)	Kufri Badshah	Kufri Jyoti	Kufri Pukhraj
30.1-35	0.0	44.5	32.8
35.1-40	50.8	45.4	44.6
40.1-45	41.2	8.4	17.9
45.1-50	8.0	1.7	4.7

Calibration of WOFOST crop growth model for potato cultivars Kufri Garima and Kufri Khyati: WOFOST (WOrld FOod STudies) crop growth model estimates the growth of an annual crop, within a given set of specific soil and weather conditions. This is a widely used model for crop growth and climate change studies. In this model, simulation of crop growth is based on ecophysiological processes, some of which are; phenological development, CO_2-assimilation, transpiration, respiration, partitioning of assimilates to the various organs, and dry matter formation. 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, UP. The statistical performance analysis applied to model predictions (Table 3) and a close match between simulated and field data for total dry matter production and tuber dry matter yield (Table 4) is shown below.

Table 3. 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 Garima		Kufri Khyati	
ME		605.0	0.00	1414	171
RMSE	0	4.583	4.774	6.669	5.455
CRM	0	0.003	0.034	-0.010	0.043
EF	1	0.996	0.999	0.990	0.955
CD	1	0.920	0.977	0.898	0.996

Table 4. Comparison of measured (mea.) and simulated (sim.) values of some important parameters.

Parameter	Mea.	Sim.	Diff.	Mea.	Sim.	Diff.
	Kufri Garima			Kufri Khyati		
Emergence (days)	22	17	5 days	16	18	2 days
Tuber initiation (days)	45	41	4 days	42	38	4 days
Total DM yield (kg/ha)	17200	16921	1.6%	18976	19238	1.3%
Tuber DM yield (kg/ha)	9510	9641	1.3%	11200	10906	2.6%

Diff.= Difference

Effect of water levels and mulching on potato under drip irrigation: At Modipuram, Irrigations applied at 125 % CPE (cumulative pan evaporation) produced significantly higher total tuber yield (35.7 t/ha) in comparison to irrigations scheduled at 75 % CPE water level which gave 32.8 t/ha. While the mulching with paddy straw @ 5 t/ha gave significantly higher total tuber yield (36.2 t/ha) than other treatments tried (Spray chemical CH-1 & CH-2). The interaction of irrigation levels and mulching was non – significant but was found statistically at par with the produce (35.6 t/ha) of polyethylene sheet mulch in potato. The similar trend was also noticed in case of large and medium size tuber yields.

Effect of water levels and mulching on potato under sprinkler irrigation: In another experiment at Modipuram, the effect of water levels and mulching was significant on total tuber yield under sprinkler irrigation. Irrigations applied at 150 % CPE (cumulative pan evaporation) produced significantly higher total tuber yield (32.7 t/ha) in comparison to irrigations given at 100 % CPE water level which produced 26.4 t/ha. While in case of mulching, the application of mulch with paddy straw @ 5 t/ha gave significantly higher yield (31.6 t/ha) than other treatments tried, but was also statistically at par with the produce (30.0 t/ha) of polyethylene sheet mulch in potato. However, the effect of mulching was non-significant on total tuber numbers as well as graded tuber yields and numbers under sprinkler irrigation.

Evaluation of chemical formulations for mitigating heat /drought stress in potatoes: Higher temperatures and drought are known to decrease the overall physiological efficiency of crop plants including potato. ICAR – IARI, New Delhi has developed several chemical formulations for mitigating heat stress in potato. A total of five different chemical formulations (CFT1 to CFT5) were evaluated in a 75-day field trial conducted using heat tolerant Kufri Surya and heat susceptible Kufri Bahar potato varieties in early crop (September planted) at Modipuram. Chemical formulations (CF) were applied as fine mist in the afternoon at 4-5 leaf stage (35 DAP) either once ore repeated after one week as per hypothesis of the formulation.

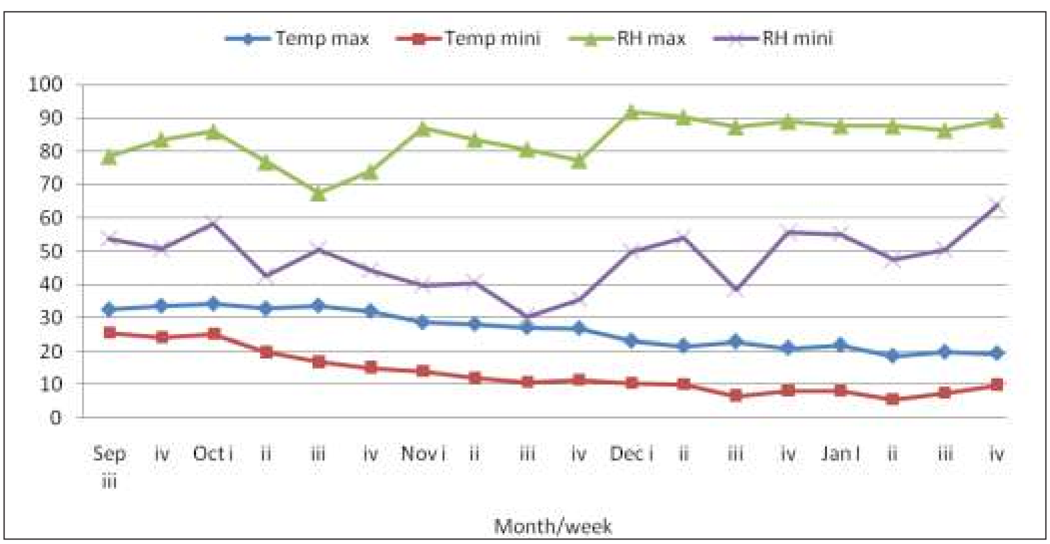


Fig. 3. Weather variables (weekly avg.) during early and main crop season at Modipuram 2016-17

CF and deficit water stress in winter potatoes: In another experiment at Modipuram, three different chemical formulations (CFT1, CFT3 and CFT6) were evaluated in a 90-day field trial using same heat tolerant and heat susceptible potato varieties as above in winter. Water stress was imposed by one less watering, withholding 3rd irrigation out of total four and CFs were applied as foliar application at 60 DAP. Water stress caused significant reduction in photosynthesis rate, stomatal conductance and the magnitude of reduction was not narrowed down by any of the CF treatments. As expected, leaf temperature and SPAD values were significantly increased under stress. Tuber yield at 75 DAP showed that it responded more positively to water spray than CF, however at the end of full crop duration (90 DAP) TY was much improved in CFT6 and it narrowed the yield gap (Fig. 4).Tuber yield both at 75 DAP and 90 DAP was improve in CFT1 in Kufri Surya suggesting a stable response to the treatment (Fig. 4). Observations in dry matter distribution pattern indicated that biomass in stem and root parts in Kufri Surya (a trait known for mitigating the heat stress) was maintained under water deficit conditions as well.

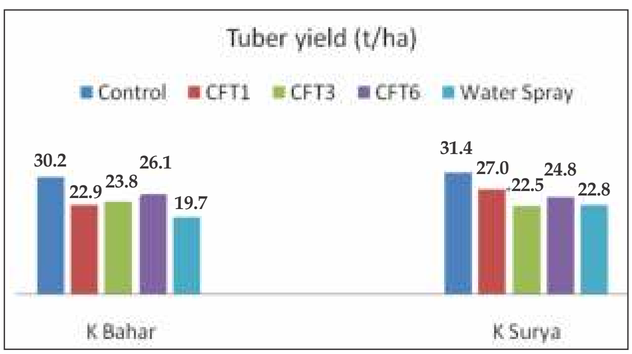


Fig. 4. Effect of chemical formulations on tuber yield at 90-day under water stress in winter crop

Effect of mulch with drip irrigation on potato: Under the climate change scenario, there is an urgent need to increase water use efficiency looking at the increasing temperature and decreasing water availability. Mulch especially reduces water evaporation from the soil and maintain stable soil temperature. Mulching also significantly decreases soil erosion, virus vector transmission in seed potatoes and it may also act as a tool for the control of nitrogen losses by the immobilization of post-harvest nitrate. For that reason, the mulch cover influences the soil moisture as well. Mulching has a positive effect on the weed density. Application of 75% CPE recorded higher number of tubers (762 thousand/ha) compared to 125% CPE (mention yield level). Application of paddy straw mulch @ 5 t/ha produced highest number of tubers (755 thousand/ha) which was higher over no mulch and 25 micron plastic mulch (Fig. 5).

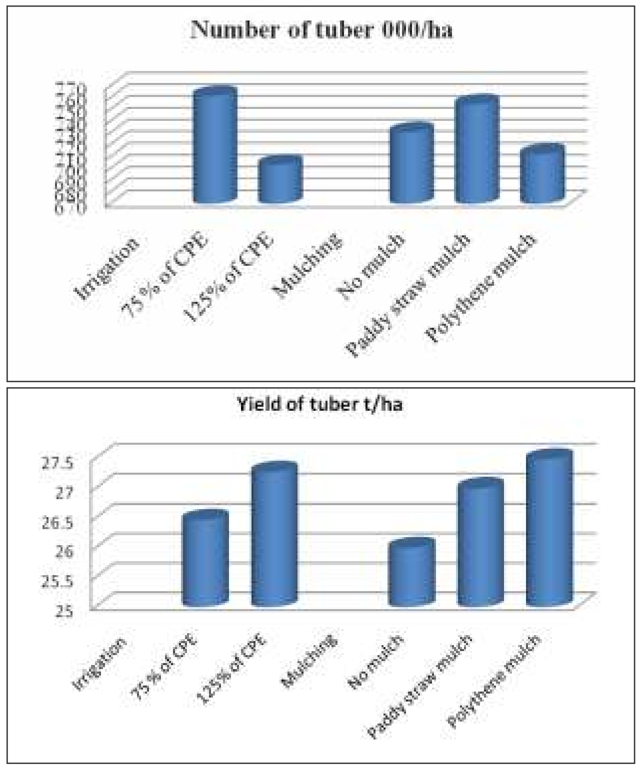


Fig. 5. Effect of mulch with drip irrigation on potato:

Effect of elevated level of CO_2 on Kufri Badshah: Effect of elevated CO_2 on growth and tuber yield of potato variety Kufri Badshah was was assessed in Open top chambers (OTCs) established at ICAR-CPRS, Jalandhar. Plant height increased linearly from emergence till about 70 DAP.At final stage of crop growth an increase of 9.14 per cent in plant height was recorded (Fig. 6). Leaf area increased up to 70 days and then declined rapidly, however, was higher at 600 ppm compared to ambient conditions (Fig.7). Tuber yield increased by 20.34 percent under CO_2 enrichment over the control (Fig. 8). The net photosynthesis was 22.38 per cent higher in forenoon and 25.47 per cent higher in afternoon under elevated CO_2 at 40 days after planting (Fig. 9). Total plant and tuber dry matter due to CO_2 enrichment increased in comparison to ambient conditions in each 10 days interval observation, however, harvest index didn't show any significant difference on CO_2 enrichment (Fig. 10).

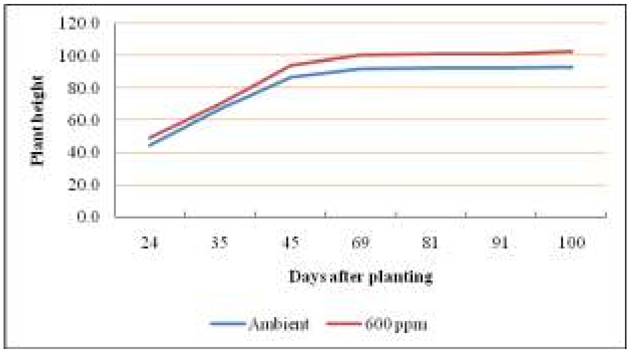


Fig. 6. Effect of elevated CO_2 on plant height of potato cv. Kufri Badshah under OTC.

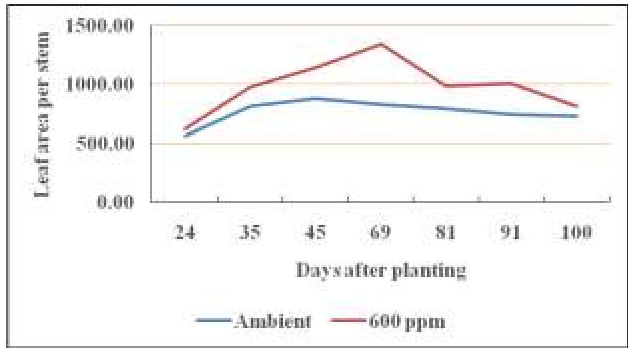


Fig. 7. Effect of elevated CO_2 on plant height of potato cv. Kufri Badshah under OTC.

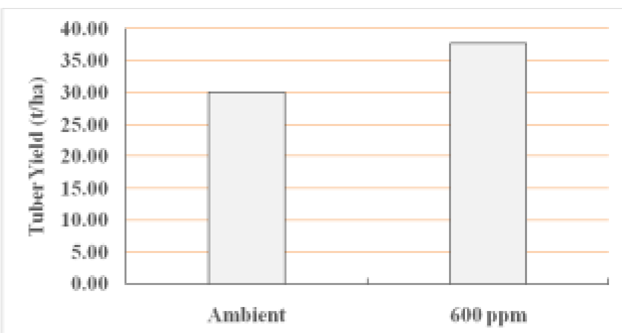


Fig. 8. Effect of elevated CO_2 on plant height of potato cv. Kufri Badshah under OTC.

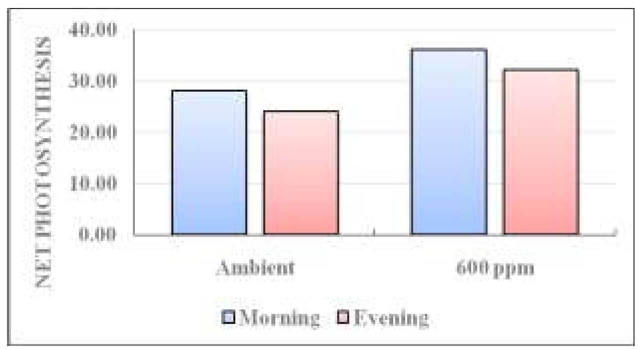


Fig. 9. Effect of elevated CO_2 on plant height of potato cv. Kufri Badshah under OTC.

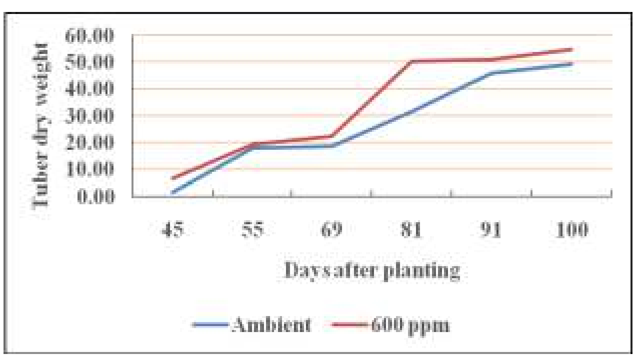


Fig. 10. Effect of elevated CO_2 on tuber dry weight of potato cv Kufri Badshah under OTC.

Expression analysis of Rubisco activase (RCA) under the elevated CO_2 concentration in Potato: Eeffect of CO_2 concentration on rubisco activase in potato leaves of Kufri Badshah grown at normal or ambient CO_2 (350 ppm) and high CO_2 (550 ppm) concentrations, four isoforms of RCA were mined from the PGSC database by keyword search. Preliminary results, found that elevated CO_2 has increased the net photosynthesis rate but the expression of RCA isoforms namely, Rub1, 67 and 16 was low as compared to the ambient CO_2

concentration. Interestingly the fourth isoform, Rub79 showed the enhanced expression under elevated CO_2 concentration (Fig.11). Expression of these isoforms under high temperature needs to be investigated to understand the effect of global climate change on photosynthesis mechanism in potato.

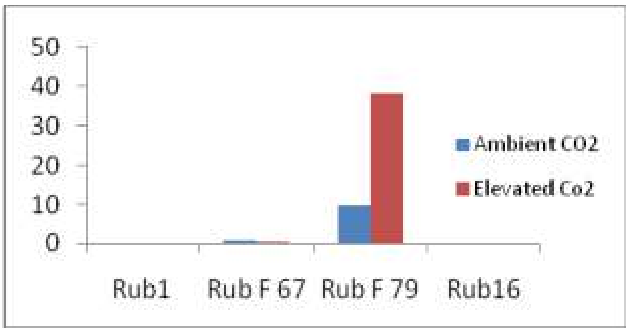


Fig. 11. Effect of CO_2 concentration on rubisco activase

Appearance of late blight in Climate analogues: Climate analogues (places where present climate is similar to the given future climates of places of interest) are important to study the appearance of late blight and subsequent effect on its incidence in future climate change scenarios. In similar climate analogues late blight may either appeare at same time or at different times. Therefore, observations of late blight appearance in different climate analogues were studied. It was observed that at similar analogous late blight appeared at different dates. At Kannauj (27.055, 79.918) late blight appeared on 20-25 December, 2016 while its analogous Bijnor (29.313, 78.377) late blight appeared on 24-27 January, 2017. A difference in late blight appearance between the Kannauj and Bijnor was less during 2014-15, However, at Patna (25.617, 85.167) which is analogous of Agra (26.753, 78.773) late blight appeared at same times (Table 5).In an another experiment conducted on two different varieties *viz.* resistant (Kufri Chipsona-1) and highly susceptible (Kufri Bahar) to know how these behave under different climate change scenarios, planting was done at 15 days interval. (17 Oct.- 2 Nov. and 17 Nov, 2016 onwards). The disease severity (DS) of late blight was observed at maturity stage of the crop with 13% DS on Kufri Bahar and 3% on Kufri Chipsona-I on 17 Oct, 2016 planting crop (first date).The late blight disease severity was 16% DS (Kufri Bahar) and 2.5% DS (Kufri Chipsona I) on second of planting whereas 86% DS (Kufri Bahar) and 13% DS (Kufri Chipsona I) on third date of planting.

Population dynamics of Pest/vector at Gwalior: The potato is grown in many parts of North-central India and to maintain the quality one has to be vigilant about pests and vectors. The most important among the vectors are Aphids (*Myzus persicae* Sulzer, *Aphis gossypii*) and whitefly (*Bemisiatabaci* G). The data revealed that *A. gossypii* arrived on potato in the months of Oct.- Nov. followed by *M. persicae* with its maximum activity in the month of February. Dry spell (no rains) observed except 28 mm rains during the 4th standard week of 2017. Early planted crop in the month of October was having more virulent population of vectors, resulting more incidence of disease (Fig.12 &13). The high temperature (30-35 ^{0}C) and dry weather during early October is favorable for the development of disease. Aphids and whitefly activity also trigger on potato crop due to high temperature and moderate humidity.

Generation of Periodic data on arrival and build-up of aphid population on Potato at Jalandhar: The arrival and build-up of *Myzuspersicae* (Sulzer) on potato crop was monitored by leaf count method and yellow water-pan traps. *M. persicae* alates were first noticed on potato in the first week of

November. The immigration continued and the population size increased gradually at first and then exponentially after the last week of December (Fig.14). The aphid reached the critical limit of 20 aphids per 100 leaves by 20th December. The population growth continued till it was more than 2900 aphids per 100 leaves by mid-February after which it declined suddenly due to fungal epizootic. The production of alatiform nymphs started towards the last week of December which indicated that immigration of alates continues at least till the last week of December. More than 1650 samples of *M. persicae* were caught and recovered from the water-pan traps.

Table 5. Locations and their climate analogous for late blight appearance

SN	Location	Late blight appearance	Analogous	Late blight appearance
1	Agra: 27.167,78.033	First week of Jan. (1-7 Jan,2017)	Etah:27.739,78.729	*First week of Jan. (3-7 Jan,2017)
2	Kannauj: 27.055,79.918	*Third week of Dec (20-25 Dec, 2016)	Bijnor: 29.313,78.377	24-27 Jan, 2017
3	Jalandhar: 31.326,75.579	*Firts week Feb, 2017 (on tomato)	Baghpat: 29.274,77.191	20-21Jan, 2017
4	Patna: 25.617,85.167	First week of Jan. (1-7 Jan,2017)	Agra: 26.753,78.773	First week of Jan. (1-7 Jan,2017)

*observation recorded by telephonic communication

Table 6. Disease severity and AUDPC of two cultivars and different dates of sowing

Dates of planting	Late blight disease severity (%)		AUDPC	
	Kufri Bahar	K.Chipsona I	Kufri Bahar	K.Chipsona I
17 Oct,2016	13 (106 DAP)	3 (106 DAP)	155.00	40.0
2 Nov,2016	16 (89DAP)	2.5(89DAP)	570.00	337.50
	98 (99DAP)	65(99DAP)		
17 Nov,2016	10 (74DAP)	2.5(74DAP)	480	77.5
	86 (84DAP)	13(84DAP)		
	100 (95DAP)	43 (95DAP)		

Population dynamics of pest/vector at Modipuram (Meerut): In an experiment planted at 8 different dates starting from 15th September to 20th October at a gap of 5 days, observations were recorded on numbers of whiteflies (*Bemisia tabaci*), leafhoppers (*Amrasca b. biguttula*), aphid- *A. gossypii* and in planting dates of 15th and 20th October, number of *Myzus persicae*/three leaves were also recorded. Crop emergence was minimum in 15th September planting as temperatures were very high during this planting time. The number of leafhopper and mites damage was also high in September planted crop although damage by mites was also recorded even in 20th October planted crop. During 2016-17 the damage caused by leafhopper was more. The crop planted on 15th September completely died after 70 days. In second week of October only on two dates of planting leafhopper and white fly could be observed (Fig. 15). On 28.10.16 even

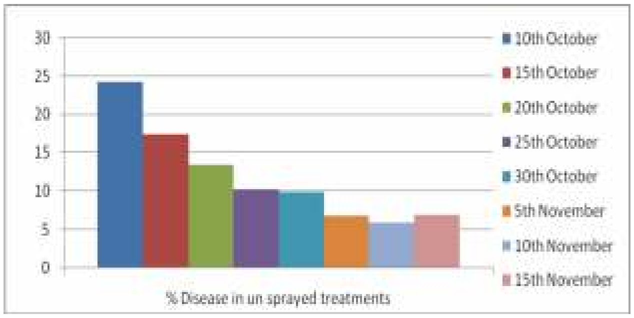


Fig. 12. Disease incidence in different planting dates of potato

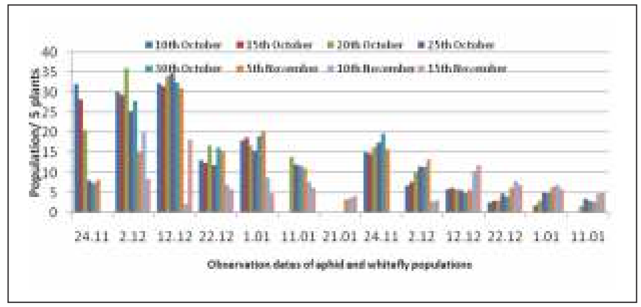


Fig. 13. Aphid and whitefly population in different planting dates of potato during 2016-17

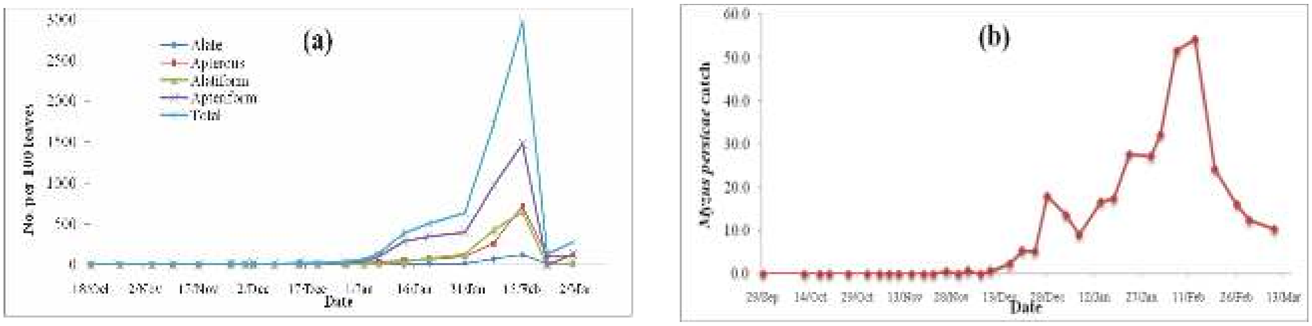


Fig. 14. Arrival and build-up of *Myzus persicae* determined by leaf count and trap catch methods. (a) population build up by leaf count method and (b) population size by trap catch.

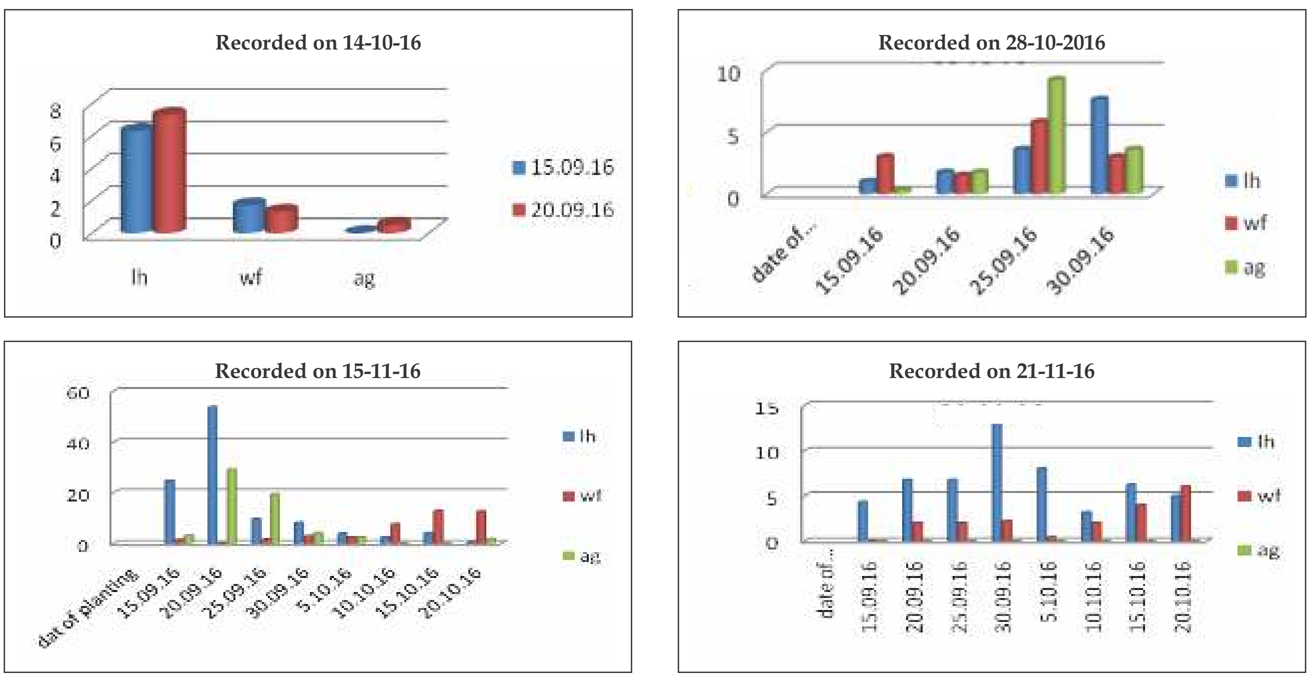


Fig. 15. Population dynamics of different insects on different planting dates

A. gossypii could be recorded along with leafhopper and whitefly in all September planting dates. During 2016-17 leafhopper population was on the rise although in last 4 years it was less in number.

Programme: Resource optimization in potato based cropping system

Research work under nine research activities was carried out in this programme during 2016-17. Main output was in seed potato production through aeroponics and augmenting micro-propagation potential of potato cultivars, yield gap analysis, development of Indian good agricultural practices (GAP) for production of potatoes, organic potato production and potato based cropping system development, long term plant nutrition studies, development of agro techniques of new potato cultivars for *Kharif* season in southern Karnataka, and mechanical technologies for potato cultivation. Aeroponis and micro-propagation findings are presented in the section of Division of Seed Technology. Other achievements are described here.

Comparing institute production technology with farmer's practices for yield gap estimation: Based upon information available about the farmers' practices of raising potato in North-western hills, Western U. P. and Bihar, experiments were conducted during 2016-17 at Shimla, Modipuram and Patna. At Shimla, results revealed that adoption of institute recommendations (mancozeb as prophylactic and curzate/acrobat with triton as sticker; fertilizer on soil test basis and two earthing) resulted in 29.6% higher tuber yield over farmers' practice (dithane-M 45; 126: 64: 44 kg N-P-K /ha and one earthing). At Modipuram, newly released varieties K. Mohan (48.0 t/ha), K. Garima (40.1) and K. Khyati (37.8) were superior in tuber yields in comparison to K. Bahar (29.4) and K. Pukhraj (36.1). Their productivity was 28.6-63.3% and 4.7-33.0% higher over K. Bahar and K. Pukhraj. Variety K. Bahar recorded 17.1 and 22.5% higher tuber yield with soil test based (28.1 t/ha) and recommended dose (29.4), respectively over Agra farmer's practice without earthing up (24.0) (Fig. 1).

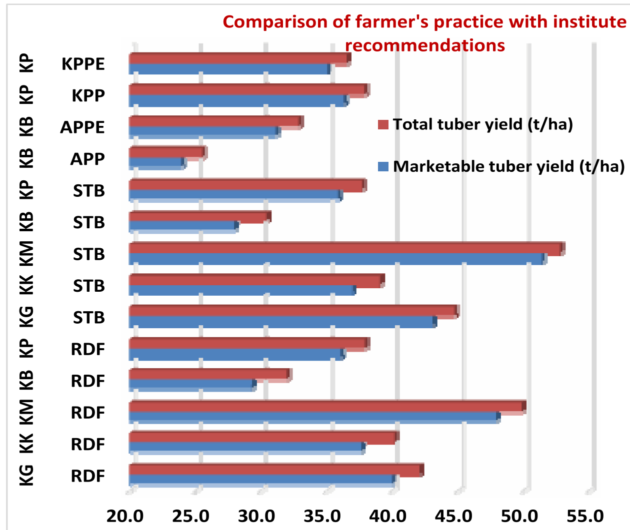


Fig. 1. Comparison of farmer's practices with institute recommendations

Developing Good Agricultural Practices (GAP) for production of potato crop: GAP addresses daily on-farm activities and alert growers to procedures that promote safe production and handling of produce. Efforts are on for developing this document for production and handling of potato crop which are safe to consume, environment friendly and non-polluting. Documentation is in progress to develop Indian GAP for production of potato crop. At Shimla, an experiment was conducted to work out the N application rate for three potato cultivars for optimum yield under mid-hill condition. Results revealed that cvs. K. Jyoti, K. Girdhari and K. Himalini required 150 kg N ha^{-1} (100% of recommended dose) for optimum yield. Tuber shape in potato has also emerged an important trait in ascertaining the suitability for a particular segment. Whether fertilizer application influence/ alter the tuber shape *per say* in a variety was investigated in K. Mohan at N levels 140 and 210 kg ha^{-1}. Random samples analyzed for quantification of shape (potato shape index) from replicated trial, representing 15 tubers each in 3 broad size categories (>100, 50-100 and <50g) revealed that tuber shape is largely a genotypic trait and influenced negligible by N (Fig.2).

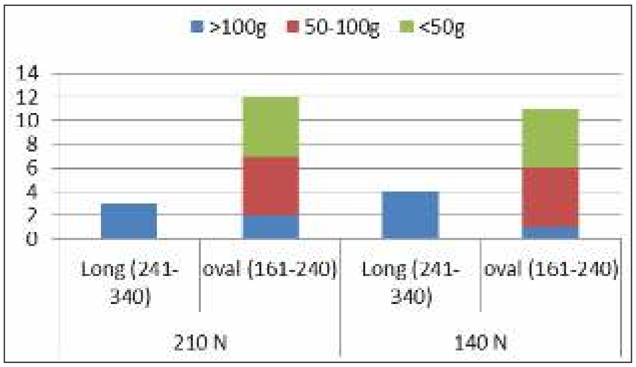


Fig. 2. N levels and tuber shape (estimated as potato shape index) in potato variety K. Mohan

Organic potato production technology development: Conclusions of three year organic farming trials conducted at Modipuram are as follows:

Promising genotypes: K. Khyati (28.4 t/ha), K. Mohan (28.3), hybrid MS/0-3808 (27.8) and K. Garima (27.0) are promising genotypes for table potatoes due to their better yield potential and % yield maintenance over popular varieties K. Bahar (20.5) and K. Pukhraj (21.2). K. Himsona (21.5 t/ha), K. Chipsona-3 (20.3) and French fry hybrid MP-04/578 (21.3) are better genotypes for processing purpose (Table 1).

Healthy seed potato production for organic farming: Seed potatoes can be produced by integrating eco-friendly methods for reducing vector population below critical limits (20 per 100 compound leaves). Use of yellow water traps, yellow sticky traps, and weekly spray of summer oil is sufficient for reducing vector population. Light traps and *neem* dried leaves as mulch in furrows are used for reducing the population of defoliaters. Timely planting of seed crop, organic nutrient management, integrated pest management, suggested three roguing starting from 45 days after planting, and haulm cutting at 85-90 days before aphids cross critical limit will provide healthy seed for organic potato growers.

Drip irrigation: In vegetable based crop sequence (cowpea- potato- okra), organic system (crop residue recycling: CRR) and organic system (integrated approach: IA) are promising as they attained 60.0 and 55.8 t/ha system productivity, respectively, which was 77.9 and 72.5% of inorganic nutrition (77.0 t/ha) in first year. Productivity improved to 84.8 and 82.7%, respectively in both systems during second year as compared to inorganic nutrition.

Sprinkler irrigation: In food grain based rotation (groundnut- potato- maize+ *moong* bean), organic system (IA) recorded 56.6 t/ha system productivity, which was 89.0% of inorganic treatment (63.6 t/ha) in first crop season. This system attained 91.3% of inorganic nutrition system productivity during second year.

Flood irrigation: In vegetable based sequence (cowpea- potato- okra), organic system (IA) is better with 55.6 t/ha system productivity (77.2%) in comparison to inorganic nutrition (72.0 t/ha) in first year. Productivity improved to 82.0% in this treatment in second year as compared to inorganic treatment. In food grain based system (groundnut- potato- maize+ *moong* bean), again organic system (IA) has performed better with 77.2% of system productivity of inorganic nutrition in first year, which improved further to 82.0% in second season.

Table 1. Mean marketable tuber yield (t/ha) of promising genotypes evaluated under inorganic (IN) and organic (OR) nutrition

Genotypes	Marketable tuber yield		
	IN	OR	Mean
K. Khyati	43.8	28.4	36.1
K. Garima	43.8	27.0	35.4
K. Mohan	51.4	28.3	39.8
MS/0-3808	44.0	27.8	35.9
MP/04-578	35.6	21.3	28.4
K. Himsona	33.9	21.5	27.7
K. Chipsona-3	36.3	20.3	28.3
K. Bahar	33.9	20.5	27.2
K. Pukhraj	42.9	21.2	32.1
Mean	40.7	25.3	33.0
Statistics	*CD* $_{0.05}$		
Nutrition (N)	2.40		
Genotypes (G)	4.54		
Interaction N ×G	6.44		

Development of potato-based cropping system for irrigated organic ecosystem: A fixed field experiment was conducted during 2016-17 at Patna to develop potato-based cropping systems for organic farming under irrigated condition. 100% RDN- vermi-compost treatment recorded highest cumulative yield (46.5) followed by 100 % RDN-FYM (44.0) among all sequences i.e. potato-onion-maize, potato-sunflower-cowpea and potato-mung-rice (Fig. 3).

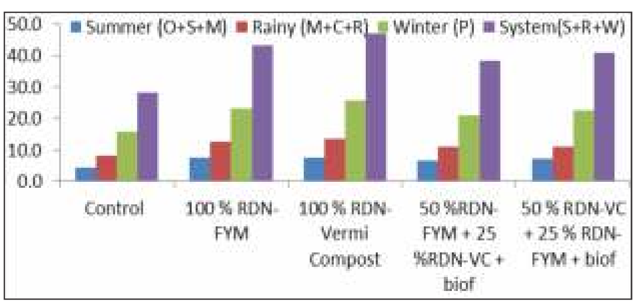


Fig. 3. Cumulative economic yield (t/ha) of three crops in each season during 2016-17

Development of potato based cropping systems for different agro-ecologies

Evaluation of potato based cropping systems: In a study at Gwalior, yield of *Kharif* crops was influenced by intercropping systems. Intercropping pearl millet with cowpea increased pearl millet yield by 4 q over its sole crop yield however intercrop yield of cowpea pod was low (2.4 q). Low yield of cowpea pods in pearl millet+ cowpea intercropping was due to luxuriant growth of pearl millet and its canopy coverage. Good cowpea pod yield (24.6) in maize+ cowpea intercropping system was obtained due to less canopy coverage by maize crop resulting in good growth of cowpea. However, there was reduction in intercropped maize yield (16.2) over its sole yield (25.6). Sole cowpea produced highest pod yield compared to their intercropping treatments.

Effect of cropping system and nutrient management practices on productivity, nutrient acquisition and soil health of potato: At Patna, four sequences (Potato-cowpea-maize, Potato-bottle guard- Rice, Potato-onion-Rice & Potato-onion-green manuring) were evaluated under five nutrient management options (T1- Control, T2- 100% RDF –Fertilizer, T3-50% RDF+50% RDN-FYM, T4-50% RDF + 25% RDN-FYM+

Biofertilizers & T5 25% RDF + 50 % RDN-FYM+ Biofertilizers). Nutrient management option of 50% RDF+50% RDN-FYM was comparable to 100% RDF –Fertilizer in terms of productivity of individual crop and of overall systems in all four potato based crop sequence.

Effect of cropping system and nutrient management practices on potato based cropping systems under Meghalaya Agro-ecological condition: A field experiment was conducted during summer and autumn season of 2016 at Shillong to find out the best potato based cropping system and nutrient management practices in Meghalaya. Among cropping systems, potato-cabbage gave highest potato equivalent yield (30.0 t/ha) followed by potato-radish (28.9 t/ha). Nutrient management practice (50% RDF+ 25% RDN- FYM+ *Azospirillum*+ PSB to potato & 50% RDF to subsequent crops) gave highest potato equivalent yield of 27.9 t/ha (Figs. 4-5).

Developing potato based systems in Nilgiris: Sequential planting of three different component crops viz., cabbage and garlic were tried with potato. Potato was planted as main crop in summer season and other crops were planted subsequently in autumn. Potato yield in summer ranged between 8.8-19.6 t/ha. Yield of cabbage in autumn crop ranged between 64.6-94.5 t/ha and potato equivalent yield of cabbage was 31.3 t/ha. Yield of garlic during autumn ranged between 4.6-5.9 t/ha and its potato equivalent yield was 39.6 t/ha.

Long term plant nutrition studies in potato based cropping systems

System Productivity: Among seven treatments tested, tuber yield with application of vermi-compost was higher than absolute control. Yield of wheat, potato, onion and maize was higher in 100% recommended NPK through inorganic fertilizer than that of 100% organic treatment. Yields of rice, maize, groundnut and green gram was at par in both organic and inorganic treatments (Table 2). Application of secondary nutrients along with 100% NPK slightly increased productivity of all systems as productivity was higher than 100% NPK only. Average system productivity was highest in maize-potato-onion (63.6 t/ha) followed by groundnut- potato green gram (50.9 t/ha). Lowest system productivity was recorded in rice-potato-wheat (43.2 t/ha). In all organic treatments, tuber size remained smaller than inorganic fertilizer. Quality parameters were better under organic treatment and cropping system had no significant effect on quality traits in tubers. Application of 100% NPK+ secondary nutrients and residue of previous crop increased potato yield in all three cropping system.

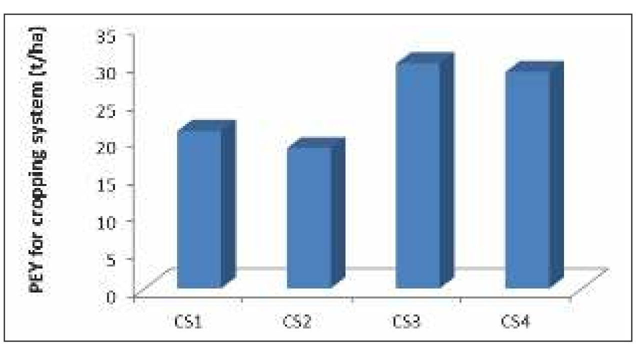


Fig. 4. Potato equivalent yield (PEY) for various cropping systems

CS1: Potato-cauliflower, CS2: Potato-french bean, CS3: Potato-cabbage, CS4: Potato-radish

Fig. 5. View of cropping system experiment at CPRS, Shillong

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

Disease Incidence: Observations were recorded in three cropping systems *viz.*, potato-wheat-paddy, potato-onion-maize and potato-green gram-groundnut. Results of foliar diseases of potato like Phoma and leaf spot complexes revealed that absolute control (no nutrient applied), 100 % NPK through organics manure and 100% organic+ crop residue had high disease incidence in all three systems. Severity of late blight in potato-green gram-groundnut was less in organics treatments. Black scurf of potato incidence in all cropping systems (Fig. 23) was highest in 100 % NPK through inorganic fertilizer treatment (12%DI). Highest disease incidence of black scurf was recorded in 100 % NPK through organic fertilizer (28% DI) in potato-onion-maize system, while in potato-green gram-groundnut system highest incidence (27% DI) was in 100% organic+ crop residue (Figs. 24 & 25).

Pest Incidence: Population of leafhopper and mite did not build up on potato crop Whitefly and % incidence of APCLV on potato crop did not show significant differences among treatments of all cropping systems, however the treatment consisted of 100% organic or part of organic manure recorded low incidence of whitefly and corresponding development of disease as compared to 100% inorganic nutrition or part of it along with control treatments (**Fig. 26**). Control showed higher population of whitefly comparable to 100% NPK inorganic treatment. Population of thrips on groundnut, stem borer damage in maize, and leaf folder and stem borer damage in rice did not show any significant difference among various treatments.

Table 2. Yield of maize-potato-onion and potato equivalent yield (PEY)

Treatment	Yield (t/ha)				
	Onion	Maize		Potato	PEY
		Grain	Stalk		
Absolute control	9.9	0.89	4.76	7.6	36.7
100% NPK through inorganic	20.6	1.70	5.30	27.6	71.8
100% NPK through organic	17.2	1.28	5.91	13.8	55.8
50% inorganic + 50% organic	19.2	1.48	5.52	22.6	65.8
100% inorganic + secondary nutrient	25.5	1.93	7.70	28.5	87.0
100% inorganic + crop residue	23.3	1.87	7.00	25.2	78.6
100% organic + crop residue	14.4	1.11	5.22	13.7	50.0
CD ± 0.05	**1.22**	**0.48**	**0.52**	**1.42**	**2.22**

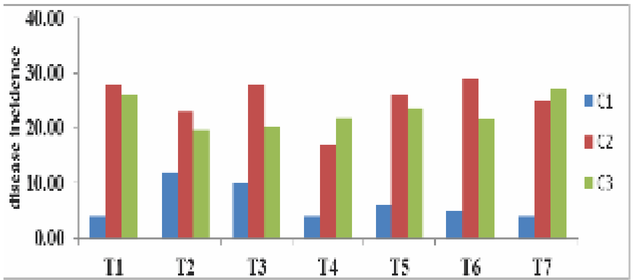


Fig. 6. Incidence of black scurf of potato in potato-wheat-paddy (C1), potato-onion-maize (C2) & potato-green gram-groundnut (C3) cropping system

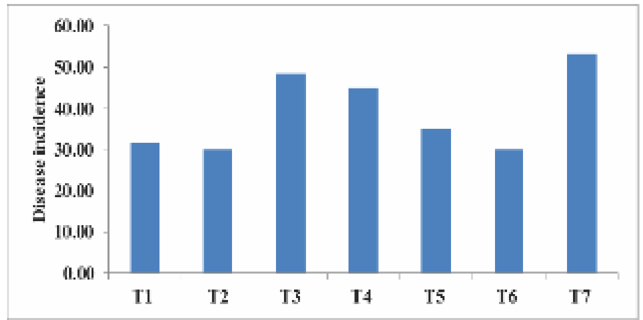


Fig. 7. Incidence of Banded sheat blight of maize in potato -onion-maize (C2) cropping system

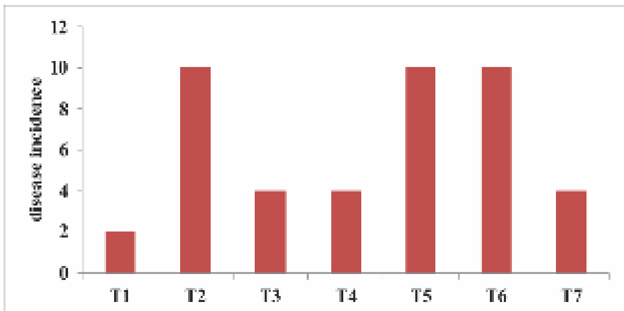


Fig. 8. Incidence of *Alternaria* leaf spot on onion in potato -onion-maize (C2) cropping system

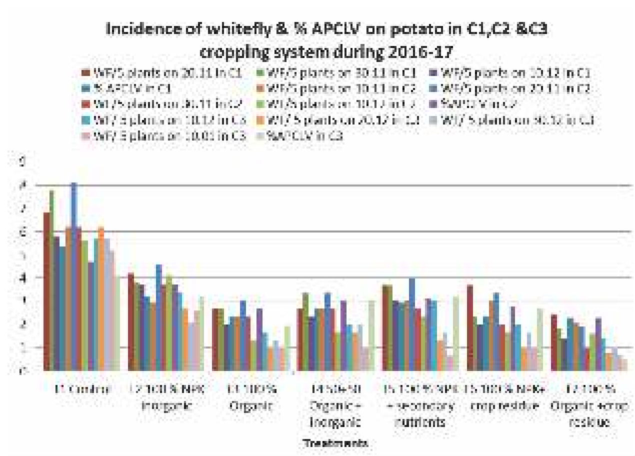
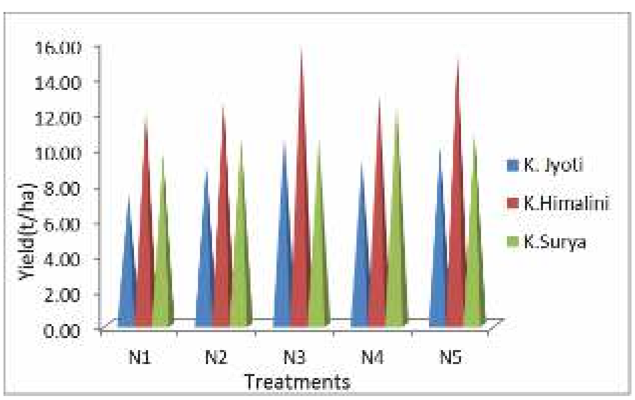


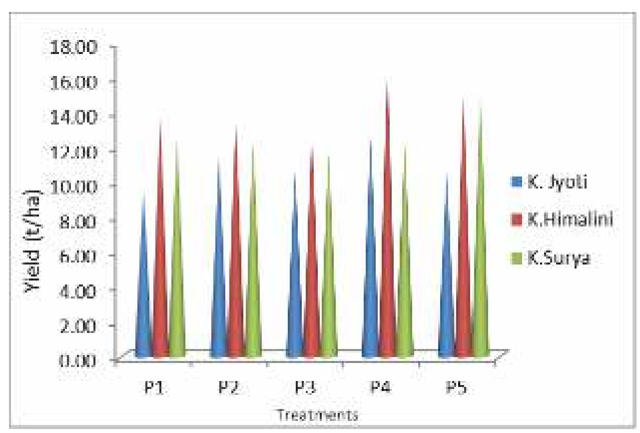
Fig. 9. Incidence of white fly and APCLV in potato crop

Optimizing macro-nutrient requirement of potato cultivars suitable for *kharif* season: K. Himalini (15.8 t/ha) and K. Jyoti (10.6 t/ha) recorded highest yield at 100 kg N/ha, while K. Surya (12.4 t/ha) had maximum productivity at 150 kg N/ha (Fig. 10). K. Himalini (16.5 t/ha) and K. Jyoti (12.5 t/ha) recorded highest yield at 120 kg P_2O_5/ha, whereas, K. Surya (14.8 t/ha) had maximum productivity at 160 kg P_2O_5/ha (Fig. 11). K. Himalini (22.9 t/ha) recorded highest yield at 100 kg K_2O/ha and K. Surya (21.4 t/ha) at 150 kg K_2O/ha, whereas, K. Jyoti (16.8 t/ha) had maximum productivity at 200 kg K_2O/ha.



N1-0 kg/ha N, N2-50 kg/ha N, N3- 100 kg/ha N, N4- 150kg/ha N, N5- 200 kg/ha N

Fig. 10. Response of potato varieties to different nitrogen levels



P1-0 kg/ha P P2-40 kg/ha P, P3- 80 kg/ha P, P4- 120kg/ha P, P5- 160 kg/ha P

Fig. 11. Response of potato varieties to different phosphorus levels

Mechanical technologies for potato cultivation

Assessment of potato damage during mechanical operations and its remedial measures: A tractor operated two row potato elevator digger was tested at three different forward speeds and at same harvesting depth for assessment of damage index on harvested potatoes of cv. K. Gaurav and K. Pukhraj. Severe damage index of cv. K. Pukhraj with a tractor operated potato elevator digger was minimum (17.8) at forward speed of 3.2 km/hr, whereas, scuffed and slight damage indices (10.1 & 5.4) were noted minimum at forward speed of 2.0 and 2.6 km/hr, respectively. Total damage indices of K. Gaurav were 40.1, 39.4 and 34.9, respectively at tractor's forward speed of 2.0, 2.6 and 3.2 km/hr, respectively (Fig. 12-13).

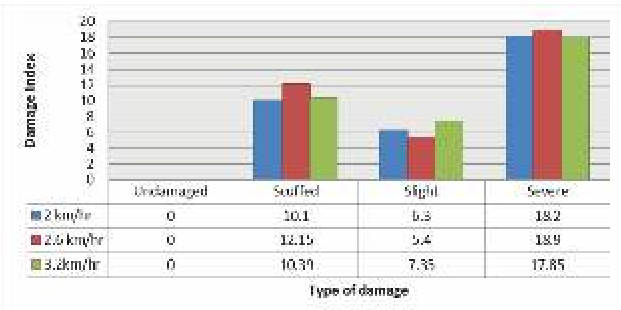


Fig. 12. Damage Index at tractor's three different speeds of operation (Variety K. Pukhraj)

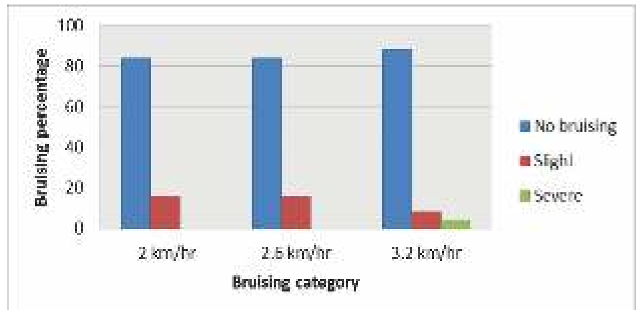


Fig. 13. Effect of forward speed of tractor on potato bruising with elevator digger (Variety K. Pukhraj)

Development, improvement and evaluation of potato combine harvester: Two row tractor operated potato combine harvester having provision for side conveying of tubers in trolley (Prototype I) was improved for better separation and to reduce tuber bruising. It consisted of six major units *viz.*, main frame, digging system, elevator conveyor, side delivery/discharge conveyor, power transmission and transport system. An inclined rod chain type conveyor type of trash separation and soil sieving system was provided to prototype. This rod chain type conveyor (length 1070 mm & width 725 mm) consisted mainly of 57 numbers of 12.5 mm diameter MS rods with pitch of 25 mm. Trash separation and soil sieving system was held with the help of two shafts supported by bearing brackets. A wooden roller of 100 mm diameter had also been provided in this system to maintain proper tightness of the system. MS sheet covers had been provided on sides of the system to disallow falling of the tubers.

Electromagnetic grading mechanism for minitubers: Minitubers are produced in millions especially in aeroponic system. These vary in size from about 0.2 to more than 4.0 gram. For marketing, these tiny tubers need to be graded precisely. To meet this requirement a new grading mechanism based on electromagnetic vibration principal was designed and improved after preliminary trials. Design has been prepared keeping in view the size composition of minitubers and need of adjusting the grading segments required in the market.

Automation of gun type spraying system for potato crop: Tractor operated gun type power sprayer is very popular in potato crop. An automatic swinging system was designed to avoid manual intervention in existing gun type sprayer. Spray gun was mounted on a swinging arm which is powered by a 12 Volt DC motor. Motor rotates at the rate of 45 rpm and rotary motion was converted into swinging motion using Grashoff 4-bar linkage mechanism. Arm swings around an angle of 150 degree and covers 7.2 m swath. The frequency of automatic swinging mechanism was 0.75 Hz, which is 4 times greater than the manual swinging. The developed system was tested in field condition at a pressure of 30 kg/cm^2 with a forward speed of 2.7 km/h. Swath of sprayer was 7.2 m with 20% overlap (Fig. 14).

Potato minituber grading cum counting machine: A vibration based grading machine was designed for minituber grading. It divides the minitubers in to three grades. The machine consists of a hopper, electromagnetic vibrator and a SS -'V' grooved conveyor with variable opening. Initially material conveyed from the hopper in to V- groove conveyor by virtue of vibrator provided acceleration and passed through the variable opening. As the tubers travel in V-groove, small size tubers drop first than medium and large, and collected in separate boxes. An optical sensor based electronic counting setup was designed for counting of minitubers. System consists of feeder, sensor, microcontroller and display unit. Tuber is singualted and conveyed towards the optical sensor which sense tuber and send signals to microcontroller for its processing.

Fig. 14. Field testing of automatic gun type sprayer

Division of Plant Protection

Programme: Re-defining epidemiological parameters and management approaches for potato pathogens

Disease monitoring and pathogens profile

Late blight appeared on 4th July, 2016 on cv. Kufri Jyoti in Shimla. Overall, the severity of potato late blight in Himachal Pradesh ranged from 25-80% depending upon the cultivar grown and plant protection measures adopted. In western Uttar Pradesh the disease appeared in Meerut on 28th December, 2016 on cv Kufri Pukhraj with 2.0% disease severity but did not spread further for one week due to low temperature; thereafter its build up was high. Late blight survey was carried out from 3rd Jan, 2017 to 2nd March, 2017 in different districts of western UP (Meerut, Muzaffarnagar, Bijnour, Baghpat and Hapur). Highest disease severity was recorded at Hapur (100%) and Meerut districts (95%), whereas lowest severity (2%) was in Baghpat. Since disease spread occurred at late stage of the crop, only 5 %yield loss was predicted in Hapur and Meerut districts.

The potato tuber samples (var. Lady Rosetta) with dry rot symptoms were received from Gujarat. The fungus – Sclerotium rolfsii was found associated with dry rot symptoms (Fig. 1).

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 adapting to the new climate and hosts. It is essential to understand the pathogen variability to devise suitable management strategies. In this regard, the population of *P. infestans* was characterized using both biological and molecular markers. In the previous studies, we have concluded that A2 mating type has established itself in the hills while A1 in sub-tropical plains. In order to determine whether sexual reproduction takes place in the field, attempts were made to detect oospores in the plant tissues but no oospore

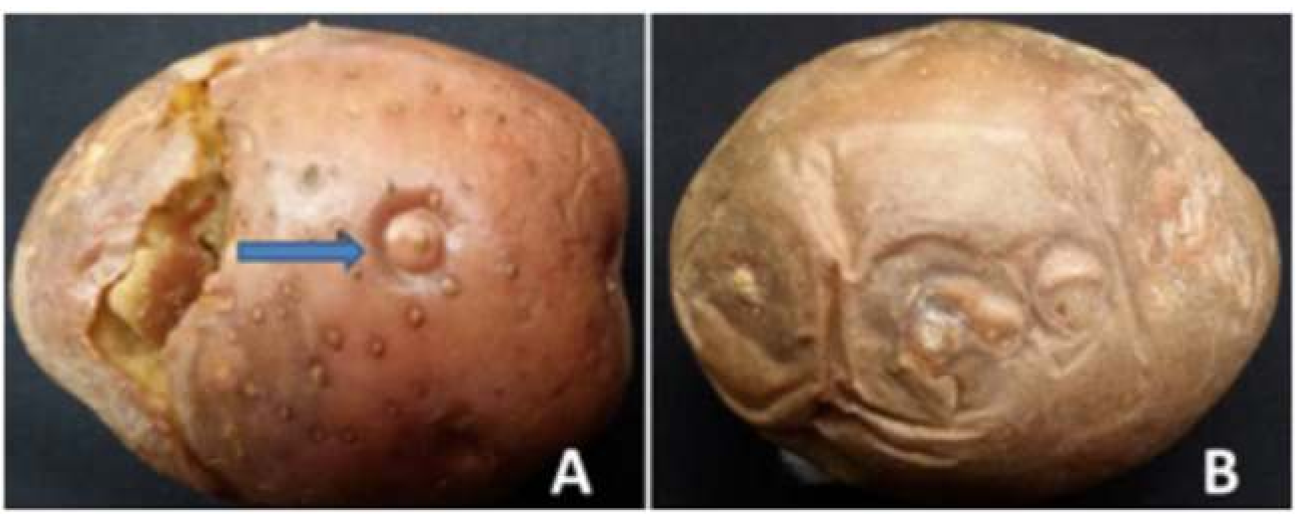


Fig. 1. Dry rot of potato due to *Sclerotium rolfsii* in Gujarat; A) initial symptom, B) dry rot symptoms

production could be detected in those samples. Since last year, population of *P. infestansis* being monitored for sensitivity to cymoxanil, dimethomorph and fenamidone fungicides and all the tested isolates were observed to be sensitive to these new fungicides.

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 from Uttar Pradesh, Bihar, Punjab, Himachal Pradesh, West Bengal, Tamil Nadu, Assam, Meghalaya and Rajasthan was genotyped using two polymorphic SSR primers (Pi89 & Pinf SSR1). Though two different alleles (177/200bp and 181/169bp) were detected with primer Pi89 in most of the isolates, few isolated showed presence of only single allele (202bp, Fig. 2). Similarly, two alleles (230/244bp) were observed with primer Pinf SSR1 (Fig.3).

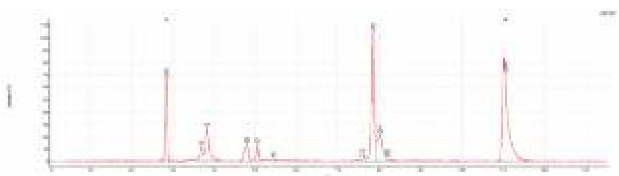


Fig. 2. Electropherogram of *P. infestans* isolate with Pi89 primer showing one allele

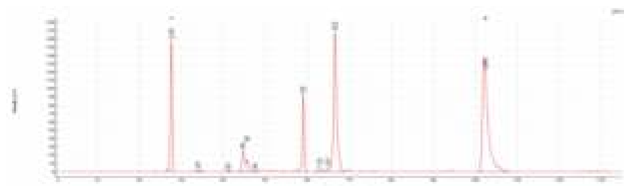


Fig. 3. Electropherogram of *P.infestans* isolates with Pinf SSR1 primer showing two alleles

Comparative genome analysis of Phytophthora infestans

Management of late blight pathogen is constrained by its remarkable speed of adaptation to control strategies such as deployment of resistant cultivars. Keeping this in view, re-sequencing of *P. infestans* whole genome of Indian A2 mating type was done. Genome size of this pathogen is about 240 Mb and we have generated ~50X coverage of whole genome sequence using Ion Torrent (Next Generation Sequencing) technology and Illumina platform. Hybrid assembly of both the technology covered whole genome of around 238 Mb. The detailed assembly report is attached below in Table 1. The reference considered here is *P. infestans* T30-4 (AATU01). Considering the huge contig number, we need to include matepair/ longer read length or higher insert size library which can help us to reduce the contig number keeping the information intact.

Table 1. Hybrid assembly of *Phytophthora infestans* genome details

Category	Number_of_contigs	Total_genome_length
All_contigs	1097286	238_MB
contigs_>=_200nt	308616	135_MB
contigs_>=_500nt	63636	65_MB
reference*_aligned_contigs	674828	163_MB

Complete genome of ToLCNDV-[potato] isolate from Kanpur

Complete genome of a *ToLCNDV-potato* isolate (KAN-6) collected from Kanpur was determined. The DNA A was 2739 bp long with a maximum of 96.0-96.8 % identities to ToLCNDV isolate from pumpkin (JN129254) and ashgourd (JN208136). It shared 94.8 % identity to MOD21 and FAI-19 isolates, from Modipuram and Faizabad, respectively and 94.9 to 95.2 % identities to other ToLCNDV isolates from potato. The DNA B of KAN-6 isolate was 2693 bp long and had a maximum of 93.4 % identity to DNA B of ToLCNDV isolates from pumpkin (AM286435) and ashgourd (JN208137). It showed 87.5 -88.0 % identity to DNA B of ToLCNDV isolates from potato.

Molecular diagnostics and detection of potato pathogens

LAMP assay for detection of PVX and PVS

Globally, a novel technique i.e., loop-mediated isothermal amplification (LAMP) for nucleic acidamplification has been developed and is being used successfully for detection of several animal and plant viruses. The technique is simple, highly specific, rapid and can amplify DNA under constant temperature. Last year we developed LAMP assay for detection of ToLCNDV-potato and this year the assay was extended for detection of PVX and PVS. Primers were designed targeting coat protein (CP) gene of PVX and PVS and RT-LAMP reactions were setup using cDNA of known PVX and PVS positive potato leaf samples as template and reaction mixture. The amplification was carried out at 65°C for 30 min followed by 80°C for 10 min. The results were visualized in gel electrophoresis and also viewed directly by naked eyes by adding a fluorescent SYBR gold staining dye where change in colour from dark orange to fluorescent yellowish green (Fig. 4) was observed in positive samples. The assays were further optimized by different combinations of primers sets, reaction mix components, duration of incubation, reaction volume, its sensitivity, cross reactivity with other potato viruses and finally validated for its consistent repeatability, where the assay showed consistent results indicating that the optimized assays are reliable and can be adopted for quick and reliable detection of PVX and PVS in diagnostic laboratories.

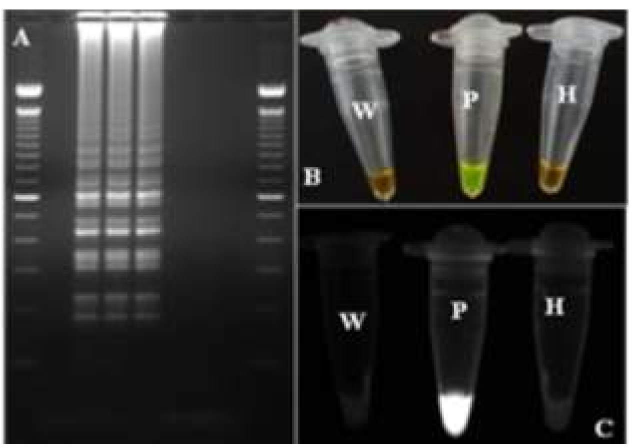


Fig. 4a. Optimization of RT-LAMP for detection of PVX (A), visual detection by using SYBR green fluorescent dye (B), under gel doc SYBR green fluoresce (C).

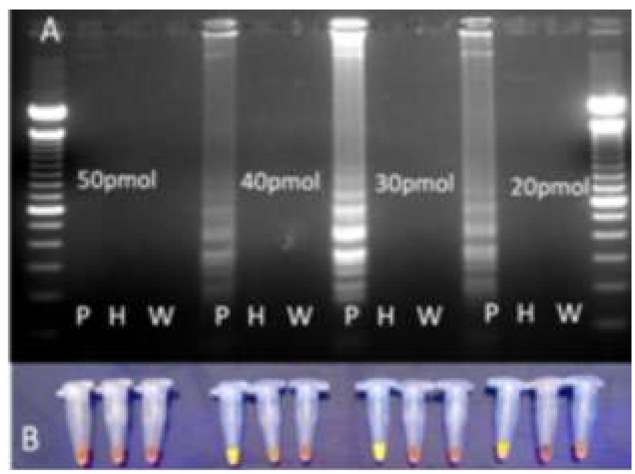


Fig. 4b. Optimization of RT-LAMP for detection of PVS. BIP and FIP primers 50, 40, 30, 20pmol subsequently lane with healthy control and water control, respectively (A). Visual detection by SYBR gold nucleic acid gel stain (B).

Simplified nucleic acid release protocol for RT-PCR based detection of potato viruses

Now-a-days most of the diagnostic laboratories depend on kit based nucleic acid extraction system for total RNA isolation, which is time-consuming, expensive and laborious. Hence, attempts were made to develop a simple, cost-effective and rapid one-step viral nucleic acid release protocol suitable for RT-PCR based diagnostic assays. A disc of infected leaf (PVY) sample was simply crushed in an Eppendorf tube containing 100µl nucleic acid release (NAR) buffer and incubated at 95°C for 10 min followed by a short spin. The supernatant was transferred to a fresh Eppendorf tube which is used as a template (RNA) for further studies. RT-PCR was carried out using cDNA synthesis kit and in-house optimized PCR conditions and master mix with primers targeting coat protein gene of PVY. The protocol was compared with kit based RNA isolation and found equally sensitive. The protocol was validated by running across more than hundred samples for detection of PVY where, it showed consistent results (Fig. 5) indicating its reliability. The assay was further extended for detection of other RNA viruses infecting potato i.e., PVX, PVA, PVM, GBNV from thrips and a DNA virus (ToLCNDV-potato) as well. The protocol is very simple, less laborious (two simple steps) and time-saving (10-12 minutes) as compared to kit based protocol involving 9-10 steps and economical. Hence, it can be used in diagnostic laboratories for detection of potato viruses.

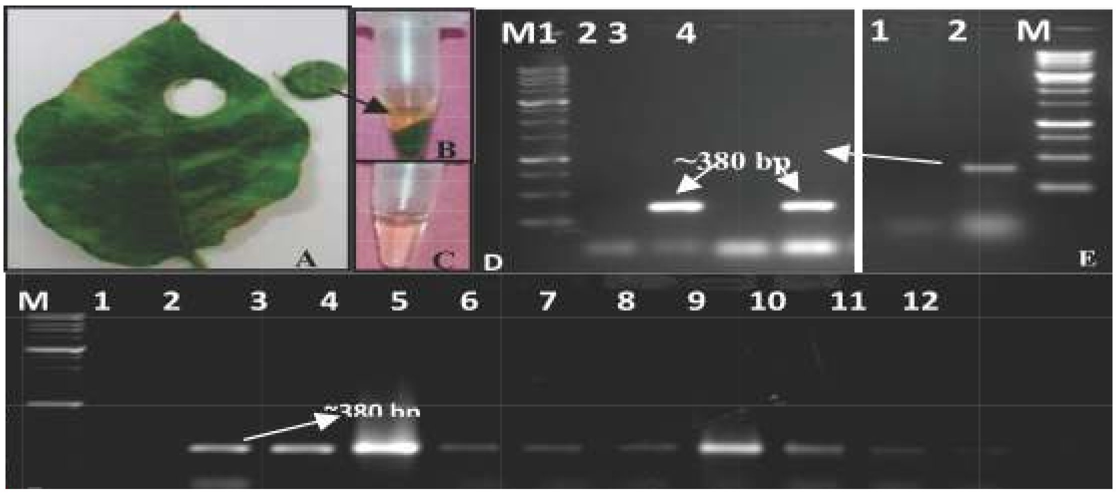


Fig. 5. Simplified nucleic acid release protocol for detection of PVY. Infected potato leaf disc (A), RNA extraction (B), eluted RNA (C). Detection of PVY by using simplified nucleic acid extraction buffer (D) where lane M: 1kb DNA ladder (in all gel images), lane 1 & 3 are water controls, Lane 2 & 4 are positive controls. RT-PCR using RNA isolation kit (E) where lane 1 is water control and lane 2 is positive control. Detection of PVY in suspected potato samples using simplified nucleic acid buffer (F) where, lane 1 is water control and Lane 2- 12 are potato leaf samples.

Quantum dots for detection and localization of potato viruses

Now-a-days quantum dots are 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 antibodies of PVX were conjugated with DIBO-modified Quantum dot nano-crystals according to Siteclick TM Antibody labelling kit. Antibody-Quantum dot conjugates were purified, concentrated and stored at 4°C for further experiments. The quality of purified Ab-QD conjugates was analyzed by Dot-Blot immune assay to determine the sensitivity limit of PVX-Antigen with Ab-QD conjugates (Fig. 6). Lateral flow immunoassay was performed to verify the quality of antigen and antibody using lateral flow strip comprising of sample pad (antigen), conjugation pad (contains Ab-QD conjugates), NCM (contains antibodies test line and IgG control line) and absorbant pad.

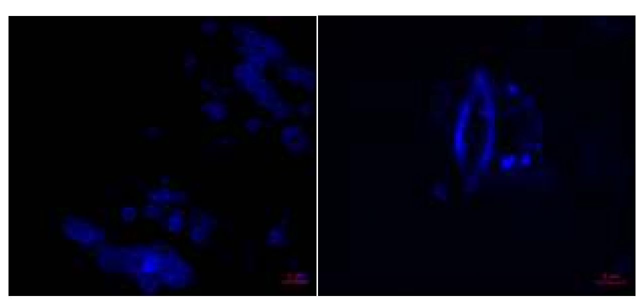


Fig. 8. Detection of PVX in plants using PVX Ab-QD under confocal microscope.

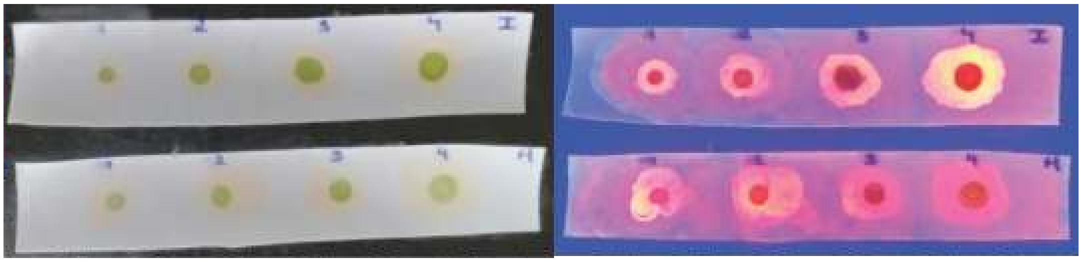


Fig. 6. Dot-Blot assay using nitrocellulose membrane with different dilutions of PVX Ab-QD conjugates observed directly and under UV transilluminator.

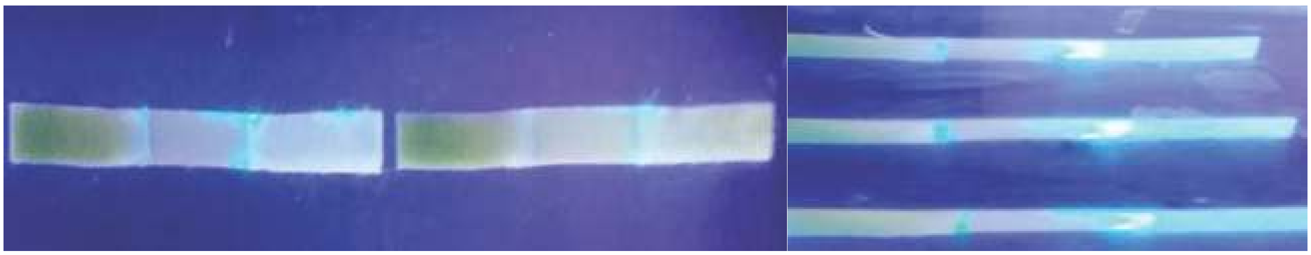


Fig. 7. Lateral flow immunoassay to analyze the conjugation of PVX Ab-QD visualized under UV transilluminator

Detection of virus using PVX Ab-QD conjugates was also confirmed using confocal microscopy where leaf sections of PVX infected plant treated with Ab-QD conjugates and liquid sample of PVX infected plant treated with Ab-QD conjugates showed fluorescence near stomata or other leaf cells (Figs. 7 - 8).

Development of Q-dot DAS-ELISA

Detection of virus using Ab-QD conjugates was also done using modified DAS-ELISA in which antibodies of PVX was coated in Black ELISA plate and blocked with 5% (w/v) BSA at room temperature and washed with PBS plus 0.1% Tween-20 (PBST). Antigen or sap (100 µl) of positive sample (diluted in PBS) was added to the wells of plate, incubated, washed and then 100 µl of antibody-conjugated quantum dots reagent (in PBS) was added and incubated at room temperature for 1 h. Finally, washing was carried out twice followed by addition of a final volume 50-100 µl of borate buffer to the wells of plate. Fluorescence in a black plate was examined in a fluorescent microplate reader (Fluoroscan Ascent FL- Thermo Electron Corporation) at particular wavelength of excitation and emission spectra of QDs (355 & 360 nm, Fig. 9). All the controls like healthy, buffer and cross reactivity controls were also maintained.

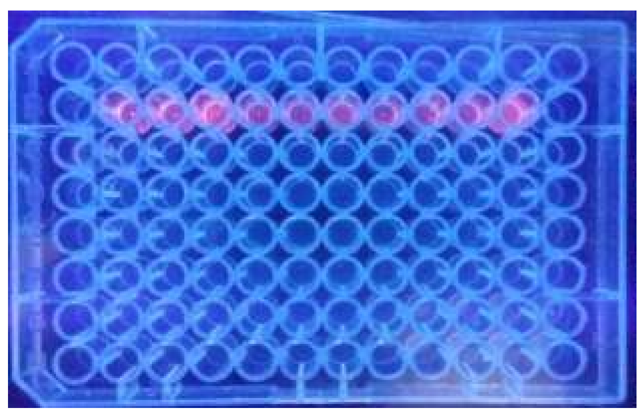


Fig. 9. Q-dot based DAS-ELISA in ELISA plate excited under UV trans-illuminator

Development of recombinant antibody production system

Since last decade researchers have shown interest in recombinant antibodies (rAbs) production in plants, bacteria and yeast by replacing the use of animals. Plants can offer a unique combination of advantages for production of antibodies since they have low production cost, year-round production capability, and higher yield of antibodies. Using the same logic, attempts were made to raise rAbs of Potato virus Y. The pure culture of the virus was mass multiplied, purified completely and the concentration of virus was confirmed in Transmission Electron microscope (TEM). The purified PVY particles were injected (immunization) in rabbits by following standard protocol. The total RNA from the blood of immunized rabbit was isolated with the help of a kit and TRIzol method as well. The primers targeting ScFv fragments of PVY antibodies were designed based on sequences available at NCBI and synthesised for RT-PCR based amplification and cloning of ScFv. The complementary DNA (cDNA) was synthesised using cDNA synthesis kit and PCR was optimized by varying the master mix and exposing to different annealing temperatures to amplify full length of ScFv antibody fragment of PVY. The amplified products were run on agarose gel and visualized in UV trans-illuminator (Fig. 10) where the primers were able to amplify the desired fragments.

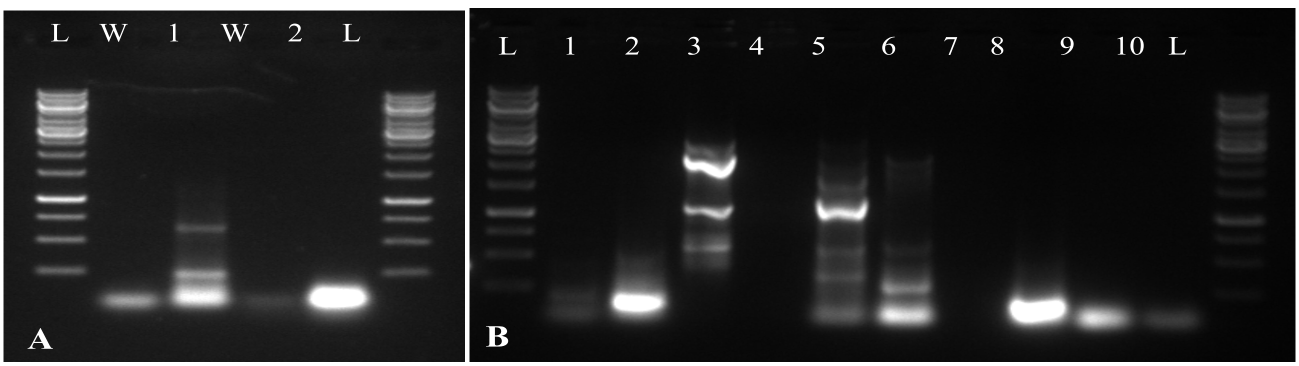


Fig. 10. RT-PCR amplification of ScFv fragments from the blood of immunized rabbit. L 1Kb ladder, W Water, 1and 2 is amplified product using the primers PVY-Cl-23-1F/1R and PVY-Cl-24-2F/ 2R targeting complete gene (A). Second image, amplified product of ScFv fragments for the blood of immunized rabbit using ten sets of diagnostic primers.

Epidemiology and forecasting of potato pathogens

Role of weeds in the epidemiology of potato viruses

Various *rabi* weeds and crops were sampled and tested for common potato viruses in Punjab. In total, 123 samples of 30 plant species were tested (3 to 10 samples per species) by DAS-ELISA and PCR. Most of the samples tested positive for *ToLCNDV-potato* (44.59 %) followed by PVA (13.01%), PLRV (8.94%) and PVY^N (7.31 %). None of the samples tested positive for PSTVd. Highest number of plant species tested positive for *ToLCNDV-potato* (21) followed by PLRV and PVY^N (8 species each). Field peas tested positive for maximum number of viruses (07) followed by *Chenopodium murale* (05). *C. album, Parthenium hysterophorus, Sonchus oleraceus* and brinjal tested positive for four viruses each. Rest of the samples tested positive for three or lesser number of viruses. *Conyza canadensis* did not test positive for any of tested viruses. This shows that these host plants are the reservoir of the viruses during off season and play an important role in the epidemiology of the viruses.

Periodic generation of data on viruliferous vectors

Determination of viruliferous nature of aphid *(Myzus persciae, Aulacorthum solani and Macrosiphum euphorbiae)* and whitefly (Bemisia tabaci) vectors will be crucial to unfold the epidemiology of potato viruses for their better management. Aphid vectors from Deesa, Pune, Hassan, Gwalior, Chindwara, Patna, Shimla were screened for their viruliferous nature to

PVY and PLRV while whiteflies from Jalandhar and Modipuram to ToLCNDV-potato. The results revealed that one fourth of the aphid samples *i.e.M. persicae, A. solani* and *M. euphorbiae* of Shimla, Gwalior, Chindwara, Hassan and Patna were viruliferous with respect to PVY. However, PLRV could not be detected in these samples. Similarly, 67% whitefly samples from Jalandhar were viruliferous to ToLCNDV-potato indicating high incidence of this virus at Jalandhar.

Development of a framework of a Decision Support System for forecasting late blight appearance and issue agro-advisories for its management

The Indo-Blightcast model developed previously for prediction of late blight appearance was embedded in the DSS which has been designed such that the user first enters the user authentication GUI which is linked to a table "location_db" that consists of nine fields (viz. password and user details like name, contact address etc). After authentication, the user is directed to another module which consists of a window with fields to select location, a calendar to select the date and fields to enter the meteorological data. Facilities to upload the data into the database, as well as viewing, editing and deleting previously entered data, have also been provided through buttons named "Input data, Load data, Edit data and Delete data", respectively (Fig.11). All the meteorological data input by the user is stored in a database "indoblightcast_db" which consists of seven fields viz. Serial number, location, date, maximum temperature, minimum temperature, maximum RH, and minimum RH. The DSS has been programmed using DOT NET technology. The front end is programmed in C# and the database at back end is designed and developed in MS SQL.

The model was validated across the agro-ecologies in India during kharif and rabi seasons of 2016-17. The model predicted late blight accurately at each location. The results showed that the disease appeared 18 days after forecast at Modipuram and Kalyani. The slightly later appearance of the disease than its predicted date recorded may be due to the delay in appearance of visual symptoms on the leaves while experience has shown that it appears quite early as small spots inside the canopy which easily escapes the attention unless observed very critically especially in a non-epidemic year since its spread is slow in such years. As regards the appearance of the disease one day before forecast at Pantnagar, this could be due to the microclimatic conditions becoming favourable prior to the overall weather conditions, as recorded in the weather observatory, in the slightly heavy soils of the region in the non-epidemic year due to which the DSV based on weather data of the observatory showed that the disease severity value remained 6 for quite a long time (6 days) before the disease was noticed. Accordingly the advisories were issued to respective regions to protect the crop from late blight attack.

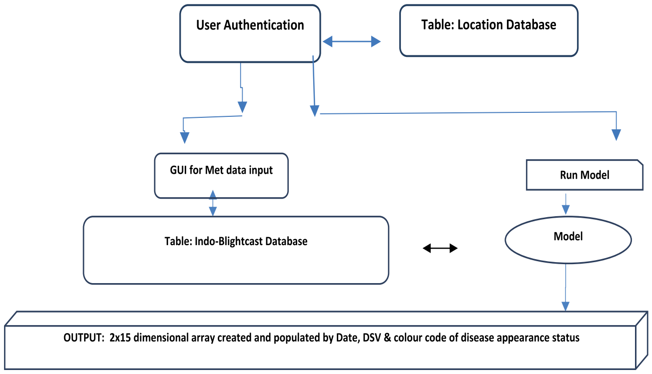


Fig. 11. Flow chart of the DSS

The number of sprays as well as the interval between sprays and the fungicide to be used is decided in this framework based on the DSVs of 15 days prior to the selected date. This is achieved by display of the DSV along with the colour code for the past 15 days from the date selected for display. Thus, the display of the status of late blight of 15 days prior to the selected date enables the user in decision making based on the DSV of the previous 15 days and accordingly changes the advisory.

Host-pathogen Interaction

Resistance and pathogenesis related metabolites and possible pathways of inducing defense against Phytophthora infestans in potato

Phytophthora infestans is a hemibiotroph pathogen which involves two phases of infection. During the early phase, the pathogen invades as biotroph and later as necrotroph. During biotrophic phase, the pathogen secrets effectors from haustoria which help in pathogenicity and induce defence mechanism (HR) depending upon genetic background of the host. In the present studies, Kufri Girdhari (Resistant) and Kufri Bahar (Susceptible) cultivars were used to see the induction of defense genes, resistance related metabolites and pathogenicity factors following pathogen invasion. Microarray analysis was performed using 39,083 protein coding genes sequence in Nimblegen platform. Differences in gene expression profile between resistant (Kufri Girdhari) and susceptible (Kufri Bahar) cultivars were identified at 24hpi(hour post-inoculation). Genes which were up regulated >2 fold in Kufri Girdhari (5308) and Kufri Bahar (3889) were mapped to potato genome using MAPMANer software. In Kufri Girdhari, expression differences were observed in the category of signal transduction, transcription factors and hormone signalling in comparison to Kufri Bahar (Fig.12). In total, 215 signalling receptor proteins were involved strongly in inducing defense pathway compared to Kufri Bahar (63 signalling receptors). Transcription factors like ERF (30), WRKY (17), MYB (28) were strongly induced in

(a) Kufri Girdhari **(b) Kufri Bahar**

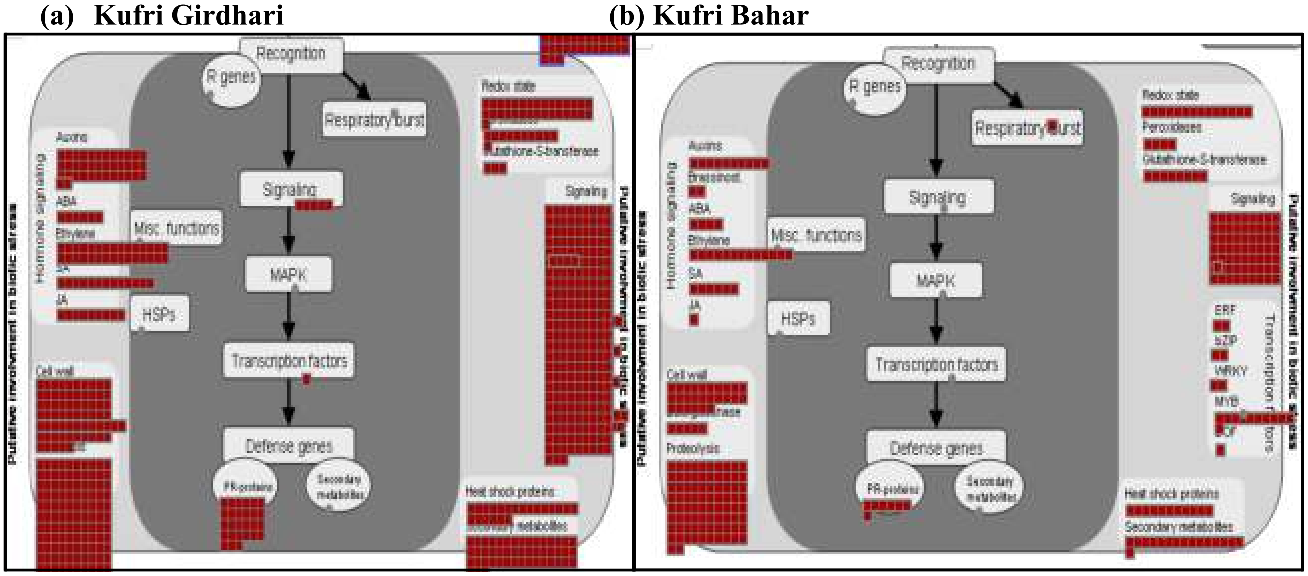


Fig.12. Genes that were differentially expressed between Kufri Girdhari (a) and Kufri Bahar (b) at 24hpi with *P*. infestans using MAPMAN. Red indicates that number of hits on potato genome and up-regulated genes and brown indicated down regulated genes. Highlighted portions show differences in number of genes in the pathway of both the cultivars.

Kufri Girdhari compared to Kufri Bahar. Whereas cell wall related, peroxidases, redox state genes and hormone signalling like auxin, salicylic acid, glucanase and PR proteins were highly induced in resistant cultivar compared to susceptible cultivar. Secondary metabolites, heat shock proteins and protelolysis factors were down regulated in Kufri Bahar cultivar. The differences in expression of these genes are entirely consistent with the fact that these genes have often been identified as differentially expressed in response to pathogen attack. The findings of this study would help in understanding the possible defense pathway as well as pathogenicity factors responsible for late blight in potato. Once the roles of such genes are known, the most useful genes would be used for the management of late blight using conventional and molecular approaches.

RNA-seq analysis of potato plants inoculated with ToLCNDV-potato

RNA-seq analysis was carried out to identify differentially expressed genes (DEGs) in Kufri Bahar along with a susceptible check, Kufri Pukhraj. Eight RiboMinus RNA libraries prepared from inoculated and un-inoculated potato plants of resistant (Kufri Bahar) and susceptible (Kufri Pukhraj) cultivar at 15 and 20 DAI were sequenced using Ion Proton TM system. A total of 278.55 million reads were generated with an average of 34.82 million reads per sample. Analysis using potato genome from PGSC showed that genes were differentially regulated during ToLCNDV-potato infection in susceptible and resistant cultivars. The unique DEGs identified through Venn diagram analysis were further subjected to GO analysis using Blast 2 GO 4.0.2. to better understand their function by categorizing them under biological process, molecular function and cellular component. DEGs identified in RNA-seq analysis were validated using RT-qPCR assay. Sixteen DEGs including genes encoding LRR protein, F-box proteins, cell division control 20, Mads box protein and translation initiation factors were selected for validation.

Agro-infiltration studies using infectious clones of ToLCNDV-potato

Infectious clones were developed by cloning partial dimers of DNA A and DNA B components of three ToLCNDV-potato isolates (MOD21, FAI-19 & KAN-6), in plant transformation vector and mobilized into *Agrobacterium*. These cultures were artificially inoculated into *N. benthamiana*

Fig. 13. Symptom expression in tobacco (A) and potato (B) plants

and potato plant leaves. The symptoms progressed faster in KAN-6 (both DNA A and DNA B) inoculated plants with prominent yellow mottling, small young leaves and severe downward curling of leaves. MOD-21 inoculated plants also showed typical downward curling and stunted growth; but yellow mottling only in older leaves. Out of three, the FAI-19 was the mildest one and showed only downward curling symptoms. MOD-21 and KAN-6 inoculated Kufri Pukhraj plants showed typical symptoms of apical leaf curl disease, i.e. curling of leaves and mosaic symptoms with stunted growth that are similar to those occurred in virus infected plants in the field (Fig. 13), whereas FAI-19 produced only restricted yellow spots. However, MOD-21 produced more prominent yellow mosaic symptoms which had bright yellow patches as compared to KAN-6.

Development of event PCR protocol for identification of ToLCNDV-potato transgenic events

Last year we did flanking sequence analysis of selected events to know the chromosome location of the integrated gene/T-DNA in the identified event. This year we performed event PCR using primers specific to the pBI121 T-DNA region and flanking sequence (potato genome sequence) to authenticate the identified sequences. The expected amplified product i.e. 539 bp from KPLC2-53 and 756 bp from GTLC2 -127 (Fig. 14) in the selected events and the absence of the fragments in other events confirmed the integration of the T-DNA/transgenic DNA in the potato chromosome. Results revealed that no conserved domain have been detected for the obtained flanking sequences thereby indicating that inserted site have not disturbed the potato genome.

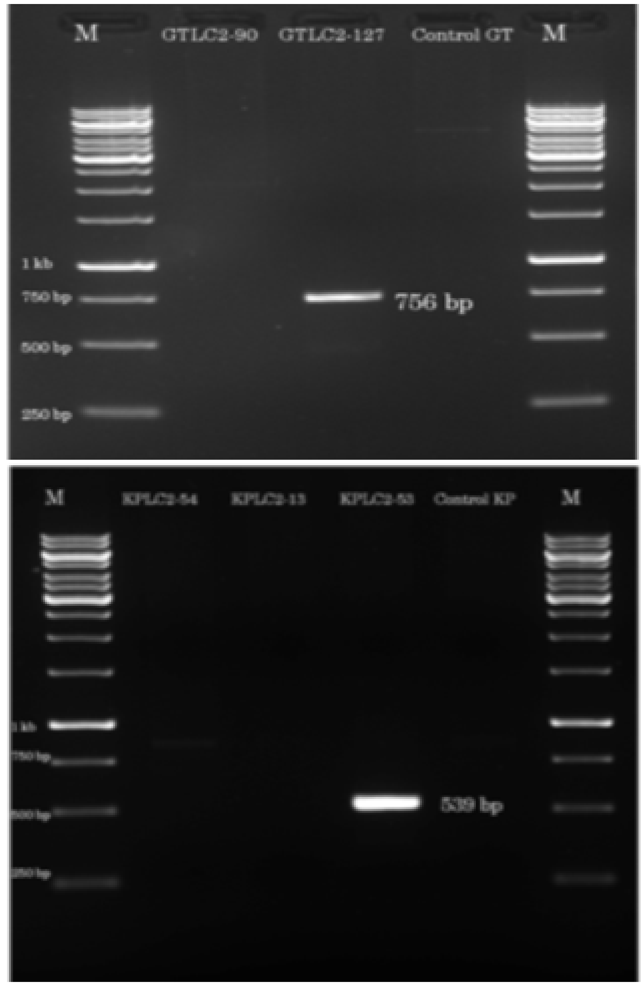


Fig. 14 Event PCR analyses in KPLC2-53 and GTLC2-127

Management of potato pathogens

Chemical management

It is well known that *P. infestans* adapts to fungicides very quickly hence, there is need to test new molecules against this pathogen regularly for their inclusion in spray schedules for proper management of the disease. In this context series of experiments were conducted. At Modipuram, out of eight treatments tested, application of dimethomorph (0.2%), *cymoxanil +mancozeb* (0.3%), *ametoctradin+dimethomorph* (0.2%) and *phenomidon +mancozeb* (0.3%) resulted in 23, 26, 26.67 and 31% disease severity respectively as against of 98.33% in control. Similarly, fungicides were also evaluated at Shimla. Results revealed that application of *famoxadone* + *cymoxanil* (0.1%) and *ametoctradin* + *dimethomorph* (0.2%) resulted in minimum disease severity (15%) followed by *dimethomorph*+*mancozeb* (0.3%) as against 80% in control.

Similarly, fungicides were tested for developing spray schedules for managing late blight of potato. 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 (28.00%) against control (95.00%). The next best treatment was prophylactic spray with mancozeb (0.2%) followed by dimethomorph + mancozeb (0.3%) and one more spray with dimethomorph + mancozeb (0.3%) after 7 days. These results are in conformity with last year's results.

Experiment conducted at Ooty in kharif season revealed that prophylactic spray with mancozeb @ 0.2% followed by dimethomorph + mancozeb @ 0.3% at onset of the disease and one more spray with mancozeb recorded lower AUDPC (160) as compared to control (305). Results of experiment conducted at Hassan during Kharif season revealed that prophylactic spray with chlorothalonil @ 0.2% followed by ametoctradin + dimethomorph 0.2% at onset of disease and one more spray with chlorothalonil @ 0.2% resulted in minimum late blight severity (3.6%). The next best treatment was prophylactic spray of mancozeb @ 0.2% followed by cymoxanil + mancozeb @ 0.3% and one more spray with mancozeb (3.75 %) (Fig.15).

Effect of zinc on ToLCNDV-potato multiplication in tissue culture raised plant under in–vitro conditions

The intensity of ToLCNDV -potato has increased across the country during last two decades. Therefore, an effective strategy able to confer plants with resistance against ToLCNDV-potato is needed. Several micronutrients are reported to inhibit the virus multiplication and induce resistance in plants. In the present study, effect of artificial zinc (in the form of ZnSO4, ZnO and Nano ZnO) amendment on ToLCNDV-potato infected plants under tissue culture condition was studied. The plants were evaluated after 30 days for virus multiplication or inhibition. The plants were assessed by quantifying total virus load through real-time PCR. The results showed that the application of Zn in different form inhibited the ToLCNDV-potato in infected plants compared to control (Fig.17). It showed a possible role of zinc in inhibition of virus and warrants further in depth studies.

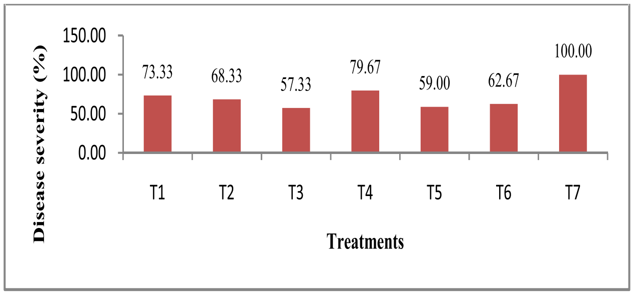


Fig. 15. Evaluation of botanical based formulation against late blight of potato at Modpuram.T1: Botanical (3%), T2: Mancozeb (0.2%), T3: Chlorothalonil (0.2%), T4: Propineb (0.2%), T5: Mancozeb (0.2%) + botanical (3%), T6: Botanical (3%) 3spray and one spray of Mancozeb (0.2%), T7- Control

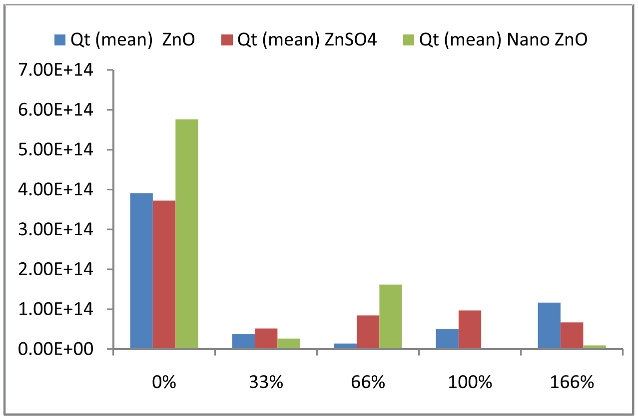


Fig.17: Real time analysis of total virus load/copies after 30 days of application of Zn in different form in different concentration

Biotechnological approaches

dsRNA based fungicide for management of potato late blight

In earlier studies, we developed anin *vivo* expression system to produce large amounts of dsRNAs encoding *P. infestans* genes, with a view to provide a practical control of late blight diseases in potato. Furthermore, we have demonstrated that easy to obtain, crude extracts of bacterially expressed dsRNAs are equally effective protecting potato against *P. infestans* infections when sprayed onto plant surfaces along with emulsifying agents like tween 20 to enhance the stickiness of dsRNA by a simple procedure. Late blight symptoms were observed significantly lower when plants were sprayed with bacterial lysate before pathogen inoculation (Fig.16). Further work is necessary to standardise the ingredients required for dsRNA formulation for effective delivery of dsRNA.

Fig. 16. Screening of dsRNA against late blight

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

The best approach to interfere in pathogenicity of *Phytophthora* is to simultaneously target multiple genes through siRNA that would significantly inhibit the pathogen life cycle. Based on this hypothesis, last year we created multi siRNA vector targeting various cellular processes of *P. infestans* including sporulation, signalling process and protein synthetic machinery of the cell. The efficacy of siRNA has been assayed/checked using *in vitro* dsRNA technology through detached leaf assay against *P. infestans.* Results were highly significant in terms of non-development of symptoms in dsRNA treated leaves (Fig. 17). This would give a proof of concept for development of RNAi based fungicide as well resistant genotypes through RNAi technology.

Fig. 17. Detached leaf assay of dsRNA treated zoospores for development of late blight symptoms

Development of RNAi and protein mediated gene construct for bacterial wilt resistance in potato

Since none of the potato genotypes including wild species has resistance genes, the identification and discovery of resistance gene(s) for successful breeding programme is a challenging task. Therefore, we attempted one strategy to isolate candidate genes required for susceptibility (plant disease susceptibility factors) or create knock-down plants showing a disease-resistant phenotype. In our earlier studies, we demonstrated using VIGS technology that PAP2 gene is responsible for causing wilt disease viainhibition of reactive oxygen speciesaccumulation and hypersensitive response. Based on this proof of concept, we developed RNAi construct encoding PAP2 gene for developing resistance against bacterial wilt (Fig.20a). Down regulation of PAP2, allowed the expression of Flagellin sensing receptors, to induce defense lipid signalling pathway for imparting resistance to bacterial wilt. This need to be validated by over-expressing the FLS2 gene. Therefore,the 3.5Kb FLS2 coding sequence has been cloned from *Ralstonia solanacearum* inoculated Kufri Jyoti plants showing resistance after VIGS treatment (Fig. 18).

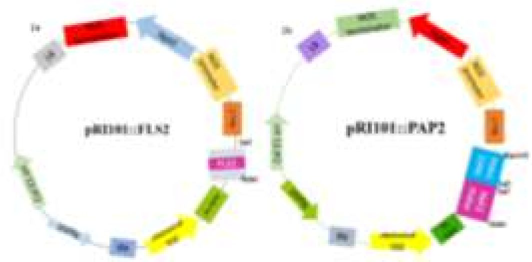


Fig.18. The pRI101 T-DNA vector map showing the 35S::FLS2 and RNAi::PAP2 gene construct driven by CaMV35S and Arabidopsis translation enhancer.

Development of potato transgenics with resistance to major viruses

Transgenic lines of potato cultivar Kufri Pukhraj i.e., KPYS1, KPYS13, KPYS18, KPYS20, KPYS21, KPYS26, KPYNT3, KPYNT9 and a healthy control were planted in pots in containment facility (transgenic glass house) and challenge inoculated with the pure culture of PVY. The lines were examined for their resistance against PVY by observing the symptom expression over control. Among the lines, KPYS-13 and KPYS-20 showed resistance as the symptoms were not expressed in the selected lines (Fig. 19). The line KPYS-13 was selected for event PCR studies and later other traits will be studied. These lines are parallely being maintained in tissue culture facility as well.

Fig. 19. Screening for resistance of Potato virus Y transgenic lines by challenge inoculation. Pots 1-3 and 7-9 are control lines and pots 4-6 (KPYS-13) and pots 10-12 (KPYS-20) are transgenic lines showing resistance against PVY.

Mass multiplication and screening of transgenic lines i.e. GTLC2-127 and KPLC2-53 for virus resistance

Two promising transgenic resistance lines (GTLC2-127 and KPLC2-53) of ToLCNDV-potato were mass multiplied in tissue culture and screened for virus resistance through whitefly transmission under glass house conditions. Confirmation of integration of transgene was done through event PCR analysis.

Biological approaches

Screening of microbes against Phytophthora infestans and Ralstonia solanacearum under glasshouse conditions

Endophytic bacteria, found effective *in-vitro* against *P. infestans* and *R. solanacearum* in previous studies, were tested for their efficacy against late blight and bacterial wilt in pot experiments under screening chamber/glass house conditions. Results revealed that when endophytic bacterium suspension (OD=1.0) was sprayed 24h before *P. infestans* inoculation, it resulted in 21.59 to 52.77% reduction in late blight over untreated plants. The highest reduction was recorded in BE-14 and BE-50 treated plants (Fig. 20).

Fig. 20. Screening of endophytic bacteria against late blight

Testing of endophytic bacteria against bacterial wilt was studied by conducting two experiments. In first experiment, the sick soil in pots was drenched with suspension of respective test endophytic bacterium (200ml/pot; OD=0.15 at 600nm) and then healthy tubers of var. Kufri Jyoti (whole as well as cut tubers) were planted. In second experiment, healthy tubers (whole as well as cut tubers) were dipped in respective test endophytic bacterium suspension (OD=0.15 at 600nm) for 30 minutes, shade dried and then planted in pots filled with sick soil.

Identification of endophytic bacteria found effective against Phytophthora infestans, Ralstonia solanacearum and Streptomyces scabies

The 16S rRNA gene was amplified from DNA of nine endophytic bacteria which were found effective *in-vitro* against *Phytophthora infestans, Ralstonia solanacearum and Streptomyces scabies*by PCR using the primers Eu8f/ Eu1492rand sequenced. The endophytes have been identified as *Bacillus subtilis, B. pumilus* and *Enterobacter sp*. (Fig. 21).

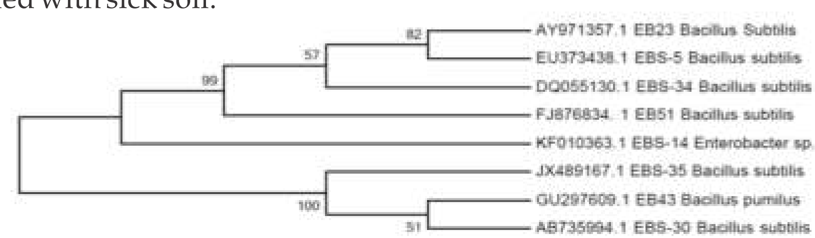


Fig. 21. Phenogram expressing the relationships of identified bacterial endophytes to taxonomically similar microorganisms based on the 16S rDNA gene sequences.

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

Field trials were conducted at ICAR-CPRIC, Modipuram, ICAR-CPRS, Jalandhar and ICAR-CPRI, Shimla (Lower Lab) to see the effect of bio-fumigation of soil with brassicas on management of soil and tuber borne diseases especially russet scab, black scurf and brown rot/ bacterial wilt. In the second 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 at Jalandhar but at Modipuram Indian mustard, taramira and radish showed less black scurf incidence (up to 70%) as against control (100%). Similarly, in the first year of experimentation, none of these five brassicas proved effective against brown rot/ bacterial wilt at Shimla. The trials will 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 germ-plasm

Five *in-vitro* cultures of potato imported by M/s Technico Agri Sciences Pvt. Ltd were tested for post entry quarantined pathogens. Testing of another 10 *in-vitro* cultures of potato, imported by M/s PepsiCo India Holdings Pvt. Ltd., is in progress.

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

One thousand nine hundred and six samples of M/s Technico Agric Science Pvt Ltd. Baddi, Solan (HP), M/s Bhatti Tissue Tech. Jalandhar 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, PSTVd and ToLCNDV-potato by PCR/RT-PCR. Besides, one hundred and thirty samples from M/s Nishant Biotech, Bilaspur, HP were also tested for apple viruses namely ACLSV, AMV, ASGV, ASPV, PNRSV under NCS-TCP. Apart from this, nearly 600 samples from M/s Pepsico India Holding, Hoshiarpur (Punjab), M/s Technico Agri Science Pvt. Ltd. Baddi, Solan (HP), M/s Dayal Seed Pvt. Ltd., Partapur, Meerut and M/s Merino Industries Ltd., Hapur, were also tested for different viruses through DAS-ELISA/ PCR under non-ATL.

Cross pathogenicity test of ten Ralstonia solanacearum strains on different hosts

Cross pathogenicity of ten *R. solanacearum* strains viz., BRS (tomato strain from IIHR, Bengaluru), UTT-25 (tomato strain from IARI, New Delhi), Rs-09-161 (brinjal strain from ICAR Goa), Rs-10-244 (chilli strain from ICAR Goa), GRs-Sik (ginger strain from IISR, Kozhikode), Grs-Mep2 (ginger strain from IISR, Kozhikode), RS-2, RS-25, Rs-48, RS-75 (potato strains from CPRI, Shimla) was examined on potato (Kufri Jyoti), tomato (Pusa Ruby and Arka Vikas), Brinjal (Arka Keshav), capsicum (Arka Mohini) and ginger (Rajatha) in a glass house condition. The results (Figs. 22-24) revealed that;

- All the strains, except Grs-Mep2, were pathogenic on potato var. Kufri Jyoti and tomato var. Pusa Ruby.
- Only six strains viz., BRS, UTT-25, Rs-09-161, Rs-10-244, RS-2 and RS-25 were pathogenic to tomato var. ArkaVikas.
- Only six strains viz., BRS, Rs-09-161, GRs-Sik, Grs-Mep2, Rs-48, and RS-75 were pathogenic on brinjal var. Arka Keshav.
- To capsicum (var. Arka Mohini), only four strains viz., BRS, Rs-09-161, Rs-10-244, and RS-2 were pathogenic.
- None of the 10 strains was pathogenic to ginger (Rajatha) even after 49 days of inoculation.

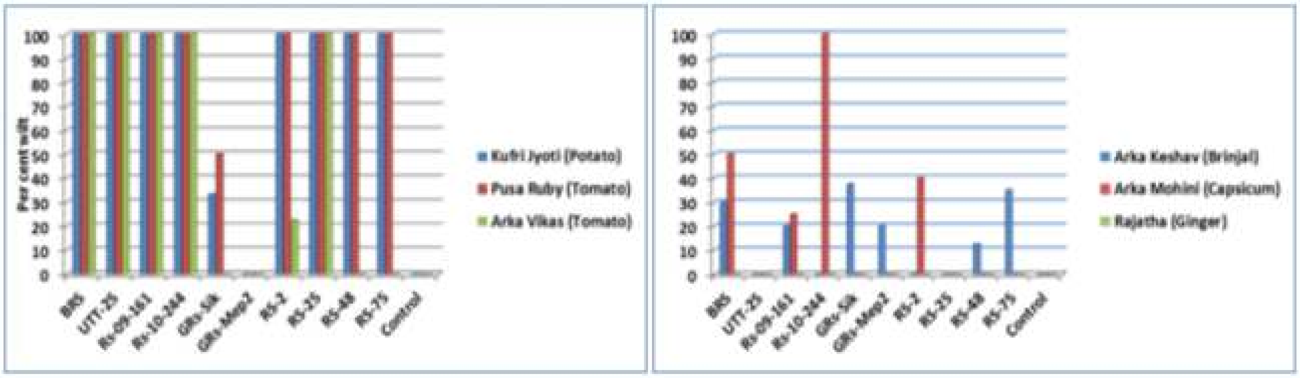


Fig. 22. Pathogenicity test of *R. solanacearum* strains on potato, tomato (28 days post inoculation), brinjal, capsicum and ginger (49 days post inoculation)

Fig. 23. Pathogenicity test of 10 sequenced strains of *Ralstonia solanacearum* on potato var. Kufri Jyoti (photographed 14 days post inoculation)

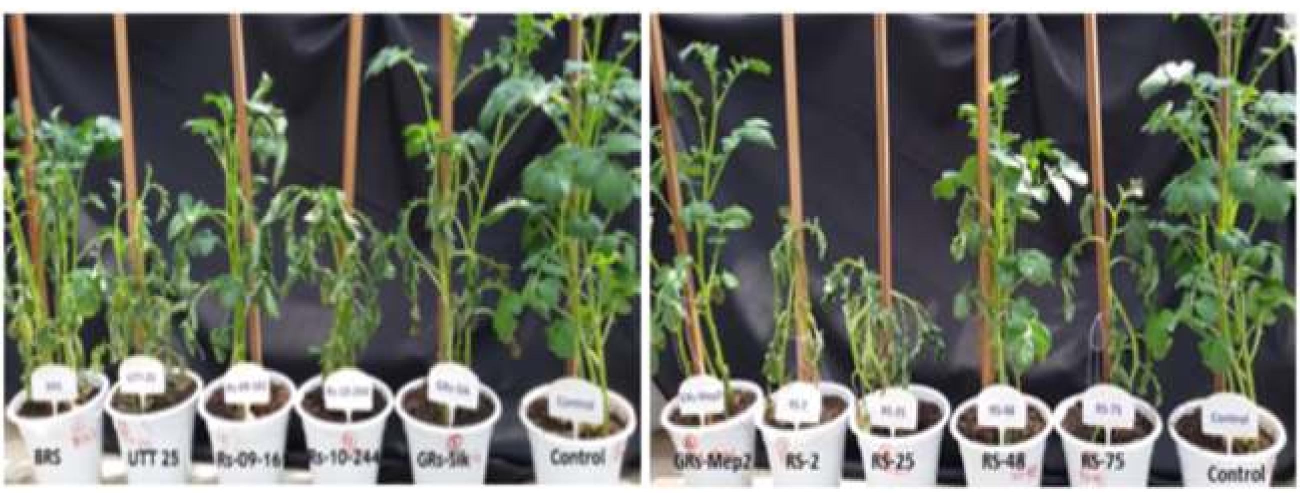


Fig. 24. Pathogenicity test of 10 sequenced strains of *Ralstonia solanacearum* on tomato var. Pusa Ruby (photographed 10 days post inoculation)

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

Monitoring and Population Dynamics of Potato Pests

Aphids, whiteflies, leafhoppers, thrips, mites and defoliators were monitored at Jalandhar, Modipuram, Shimla (summer crop) and Gwalior on seed and ware crop, other solanaceous hosts using roving surveys and yellow sticky traps (YST) during the year under report.

Aphids

At Shimla, aphids *(Myzus persicae and Aulacorthum solani)* first appeared in July 1st week and reached peak during first week of August although the overall population was very low. At Jalandhar, the population of aphids, *M. persicae* (Sulzer) and *Aphis gossypii* Glover were monitored during crop season. *M. persicae* first appeared on the potato plants in the 1st week of November and remained below economic threshold till 1st week of December after which the population increased at exponential rate and crossed the critical limit of 20 aphids per 100 compound leaves around 20th of December (Fig.1a &1b).

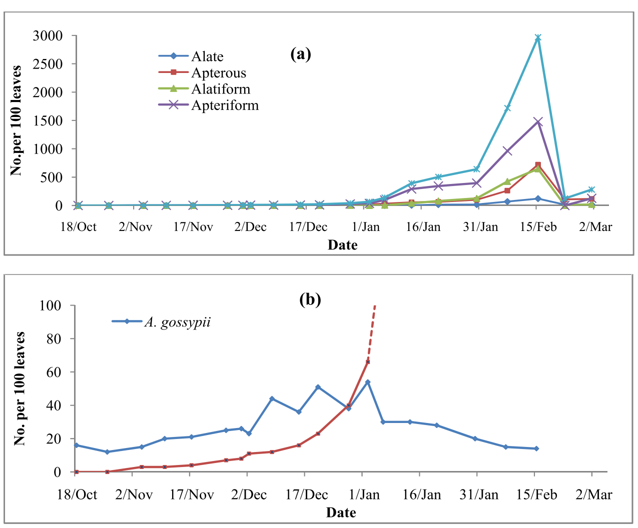


Fig. 1. Population dynamics of *M. persicae* (a) and *A. gossypii* (b) at Jalandhar

At Gwalior, a relatively low population of Myzus persicae was recorded on ware and seed potato (Fig 2). A maximum of 20 and 12 aphids per 100 compound leaves were recorded on ware and seed crop, respectively. The vector pressure was significantly low on potato at Jalandhar and also below the critical limits.

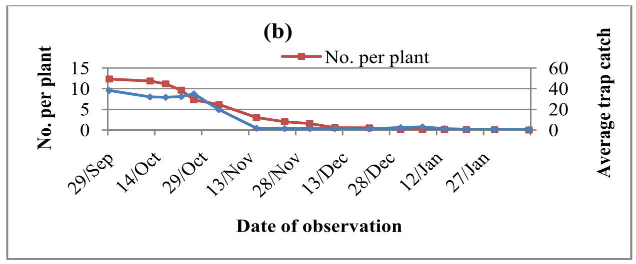


Fig. 2. Population dynamics of *Myzus persicae* at Gwalior

Whiteflies

At Shimla, only glasshouse whitefly, *Trialeurodes vaporariorum* was recorded on potato with very low incidence. At Modipuram, the survival and migration of whiteflies *(Bemisia tabaci)* during off season was studied. Whiteflies were recorded on *Ficus* sp. (ornamental) throughout March and April, on cucumber during May to mid-June, on brinjal *(Solanum melongena)*, moong *(Vigna radiata)* and tinda *(Citrullus vulgaris)* during 1st & 2nd week of June. A very high populations of whiteflies (more than 100 per leaf) were also recorded on tulsi *(Ocimum sanctum)* and urdbean *(Vigna mungo)* during July and August. Later, whiteflies migrated to early planted potato in the month of first week of October.

At Jalandhar, the population of whitefly adults showed a declining trend over time which started very high initially (Fig 3a & b). Up to 40 whitefly adults were caught on yellow sticky traps (YSTs) on an average in the last week of September however, the trap catch showed a sudden drop by the last week of October.

Whiteflies showed a significant positive correlation with temperature.

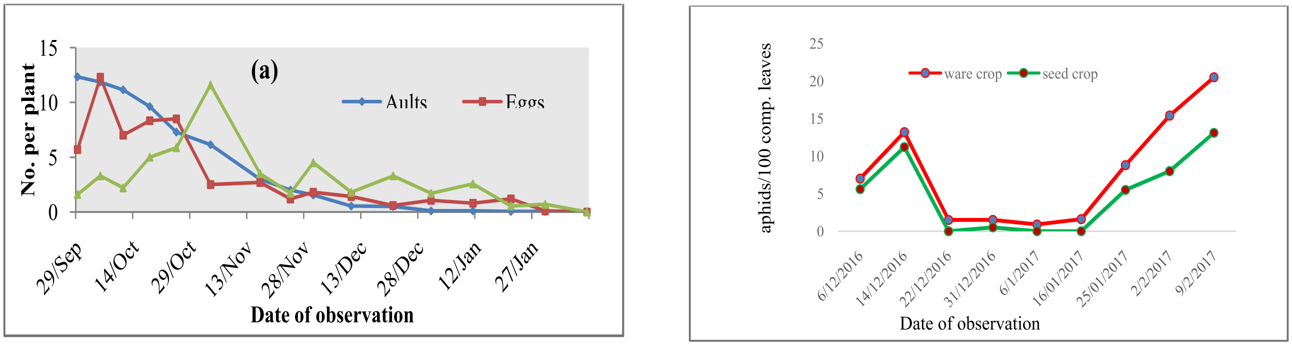


Fig. 3. Population dynamics of *B. tabaci* sampled by (a) leaf count method and (b) YST catch in potato at CPRS, Jalandhar

At Gwalior, relatively low incidence of *Bemisia tabaci* was recorded on ware and seed potato (Fig. 4). A maximum of 15 and 4 whiteflies/100 compound leaves were recorded on ware and seed crop, respectively. The whitefly was below the critical limits during crop season.

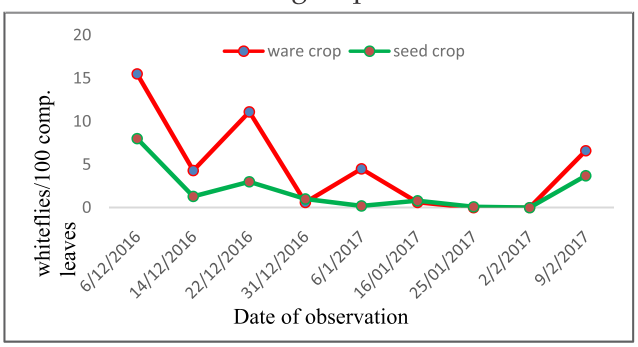


Fig. 4. Population dynamics of Bemisia tabaci on potato crop at Gwalior

Leafhoppers

At Jalandhar, the population of leaf hoppers, *Empoasca fabae* Harris and *Amrasca biguttula bigutulla* (Ishida) was initially high (8-12 per plant) but declined over time (Fig. 5a). The population fell below economic threshold by the last week of November and disappeared from the crop towards the end of January. The leaf hopper populations were found to be very sensitive to night temperature (Correlation coefficient=0.889) hence, its population declined significantly as the night temperatures went down. In addition, many other species of hoppers like brown plant hopper, green leaf hopper etc. migrating from rice fields were also found on potato plants and also on the yellow sticky traps (Fig. 5b).

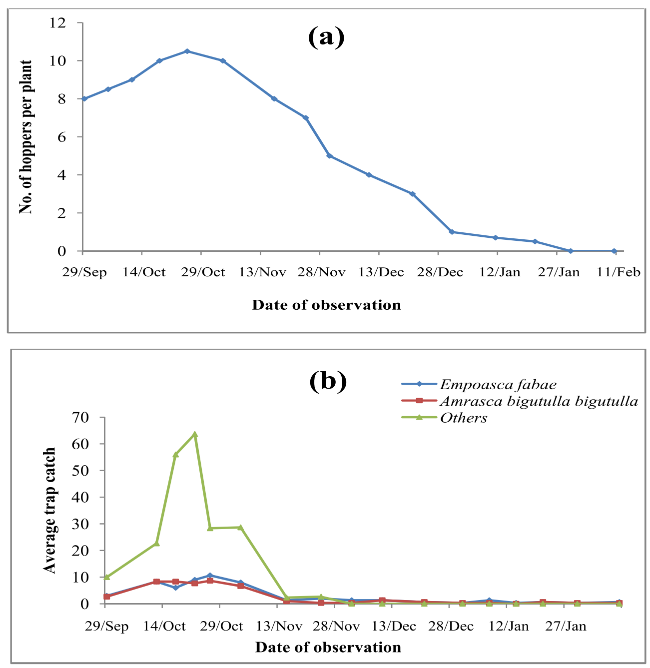


Fig. 5. Population dynamics of leaf hoppers infesting potato sampled by (a) leaf count method and (b) YST catch at CPRS, Jalandhar (2016-17).

Others

At Shimla, leaf eating caterpillars such as *Helicoverpa armigera* and *Spodoptera litura* were recorded on potato at lower densities. The flea beetle incidence (12 beetles/10 plants) and damage was moderate and lower than previous year. Thrips are vectors of number of plant viruses including Ground nut bud necrosis (GBNV). Very interestingly, some of the thrips populations (Fig. 6a) other than *Thrips palmi* from Shimla were found to be viruliferous to GBNV. The incidence of thrips population has been increasing during past two years. *Tuta absoluta*, a quarantine pest of international importance was monitored on potato as per the directives of DPPQS, Faridabad but it was not recorded on potato in Shimla hills.

Fig. 6a. Microscopic image (Stereo zoom microscope) of thrips from Shimla hills.

At Jalandhar, the population of South American tomato moth, *Tuta absoluta* (Meyrick) was monitored with sex pheromone traps using Catch Tuta-9 (Ponalabs Biogrowth Pvt. Ltd., Bengaluru) containing (E3, Z8, Z11)-tetradecatrien-1-yl acetate in and around the CPRS, Jalandhar potato farm. No *T. absoluta* adults were caught in the traps throughout the season. Foliage feeding caterpillars were monitored by field scouting and the use of light traps (one each of commercial and indigenously developed). The caterpillars of *S. litura* were found feeding on potato plants in the 2nd week of November. 1-3 adults of *S. litura* were caught in light traps per week for 3 weeks in November.

At Meerut, mite infestation was recorded very high during crop season. Severe mite burning and hopperburn symptoms were recorded in Bijnore and Muzaffarnagar. Severe mite infestation *(Polyphagotarsonemus latus)* was recorded in Dudha, Salagame, Nitturand Koppolu villages of Hassan Taluk (Karnataka) (Fig. 6b).

Fig. 6b. Symptoms of mite damage on potato leaf in Hassan

Morphological and molecular characterization of potato pests and nematodes

Insect pests

Aphids have been reported to be important vectors of five potato viruses under Indian geographical and climatic conditions. These aphids transmit potato viruses specially PVY and PLRV which are responsible for progressive degeneration of potato seed stocks and also yield loss. Therefore, it is absolutely necessary to keep a watch on kind of aphid vectors infesting crop to maintain health status. Therefore, samples were collected from Jalandhar, Modipuram, Deesa, Chindwara, Pune, Patna, Shimla (summer crop) and Gwalior on potato crop during October-January. Identification of sucking pests was done using both morphological and molecular approaches (universal primer targeting mitochondrial COI gene) (Fig. 7). Although 14 distinct aphid species have been reported on potato during last 3 years, the aphids such as *M. persicae, A. solani, A. gossypii and Macrosiphum euphorbiae* were recorded this year. The occurrence of *M. euphorbiae* on potato in Shimla hills was the first record. It is a colonizing aphid species on potato capable of transmitting number of potato viruses. Whiteflies collected from three locations (Jalandhar, Modipuram and Pune) were identified as *Bemicia tabaci*. The identification of its genetic groups are under progress. Leafhoppers recorded on potato were identified as *Amrasca biguttula biguttula.* Thrips species recorded on potato at Shimla hills were *Haplothrips* sp.

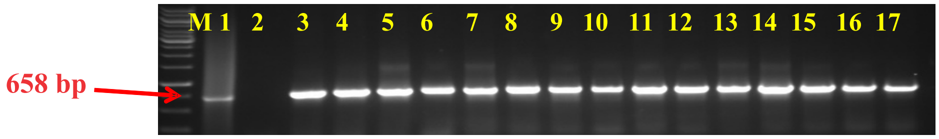


Fig. 7. PCR amplification of *COI* gene of aphid.M- Marker (1 kb), Lane 1-+ve control (658 bp), Lane 2-negative control, Lane 3-17- aphid samples of Hisar & Pune.

Whole genome (de novo) sequencing of new aphid species, Aulacorthum solani: vector of PVY and PLRV in potato

A new aphid species, *Aulacorthum solani* has been recorded in potato crops as a vector of viral diseases (Fig. 8). *De novo* whole genome of *A. solani* was sequenced using Illumina platform considering its significance as a vector. In this context, *de novo* whole genome sequencing was done to elucidate genetic mechanisms underlying viruliferous nature, translocation of viruses in insect system in order to identify candidate genes for its management. Clean high quality 220.11 million reads were assembled into contigs and further into scaffolds using de novo assembly tool of CGWB ver. 9.0. The assembly metrics indicate good quality of the *de novo* assembly. The scaffolds have been exported in the fasta format for further processing.

Table 1. Assembly matrics of whole genome of A. solani

Details	Assembly metrics
N75	3,242
N50	6,951
N25	13,377
Minimum length of the scaffold	500
Maximum length of the scaffold	642,506
Average length of the scaffold	3,545
Total number of scaffolds	89,260
Total bases	316,399,729

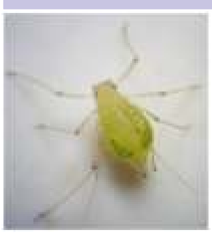


Fig. 8. Microscopic image of A. solani.

The scaffolds generated by *de novo* assembly were subjected to BLASTX. The top BLASTX hits for each scaffold were selected as a source of annotation (Table 1). The gi IDs obtained through BLAST search were filtered through the Uniprot KB database for obtaining gene symbols and GO functional annotation. The gene modelling has been performed by Fganesh tool set using nearest annotated insect gene sets from *M. persicae*-Accession PRJNA45883.; *Aphis craccivora*-PRJNA192260. In all 14,340 genes could be annotated.

Cyst nematodes

Twenty eight soil samples collected from potato growing fields of three taluks of Nilgiris during 2013-2015 were used for identification of both the *Globodera* spp. based on ITS-1 region specific primers and some morphological criteria. Amplification of the ITS-1 region of *G. rostochiensis* yielded 411 bp amplicon size and 239 bp amplicon size bands formed in G. pallida (Fig. 9). The phylogenetic analysis inferred by the sequence of the ITS-1 region confirmed 92.0-100% genetic similarities in *Globodera* spp. Seventeen isolates of

G. rostochiensis showed 92.0-99.0% genetic similarity and rest four 92.0-100% similarities. Whereas, genetic similarity among the ten isolates of *G. pallida* was 96.1 to 99.4%. Sequences of ten isolates were similar with the group of reference sequences viz., European population. Molecular characterization of PCN population using ITS-1 region specific primers revealed the presence of pure population of *G. rostochiensis* in 50% of the samples, G. pallida in10.7% and mixed population in 28.6% of samples of all the three taluk of Nilgiris. In the morphometric characters J2s of *G. rostochiensis* exhibited shorter body length (459.8µm) than *G. pallida* (493.7µm). *G. rostochiensis* (Fig.10) and *G. pallida* had difference in mean stylet length (21.1µm and 23.4µm resp.), hyaline tail terminal length (28.3µm and 24.2µm resp.) and shape of stylet knob (Fig.11). Highest mean values of vulval basin-anus distance (65.3µm), number of cuticular ridges between vulval basin-anus (18.4) and Granek's ratio (4.0µm) was recorded in *G. rostochiensis* than *G. pallida*. Hence, the present study will help to take appropriate and region specific PCN management decisions according to species dominance in that area.

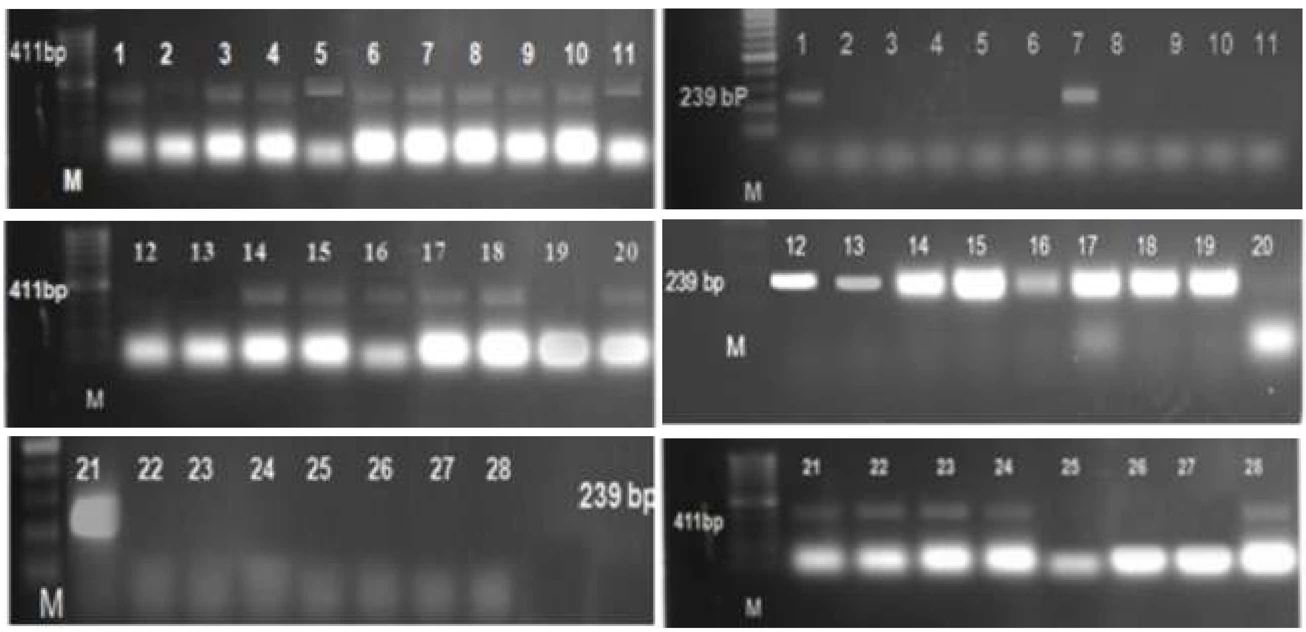


Fig. 9. Identification of PCN species with described primer-sets. M- the ladder- 100kb, Lanes 1-11, 12-20 & 21-28: populations *Globobodera rostochiensis* (411bp), Lanes 1-11, 12-20 & 21-28: populations *Globobodera pallida* (239 bp)

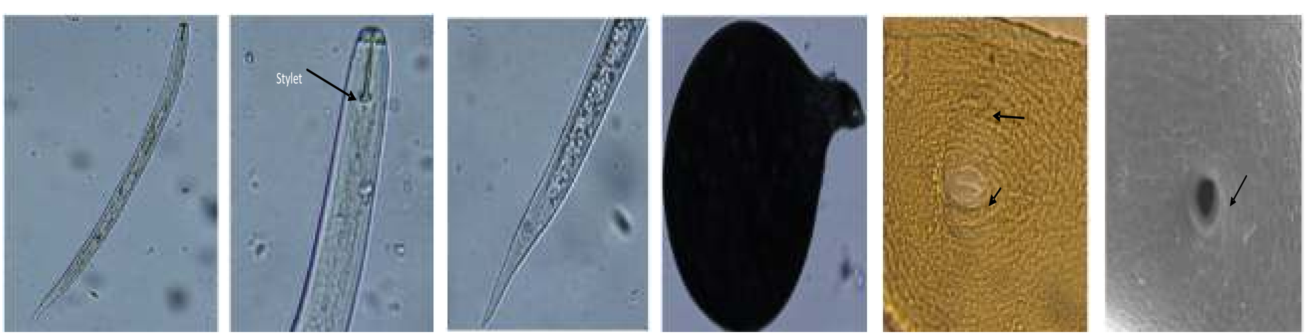


Fig. 11. Photomicrographs of the second stage juvenile and cyst of G. pallida associated with potato in The Nilgiris; a. entire body ; b. head and stylet ; c. tail ; d. spherical shaped cysts ; e. perineal region of cysts (arrows indicate vulval basin and anus) f. SEM of ridges in perineal area (arrow indicate vulval region).

Study of Within-plant Distribution of Whitefly, *Bemisia tabaci* in Potato

The within-plant distribution of *B. tabaci* eggs, nymphs and adults was studied from the last week of September to 2nd week of February in pesticide free potato fields. Twenty to twenty-five plants were randomly sampled at weekly interval. From each main stem, all leaves from top to bottom were sampled for adults. For eggs and nymphs, the detached stems were brought to laboratory and the number of eggs and nymphs on each leaf was counted under a stereo microscope. The data from all sampling dates were pooled to calculate the proportion of individuals on each compound leaf and the associated coefficients of variation (CV). Highest proportion of adults was found to reside on leaf number 3 to 7 with least CV, which represented around 75% of the adult whitefly assemblage (Fig. 12). Similarly, highest proportion of nymphs was found assembled on leaf number 2 to 5 with minimum CV which represented around 70% of the assemblage. For eggs, highest proportion with least CV was found on leaf number 6 to 9 which represented more than 60% of the compliment.

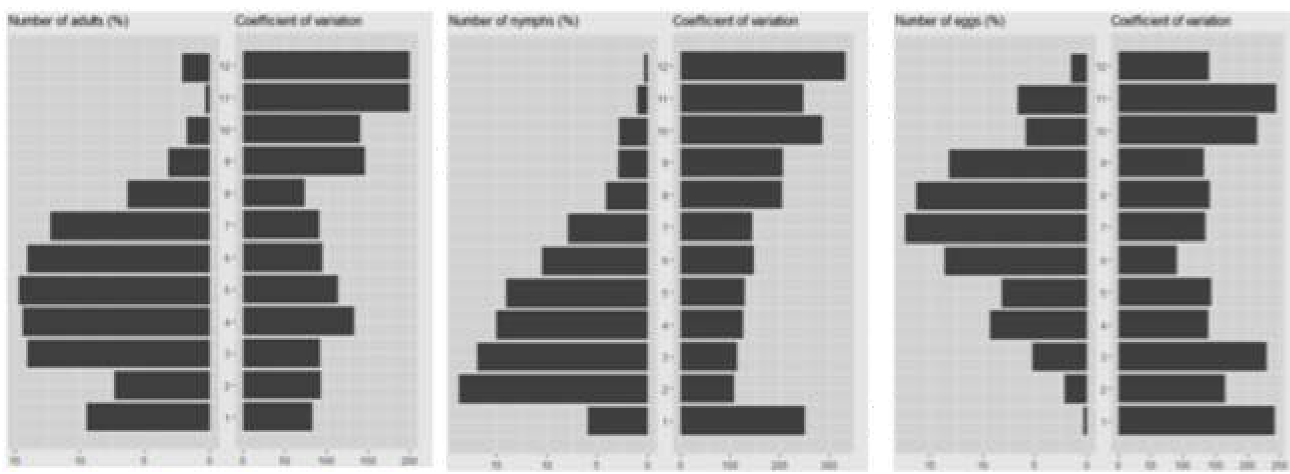


Fig. 12: Distribution and associated coefficients of variation of adults and immature stages of *Bemisia tabaci* along the main stem of potato in field (Leaf numbers 1-12, counting down from terminal leaf).

Biology and Population Growth Rate of Sucking Pests

Biology of A solani and B. tabaci on potato

Studies on biology of *A. solani* and *B. tabaci* on potato indicated that *A. solani* could pass through four nymphal instars in 10-12 days. Nymphs of *B. tabaci* could become adults in 10-15 days and life cycle is completed in 22-30 days.

Population growth rate of A. solani on potato and on other host plants

Tissue culture plants of Kufri Himalini were used to study the population growth rate and multiplication of *A. solani* over a period of time. A single first instar nymph was released on to each plant and was covered with muslin cloth and recorded multiplication of *A. solani*. It was observed that within a span of five weeks, the population levels reached to mean of 208 indicating its good colonizing ability for survival. Among the four different host plants tested for survival and multiplication of *A. solani*, brinjal was highly suitable for high population growth rate followed by potato. However, the survival and multiplication of *A. solani* were very slow on tomato and could not survive at all on cabbage.

Virus Vector Relationship in Potato

Determination of viruliferous nature of insect vectors in potato

Transmission studies revealed that aphid samples i.e. *M. persicae, A. gossypii* from Gwalior, Chindwara, Hassan and Patna were viruliferous with respect to PVY but not for PLRV. Whitefly samples of Jalandhar were found to be viruliferous to ToLCNDV-potato (60-70%). Thrips recorded at Shimla hills and Hassan was *Haplothrips* sp. and was found to carry GBNV.

Foxglove aphid, Aulacorthum solani is one of the important polyphagous pests infesting wide variety of crop plants and recently, population size and distribution of A. solani has increased manifold in potato growing regions of Shimla, Jalandhar, Modipuram and Gwalior. Viruliferous nature of A. solani with respect to most predominant viruses- PVY and PLRV was confirmed as results of transmission studies at Shimla revealed clear visual symptoms and they tested positive for their presence in 4th week of inoculation (Fig.13)

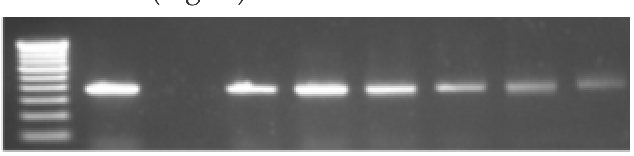


Fig.13. Detection of PVY in *A. solani* of Shimla hills, M-100 kb ladder, Lane1. Positive control (380 bp), 2-negative control, 3-8 aphid samples.

Monitoring of vectors revealed presence of Brevicoryna brassicae on potato crop at four different geographical locations viz. Jalandhar, Shimla, Modipuram and Kalyani. Hence, it was hypothesized whether it was a vector of PVYo on potato and laboratory transmission studies confirmed the status of B. brassicae as a vector.

Macrosiphum euphorbiae was recorded on potato at Shimla hills and found to be viruliferous to PVY and PLRV. In both cases the incidence of PVYo was more than PLRV in Shimla hills. The present study confirmed the occurrence of M. euphorbiae and its viruliferous nature to PVYo and PLRV on potato in Shimla hills. It was also found that M. euphorbiae could carry multiple virus infection (PVYo as non-persistently and PLRV as persistently).

Thrips population from potato of Shimla hills were found to be viruliferous to GBNV. These thrips populations were found to be different from Thrips palmi. However, systematic studies on acquisition, inoculation and transmission of GBNV to healthy potato plants under controlled conditions are yet to be generated.

Integrated Management Strategies for Suppression of Insect Pests and Nematodes

Cultural and Biological Approaches

Evaluation of trap crops against PCN

The effect of trap crop against PCN was studied during 2016-2017 with different treatments viz., trap crop in summer season alone + main crop, trap crop in autumn alone + main crop, trap crop in spring alone + main crop, trap crop in summer + autumn + main crop, trap crop in spring + summer + main crop, trap crop in autumn + spring + main crop, trap crop in summer + autumn + spring + main crop along with control. The results showed that maximum decrease in cyst population with lowest Rf value of 0.83 was recorded with trap cropping in three seasons compared to other treatments. Further, maximum yield was also found with the trap cropping in three seasons (34.31 t/ha) followed by two seasons (32.36 t/ha) whereas, the lowest yield of 29.76 t/ha was noticed in control plot without trap crop.

Effect of crucifers as bio-fumigants against potato cyst nematode

Biofumigation experiment to control PCN was conducted using cruciferous vegetables viz., radish, cabbage, mustard and cauliflower along with dazomet, carbofuran and untreated controls. The lowest Rf value of 0.53 was recorded in biofumigation with mustard followed by Dazomet (0.62). The maximum yield was obtained in biofumigation with cabbage (11.60 t/ha) and was found to be on par with radish, mustard, Dazomet and Carbofuran (Fig. 14).

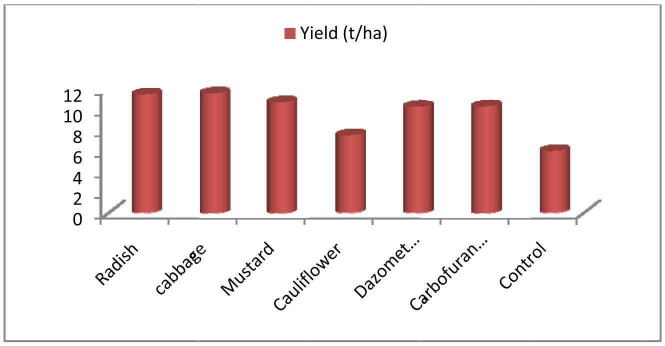


Fig. 14. Effect of bio-fumigants (crucifers) on yield of potato

Chemical Approaches

Efficacy of kaolin on sucking pests

For the management of aphids and whitefly vectors in potato, kaolin was tested at CPRS, Gwalior. Kaolin @0.5 per cent was found to significantly reduce (30 per cent) aphid population as compared to untreated control. However, standard check imidacloprid was best.

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

Mineral oils and non-edible oils were tested for their field efficacy against aphids and whiteflies at CPRS, Gwalior. The results revealed that mineral oil (3%), pongamia oil and neem oils were effective in reducing aphid population (20%). However, Imidacloprid was found to control 90% of the field populations of the aphids. White oil was also tested for the control of whitefly and aphids and it was found effective @0.5% with equal amount of soap solution and comparable to summer oil at same concentration and imidacloprid at recommended dose.

Effect of insecticide molecules on population of sucking pests under sprayed and unsprayed conditions

The population of whitefly and aphids remained low in sprayed treatments (seed treatment with imidacloprid followed by three sprays of imidacloprid, thiamethoxam & spiromesifen). The maximum mean incidence of whitefly (16.4/5 plant) was recorded on Kufri Pukhraj followed by Kufri Sadabahar (15.2/5 plant), Kufri Chipsona 1 (14.8/5 plant), Kufri Khyati (12.8/ 5 plant), Kufri Anand (12.8/ 5 plant), Kufri Surya (11.7/5 plant) and K. Chipsona 3 (10.5/5 plant) under sprayed condition when crop was 30 days old. Comparatively low incidence was recorded in Kufri Bahar (7.67/5 plant) and K. Garima (9.67/5 plant) under unprotected condition. All the potato cultivars were preferred by aphids while maximum population (17.5/5 plant) was recorded on 30 days old unsprayed potato cultivar Kufri Sadabahar The same trend was recorded throughout the crop growth as per the order of preference by aphids. The data revealed that plant protection measures were required to reduce the incidence of insect vectors on potato cultivars for getting maximum yield too (Fig. 15-18).

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

Three insecticides (Imidacloprid, thiamethoxam, spiromesifen) and fungicides (Mancozeb, Metalaxyl, Cymoxanil) in combinations along with control were applied on potato cv. K.Pukhraj during main crop season with the objective to reduce the cost of plant protection and suppressed the incidence of sucking pests and late blight damage. No phyto-toxicity was

Fig. 15. Mean whitefly population on potato cultivars under unsprayed crop

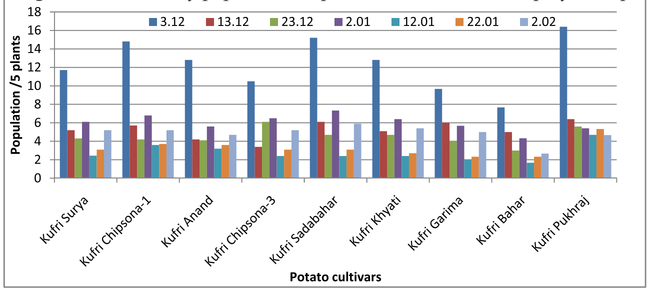
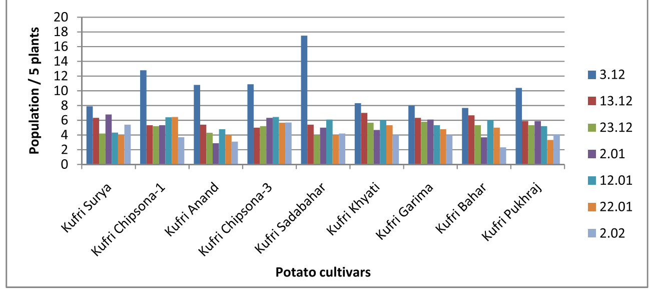


Fig. 18. Mean aphid population on potato cultivars under unsprayed crop



recorded in any of the treatment. All the combinations of Mancozeb, Metalaxyl & Cymoxanil with imidacloprid were effective in comparison to other combinations of insecticide fungicide treatments.

Effects of seed treatments in combination of insecticides and fungicides against sucking pests and incidence of black scurf disease in potato cv. K. Bahar

Three insecticides (Imidacloprid, thimethoxam, spiromesifen) and fungicides (pencycuron, penflufen, boric acid) in combinations were applied on potato cv. K. Bahar during main crop season. All the seed treatment combinations effectively suppressed whitefly and aphid population along with disease as compared to control treatment.

Effects of new insecticide as a seed treatment against sucking pests and incidence of ToLCNDv-potato on potato cv. Kufri Bahar

Seven insecticides, Spinosad, imidacloprid, thiamethoxam, fipronil, propargite, profenophos and acetamiprid were applied on potato cv. K. Bahar during early crop season with the objective to compare the effectiveness to imidacloprid. Low incidence of whitefly (2.3-6.1/5 plants) with disease incidence (14.8%) was recorded in the thiamethoxam seed treated plot in comparison to imidacloprid seed treated plots with whitefly incidence (3.1-5.1/5 plants) and 12.7% disease incidence.

Effect of carbofuran on soil pests

Application of carbofuran at the time of planting @ 65 kg/ha showed a decrease of 54.87% and 42.87% infestation of cutworms and white grub, respectively. Further, 19.82% increase in tuber number and 39.05% increase in tuber weight was noticed in treated plots compared to untreated plots.

Evaluation of new chemicals against PCN

Different doses (@ 20, 30, 40 and 50 gm/m2) of new chemicals viz., Avana, calcium cyanamide and hydrogen cyanamide with carbofuran 3G @65 kg/ha at the time of planting resulted in non-significant differences due to treatments with respect to yield and PCN population as compared to carbofuran. Reduction in yield and increase in Rf value was noticed in untreated control.

Evaluation of different doses of Dazomet (Basamid 95 G) on PCN

Field experiment was conducted during 2016-17 to see the effect of different dose of Dazomet (Basamid 95G) on potato cyst nematodes. The different levels of Dazomet @ 20, 30, 40 and 50 g/m2 were studied with untreated control and carbofuran 3G @65 kg/ha. The results revealed that Dazomet @20 g/m2 showed highest yield (29.48 t/ha) with significant reduction in PCN population followed by Dazomet @30g /m2 (26.28 t/ha) and 50g/m2 (25.23 t/ha). The reproduction factor was found lowest in the treatment with dazomet @30 g/m2(0.47) followed by Dazomet @50 g/m2(0.55) whereas in untreated control it was 1.34 (Fig. 19).

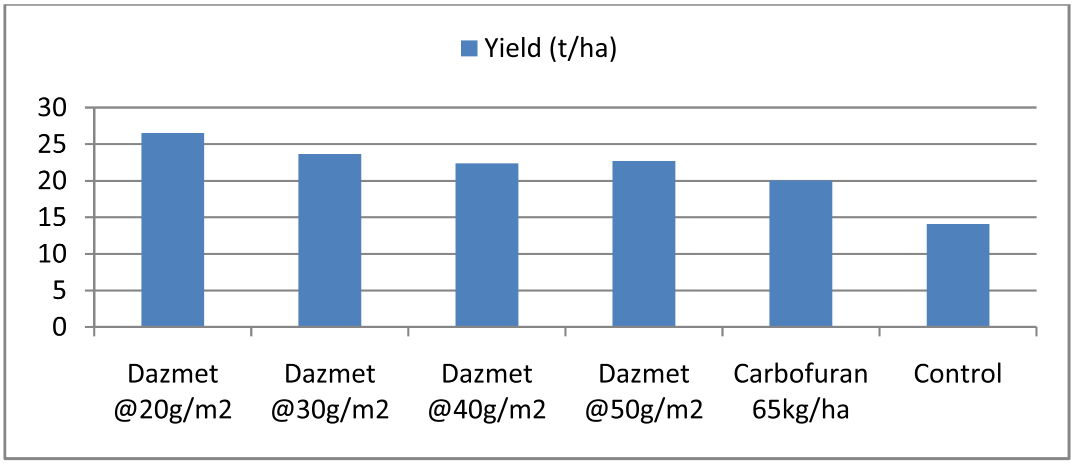


Fig. 19. Evaluation of different doses of Dazomet (Basamid 95 G) on potato yield

Biotechnological Approaches

Effect of RNAi approach on PCN

In continuation to the *in vitro* studies, the effect of dsRNA of flp32(c) gene treated PCN worms were checked under *in vivo* condition on the PCN susceptible variety. It was observed that the treated worms entered inside the roots (Fig. 20) but failed to survive (Fig. 21). This validated the effect of flp-32 (c) encoding an inhibitory neuropeptide, which when silenced, induces an increase in locomotory activity and pre-mature death of treated juveniles inside the root.

Fig. 20. Infection in roots by dsRNA (flp 32 c) treated J2 of PCN

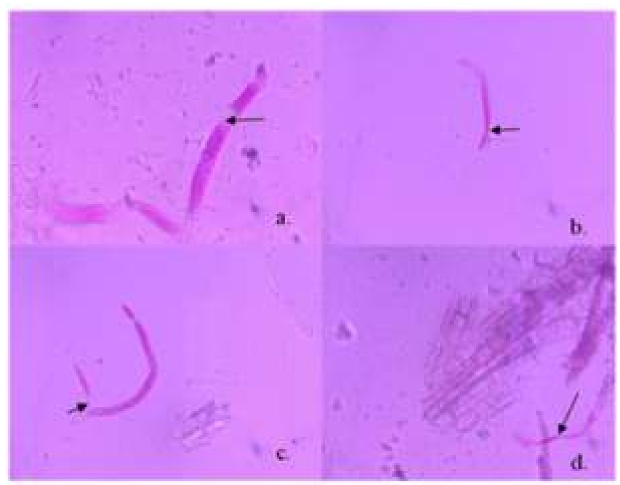


Fig. 21. Shows gene silencing effect of flp 32 (c) on shrinkage of median bulb (a), ventral code (b), tail region (c) and whole body of PCN (d)

Division of Crop Physiology, Biochemistry and Post-Harvest Technology

Programme: Post-Harvest Management and Nutritional Enhancement of Potatoes

This programme aims to assess the post-harvest losses in potatoes during harvesting to retailing chain and refinement of post-harvest handling and storage techniques to reduce the losses occurring in potatoes. Besides, the programme also emphasizes on the establishment of nutritional quality of potatoes and replace the misconceptions attached to potato consumption. Further there is need to enrich the potatoes with the nutrition and develop products which are nutritious and acceptable to the Indian consumers. All these issues were dealt during the reported period and the results are being summarized here.

Post-Harvest Loss Assessment

A survey was conducted in Adampur, Nakodar and Jalandhar East blocks of Jalandhar district of Punjab to estimate the post-harvest losses in potatoes at Farmers field. Data was collected from 60 farmers using an interview schedule. The results revealed that 1.7% of total potatoes were found damaged by insects, 1.8% were rotten potatoes, 4.9% were cut, cracked and green ones and nearly 2.7% were left in the soil after harvesting. Therefore, a total of 11% potatoes were lost at field level itself. During curing, farmers reported 2.8% loss of potatoes mainly due to weight loss. Moreover, at grading stage, further 3% potatoes were rejected.

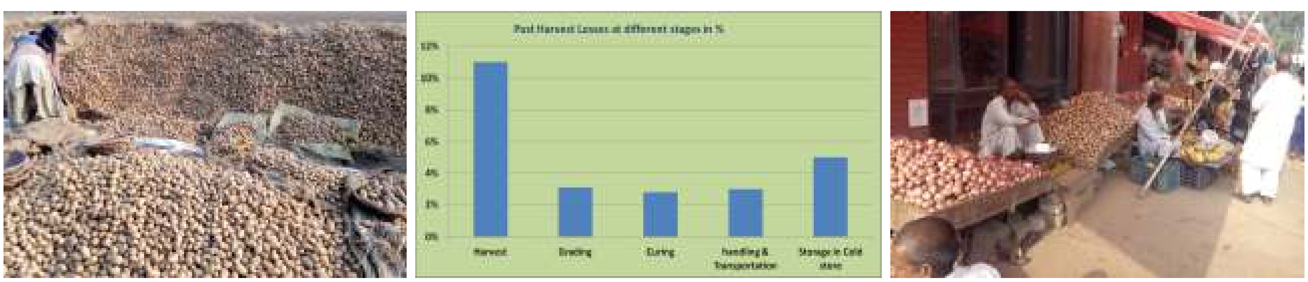


Fig. 1. Assessment of PHL's based on survey with farmers and wholesalers

Data from wholesalers were also collected from Sabji Mandi from Jalandhar. Traders reported that major potato varieties traded in the market were Kufri Pukhraj, Kufri Jyoti, S-6, Kufri Chandramukhi, Lady Rosetta, Atlanta and K-1/K-2. It was found that 1-2% of potatoes are generally lost during handling stage and 1-2% during transportation depending on the quality and distance from market. During storage for 6-7 months at cold storage, about 5% loss is caused mostly due to respiratory and evaporative weight loss in potatoes.

Post-harvest losses in potatoes were also estimated through an experiment using two potato cultivars, K. Chipsona-1 and K. Pukhraj at different stages viz. harvesting, curing, sorting, grading and packaging, during storage in heaps (without CIPC) for 3 months, at 2-4 °C for 6 months and at 10-12 °C for 3 and 6 months. Besides, the potatoes removed from storages were kept under ambient temperatures for up to 20 days and losses were assessed to compare with the conditions these potatoes are marketed and kept at consumers place.

Cv. K. Chipsona-1 (a good keeper) recorded lower PHLs at all the stages from curing/sorting till the retailer/consumer level. Mean total losses of 2.75 and 6.13% were recorded during harvesting and at curing, sorting, grading and packaging stages, respectively. Mean losses during storage in heaps following the farmers' practice without CIPC treatment up to 90 days (12-31°C, 58-78 % RH) were higher (21.05%) due to prevailing high temperatures and low humidity. Losses were the minimum (3.77%) when potatoes were stored at 10-12°C up to three months followed by 5.28% at 2-4°C up to 6 months of storage. While mean total losses of 11.61% were recorded after 6 months of storage at 10-12°C. The PHL's were similar to the losses reported by survey with farmers and traders.

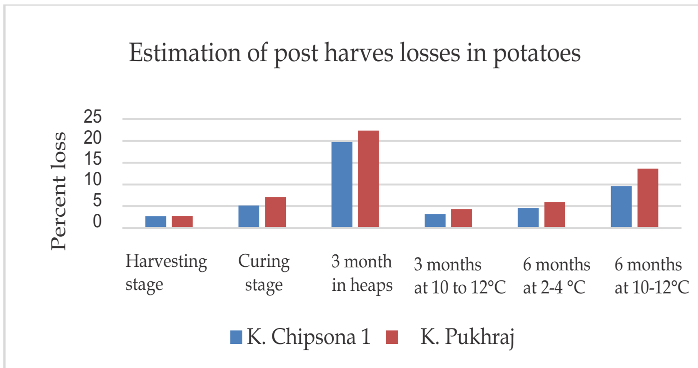


Fig. 2. PHL assessment at different stages from harvesting to storage

Generally a wholesaler, retailer and consumers store potatoes at ambient temperatures for 2-3 days, about 7 days and 7-20 days, respectively. Mean total losses after 20 days of removal from storage were minimum in potatoes stored at 10-12°C up to 3 months (4.65%) and 6 months (2.21%) of storage. Losses were less as the potatoes were treated with CIPC fog. While losses were maximum (31.83%) up to 20 days after removal from heap storage for 90 days as the ambient temperatures in June were high (28-35°C, 68-78% RH). Mean losses in potatoes up to 20 days after 6 months storage at 2-4°C were also high (21.20%) but lower than heap stored potatoes due to low ambient temperatures in September(24-32°C, 60-85% RH), but very high compared to CIPC treated potatoes due to sprouting. The results conclude that potatoes treated with CIPC may result in lower losses even during transportation and marketing.

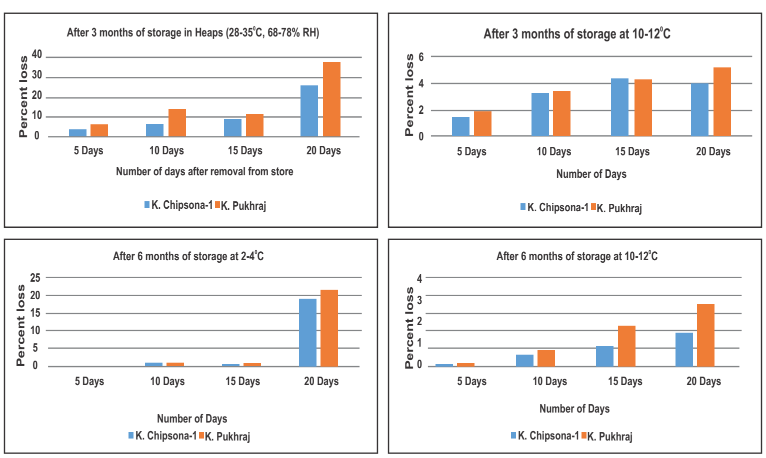


Fig. 3. PHL's in potatoes after removal from stores up to 20 days

Quantification of rot pathogens on tubers

Tuber contamination by erwinias such as Pectobacterium carotovorum subsp. carotovorum, *P. carotovorum* subsp. atrosepticum and *P. chrysanthemi* occurs mostly superficially in lenticels and suberized wounds which later cause soft rot of tubers in storage/ transportation during summer. Similarly, tubers get contaminated with chlamydospores of *Fusarium spp.* which survive in the soil as resting spores and cause dry rot of tubers when storage temperatures are above 8-10°C. An attempt was made to quantify the tuber contamination with erwinias and fusaria (peel extract method) in two potato varieties namely, Kufri Pukhraj and Kufri Chipsona 1 right from harvesting time till five months of storage under different conditions i.e. in heaps, at 2-4°C and at 10-12°C temperatures at Jalandhar. The study revealed the tubers of both the varieties were free from *Pectobacterium* contamination during all the storage stages, though they were found contaminated with *Fusarium spp.* In both the varieties, the population of *Fusarium* propagules was low at harvesting which increased until 30 days of storage under different storage conditions and then decreased gradually till 5 months of storage.

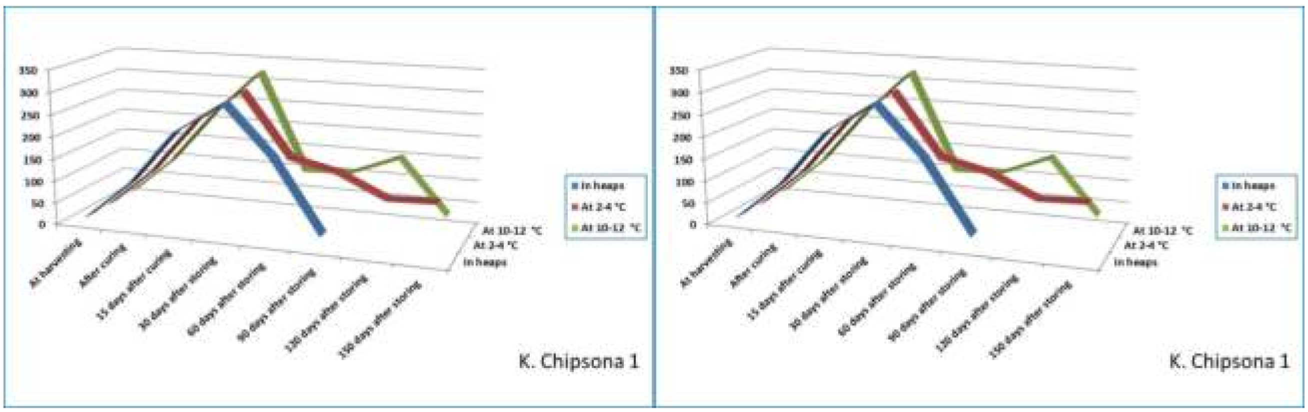


Fig. 4. Quantification of Fusarium population (x102 propagules ml-1 peel extract) on stored tubers

Dry rot caused by *Fusarium species* is generally observed at 10-12°C storage and the inoculum was found to be high in this study also, however, it decreased with storage period. On the other hand under heap storage in humid areas, soft rot is a menace. But since the storage was done at Jalandhar in comparatively non-humid climate, its inoculum was not observed.

Sprout suppression in potatoes with volatile compound

Large scale studies were conducted to confirm last year's results in walk-in-chambers (25q of potatoes) to evaluate naturally occurring volatile compound salicylaldehyde for sprout suppression in potatoes as a replacement for chemical treatment with CIPC. Treatment with salicylaldehyde suppressed sprouting in potato cultivar, K. Chipsona-1 with nil sprouting up to 7 months of storage at 12°C. Eyes remained black in this variety and total mean weight loss in potatoes remained at par with CIPC treated potatoes up to 7 months of storage. Cultivar K. Chipsona-1 recorded the best results. Salicylaldehyde treated potatoes remained totally sprout free with acceptable level of shriveling even 3 months after removal from the controlled temperature chamber in November, 2016 i. e up to about 11 months of storage during February, 2017. Thus indicating that long term storage at 12 °C with salicylaldehyde make the stored potatoes completely sprout free. Salicylaldehyde treatment did not affect the processing and organoleptic quality of potatoes. The results confirmed that tuber treatment with non-toxic compound, 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. 5. 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. This 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. Selected parents were revalidated for the selected characters before their use in breeding. Sixteen parents were grown at Kufri for hybridization and 15 crosses could be attempted due to low flowering and germination of parents and, only two crosses were successful which were planted and evaluated at Jalandhar and 17 selections were retained for further evaluation from these. 21 seedling selections from previous seedling generation were evaluated in F_1C_1 generation and 87 selections were retained for further multiplication and evaluation in F_1C_2 generation.

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 were observed. Identification of morphological markers related to good keeping quality will augment selection of high yielding good keepers.

Respiration Rates: The respiration rates in the undamaged and damaged tubers was measured as a function of CO_2 emission rates (Time 0, 1 days, 3 days and 6 days were recorded) at 8 weeks after harvest using Nikon CO_2 infra-red gas analyser. The maximum respiration rate in undamaged tubers was recorded in Kufri Sutlej and minimum in Kufri Badshah. All varieties were observed to show increased respiration rates after damage which peaked at different days after damage after which it showed a declining trend. Simple Correlation coffecient was worked out where positive and significant correlation with Pearson correlation coefficient (0.6656) was observed between respiration rates of damaged tubers at day 0 and total weight loss at 60 days of storage, in respective varieties.

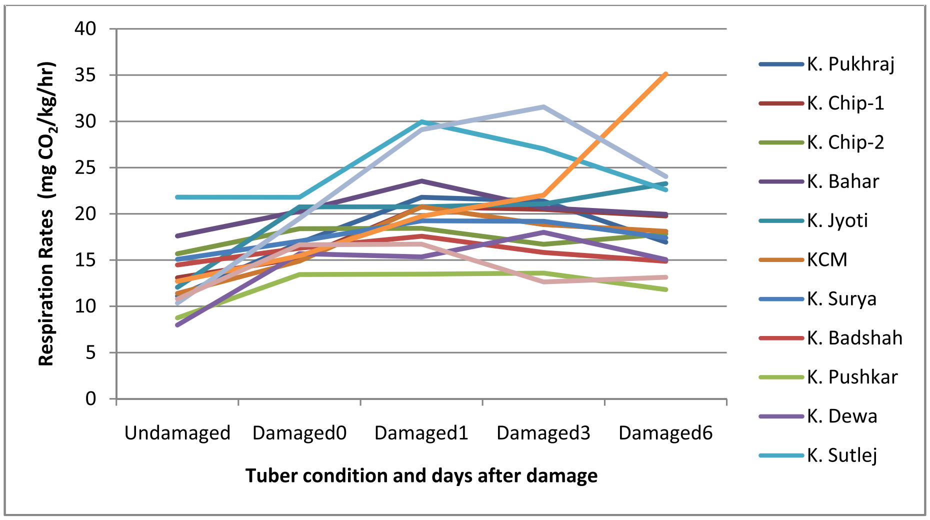


Fig. 6. Respiration rates in undamaged and damaged potato tubers

Microscopic studies on periderm thickness: The periderm of the 14 potato varieties was excised and stained with Sudan III and observed under the simple microscope. The periderm distinguishable as Phellem, pellogen and phelloderm was observed and its approximate measurement at eight weeks harvest in 3 tuber replicates was recorded using a micrometer. The maximum periderm thickness was observed in Kufri Dewa (104 µm). The correlation coefficient between total periderm thickness, phellem, phellogen and phelloderm and keeping quality parameters of total weight loss at 30, 60 and 90 days was worked out and a significant negative correlation could be established between thickness of phellem and total weight losses at 60 and 90 days with person correlation coefficients of -0.428 and -0.463, respectively. Also, between total periderm thickness and total weight losses at 60 and 90 days having Perason correlation coefficients of -0.470 and -0.420, respectively.

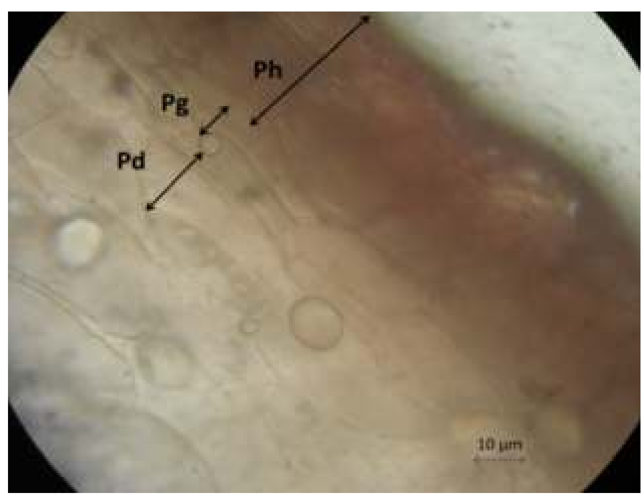


Fig. 7. Periderm in potato variety Dewa. Outer phellem (Ph), middle phellogen (pg) and inner phelloderm (pd) are distinguishable.

Biguanide related compounds in fruits and vegetables

Among the antidiabetic agents, biguanides and related compounds reduce hyperglycaemia by increasing insulin sensitivity and decrease glucose absorption. As arginine is precursor for BRCs, there is some evidence that BRCs and insulin like compounds are present in plants. Therefore, biguanide related compounds (BRCs), particularly, 1,1-dimethylbiguanide hydrochloride (also known as Metformin-HCl), phenformin, guanidine hydrochloride, insulin, galegine analogue (2-methylthio-2-imidazoline hydroiodide), arginine and urea were estimated from ten vegetables, namely, potato, garlic, ginger, coriander, tomato, mushroom, carrot, turnip, radish, green chilli and from four fruits i.e banana, orange, grapes and papaya. In most of the tested samples one or the other BRCs were present. More number of BRCs was present in turnip and orange that contained six BRCs out of the seven tested standards. Among the vegetables, the highest concentration of these compounds was reported in coriander (3.28 mg/g FW) and least in turnip (0.20 mg/g FW). Banana contained maximum concentration of BRCs (1.91 mg/g FW) and papaya contained least concentration (0.17 mg/g FW) among the tested fruits. Overall vegetables seem to be a good source of BRCs compared to fruits due to higher concentration of BRCs. The study revealed that the vegetables or fruits which we consume in our daily routine not only provide us nutrition but also have antidiabetic effect on our body.

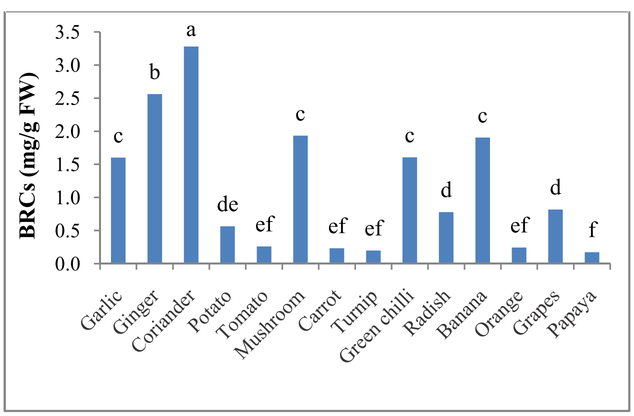


Fig. 8. Concentration of biguanide related compounds in vegetables and fruits

Biguanide related compounds in potato flesh and peel

Presence of individual biguanide related compound (BRCs) was checked in potato peel and flesh. Seven standards viz. 1, 1-dimethylbiguanide hydrochloride (also known as Metformin-HCl), phenformin, guanidine hydrochloride, insulin, galegine analogue (2-methylthio-2-imidazoline hydroiodide), arginine and urea were used for spiking of samples. The spiking results revealed that potato flesh and peel contained analogue of metformin and galegine. Metformin is used as a first line of defense in diabetic patients and galegine is known for its weight reduction property. Thirty eight indigenous potato varieties were evaluated for BRCs (mainly metformin and galegine analogue) concentration in peel and flesh. The results of HPLC revealed that overall potato peel contained higher concentration of these compounds compared to flesh. The concentration of BRCs varied from 0.47 mg/g FW to 1.90 mg/g FW in peel. Peel of K. Jyoti and K. Himsona contained higher concentration of these compounds followed by K. Kanchan, K. Jawahar and K. Lauvkar. The concentration of BRCs in flesh ranged from 0.42mg/g FW to 1.17 mg/g FW. Flesh of K. Lauvkar contained highest concentration of these compounds followed by K. Himsona and K. Sherpa. Such studies help in the removal of the misconceptions that potato cause/worsen diabetes and weight gain. Further efforts are required to increase the concentration of such compounds through breeding or molecular approaches.

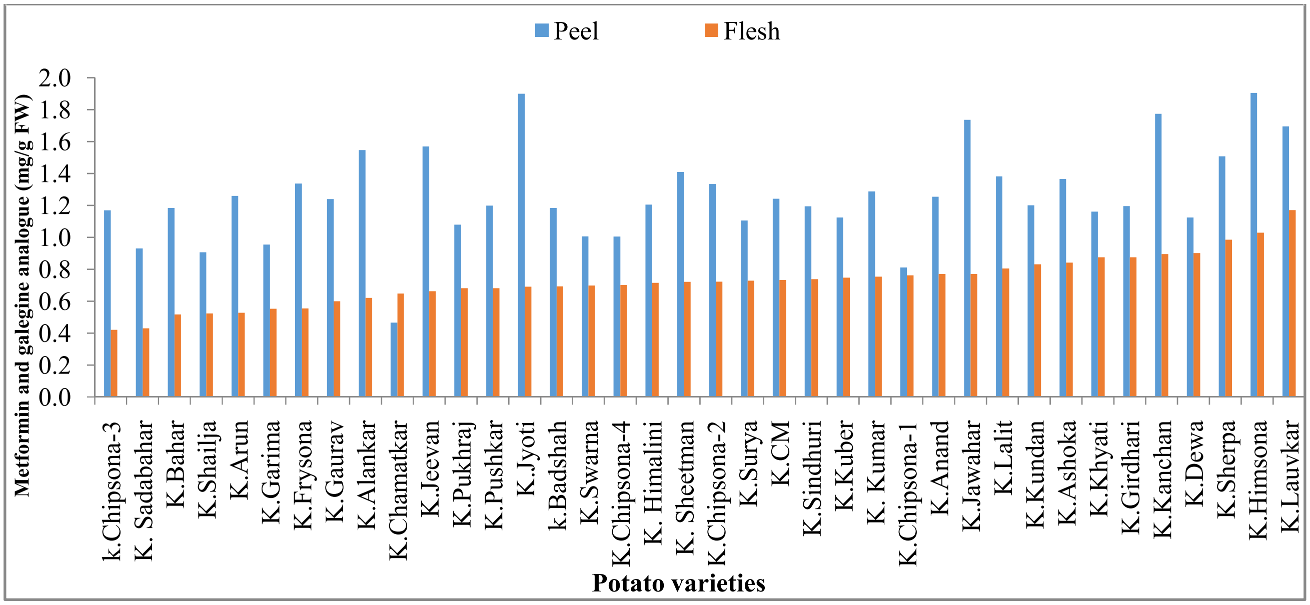


Fig.9. Biguanide related compounds in potato peel and flesh

Flavouring compounds in microwaved potato chips

Microwaved chips were prepared from different processing and non-processing/table varieties varying in sugar content. Processing varieties viz. K. Chipsona-1, K. Chipsona-2, K. Chipsona-3, K. Chipsona-4 and K. Frysona along with table varieties viz. K. Surya, K. Bahar and K. Himalini were used. Flavouring compounds in the microwaved chips varied from 3.70 µg/g FW to 6.79 µg/g FW. The microwaved chips prepared from high sugar variety such as Kufri Bahar showed no discolouration in chips. Along with good appearance, the chips prepared from K. Bahar contained high concentration of flavouring compounds, which makes it possible to use such high sugar varieties also in preparation of chips using microwave. Hence, this method of processing for preparing potato chips is suitable for both processing and non-processing varieties.

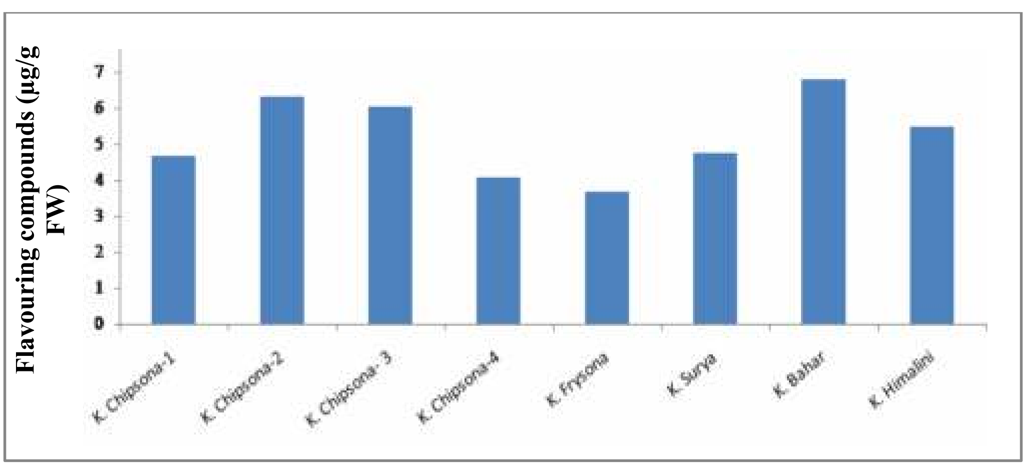


Fig. 10. Flavouring compounds in microwaved chips

Flavouring compounds in stored potato chips

Potato chips were prepared in six different frying oils i.e Gemini ground nut oil, nature fresh sunflower oil, rizol rice bran oil, nature fresh soybean oil, olive pomace oil and Gemini sunflower oil in bulk. Freshly prepared chips and chips stored in ziplocks and in presence of nitrogen for 3 months were analyzed for the flavouring compounds (AMP+GMP). Flavouring compounds varied from 2.57 µg/g FW to 8.82 µg/g FW in freshly prepared chips. Out of the six oils, chips prepared in rizol rice bran oil contained highest concentration (8.82 µg/g FW) of the flavouring compounds. Out of two types of storage i.e with and without nitrogen, chips stored in presence of nitrogen contained higher concentration of flavouring compounds compared to those stored without nitrogen in ziplocks. Flavouring compounds in chips stored in nitrogen packing varied from 2.54 µg/g FW to 5.25 µg/g FW and in ziplocks varied from 2.25 µg/g FW to 4.10 µg/g FW. The results revealed that out of the six tested frying medium, rizol rice bran oil is superior as far as flavor is concerned. Nitrogen flushing not only protects the chips from rancidity, but also helps in flavor retention.

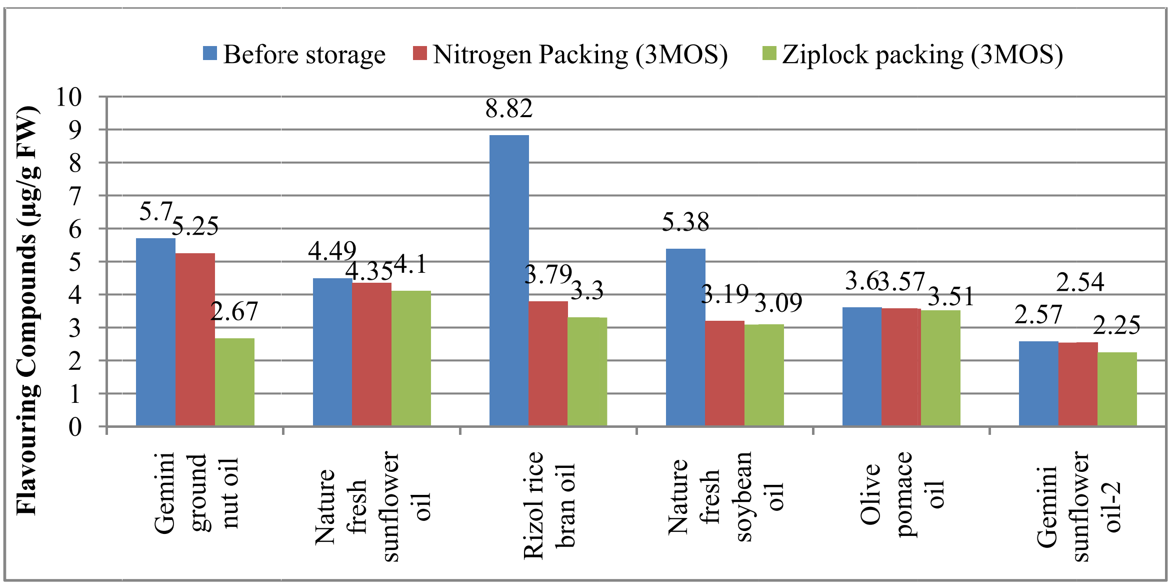


Fig. 11. Flavouring compounds in fresh fried chips and stored chips

Identification and cloning of genes associated with flavouring compounds

Potato flavour is a complex trait resulting from the presence of a combination of volatile and non-volatile compounds and has not been understood adequately. Among various metabolites, methionine metabolism has been found to be one of the important metabolic pathways associated with flavor characteristics of potato. Hence work on cloning and analysis of genes of methionine metabolism was initiated. As evident in the Fig , there are four enzymes involved in methionine metabolism. These are: Cystathionine gamma synthase (CgS), Cystathionine beta-lyase (CbL), Methionine synthase (MS), and S-adenosyl methionine synthase (SAMS). Primers for cloning of genes encoding these 4 enzymes were designed. PCR amplification using gene specific primers resulted in the amplification of cDNAs (partial) encoding these enzymes. Cloning of full length genes and their spatio-temporal expression analysis in various potato varieties is in progress.

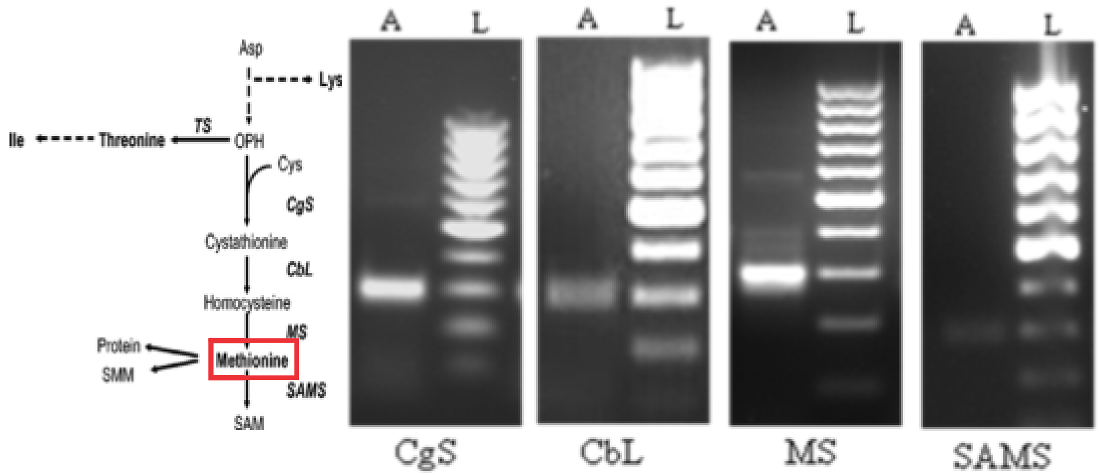


Fig. 12. Methionine Biosynthetic pathway in plants, Enzymes are Cystathionine gamma synthase (CgS); cystathionine beta-lyase (CBL); methionine synthase (MS); S-adenosyl methionine synthase (SAMS). PCR amplification of genes encoding methionine metabolism pathway enzymes. Lane A denotes amplicons of the genes; Lane L denotes 100 bp DNA ladder (right).

Dipsticks for Estimation of Glucose in Potato Tubers

Sugar accumulation in potato tubers is one of the most serious problems for the potato processing industry. As per the normal practice in India, farmers transport their potatoes to the processing industry and upon reaching the industries sites, their potato consignments are rejected due to its higher glucose content by the industry. This put the farmers in a difficult situation and leads to wastage of time and monetary losses in terms of transportation cost and rejection of the tubers. Thus, a simple and quick method for quick estimating the glucose level by the farmers and small processing units is needed. This helps both the farmers and small processing units, which will empower them in taking appropriate decisions for its post-harvest marketing /selling targets/ destinations. Keeping this in view, we have developed dipsticks for quick estimation of glucose in potato. The developed method is highly sensitive (can detect glucose upto 50 ppm concentration), quick (2-5 min.) and simple (anyone can perform). Further, the developed dipsticks were checked for their stability and shelf life and were found to give promising results up to one year.

Fig. 13. Dipsticks for glucose estimation in potato tubers

Utilization of potato flour as humectants in bakery products

To explore the potential of potato flour as humectant/anti staling agent in bakery products (muffins), an experiment was planned to utilize eight variants of potato flour prepared from Processable (K. Chipsona-1) and Table purpose potato variety (K. Lauvkar) after blanching, grilling, boiling and roasting. On the basis of higher value of water retention, water absorption and comparative lower value of set back and flavour intensity; Grilled (at 180 Watt for 25 min) potato flour from table purpose variety (GPF-T) was selected for muffin preparation. For optimization, muffins were prepared with GPF-T at 1, 3, 5, 7 % (w/w) level of the formulation and storage study was conducted for 8 days at 25±2°C and 55±5% RH. Product characterization, sensory evaluation and storage study concluded that GPF-T at 3% level can be used as potential and low cost alternative of commercially available humectants for muffins preparation and can be utilized by small scale industry entrepreneurs. Research findings can be adopted by small scale industry entrepreneurs to delay the staling of muffins by two folds without affecting the sensory scores adversely. Figures show that internal texture and colour of products remained unaffected by incorporation of potato flour.

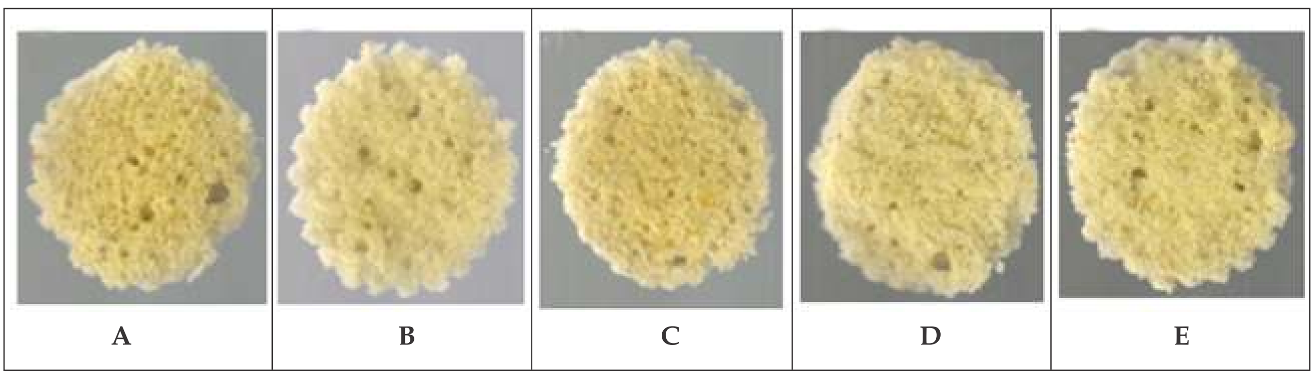


Fig. 14. Transversal section of muffins containing various level of potato flour (PF) A Control (0%), B 1% PF, C 3% PF, D 5% PF, E 7% PF

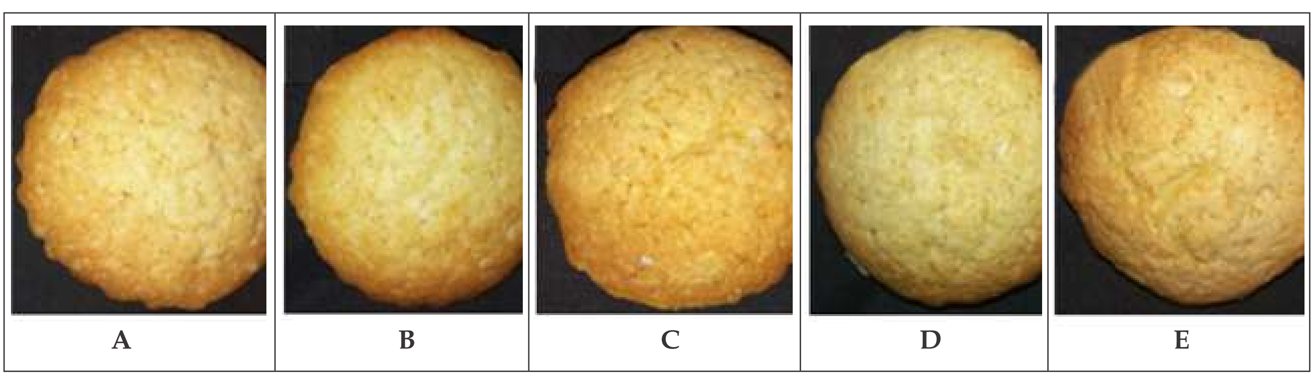


Fig. 15. Colour of muffins containing various level of potato flour (PF) A Control (0%), B 1% PF, C 3% PF, D 5% PF, E 7% PF

Mineral fortification of dehydrated potatoes

Food fortification or enrichment is the process of adding micronutrients (essential trace elements and vitamins) to food. Food fortification was identified as an important strategy by the WHO and FAO in 2006 to begin decreasing the incidence of nutrient deficiencies at the global level. This nutritional supplementation using foods as medicine (nutraceuticals) has been effectively used in treating deficiencies and disorders affecting the immune system. Iron deficiency is one of the most prevalent forms of malnutrition in the world. As iron is involved with a number of enzymes that are required for oxygen metabolism, its deficiency has important health implications such as anaemia which is associated with increased mortality during childhood and pregnancy. Zinc, a part of every tissue in the body, is another important micronutrient which is a component in literally hundreds of body functions. It plays an integral role in muscle growth, injury healing and immunity building. Calcium is essential for strong bones and overall health.

CPRI has registered the process for Dehydration of potatoes for grant of patent in 2014. Possibility was explored for fortification of the dehydrated potato shreds with essential minerals such as iron, zinc and calcium to improve the nutritive value using iron sulphate, zinc sulphate and calcium lactate as fortificants, keeping their high safety values and bioavailability in view. All these three compounds are the preferred compounds and are generally recognized as safe (GRAS) as per FDA list. Different treatments of iron concentration (0.1-0.5%), zinc concentration (1-3%) and calcium concentration (1-10%) were included in the study. Contents of iron, zinc and calcium in fortified dehydrated shreds were increased by 18-40 times, 105-224 times and 10-56 times, respectively with acceptable sensory scores. The organoleptic properties of the dehydrated potato were not altered by the addition of these nutrients and the rehydrated final products were highly acceptable. As potato is habitually accepted and consumed by the larger populations throughout India, fortified potato shreds (noodles) can serve as ready-to-eat breakfast food enriched with minerals in the coming future.

Rehydration studies of dehydrated potato dices and shreds

An indigenous technology for the production of inexpensive, light weight, dehydrated potato products with improved nutrition and longer

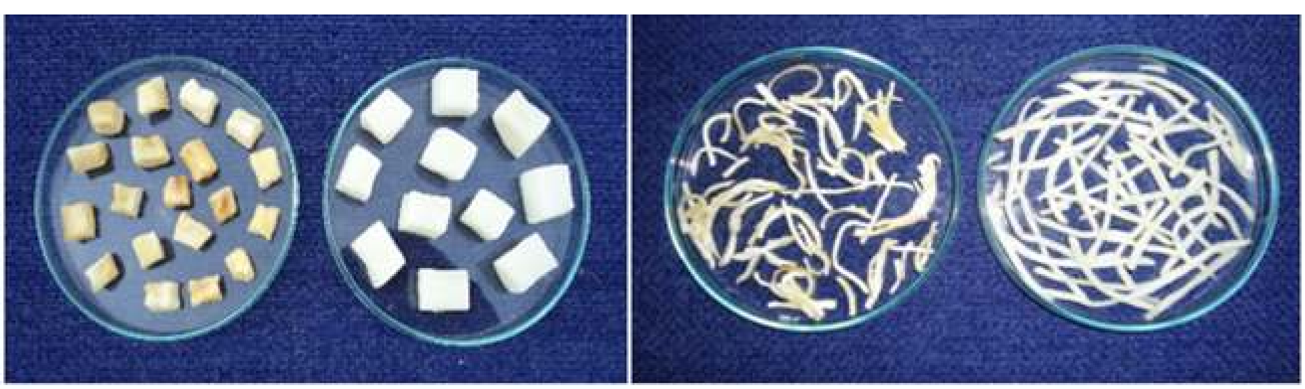


Fig. 16. Dehydrated (left) and rehydrated (right) potato cubes and shreds

shelf-life was developed and registered in Indian Patent Office and is being commercialized. Dehydrated potato cubes and shreds can be fully rehydrated and reconstituted prior to use by simple rehydration process/pressure cooking for different durations. These can be used as curried vegetable, in soup or as snack and are highly acceptable with no central hard core. Highly nutritious, tasty and crispy snack with good flavour is ready to eat within 5-6 minutes of cooking of dehydrated shreds. Rehydration capacity, taste and flavour is fully maintained during storage at ambient temperatures up to 9 months.

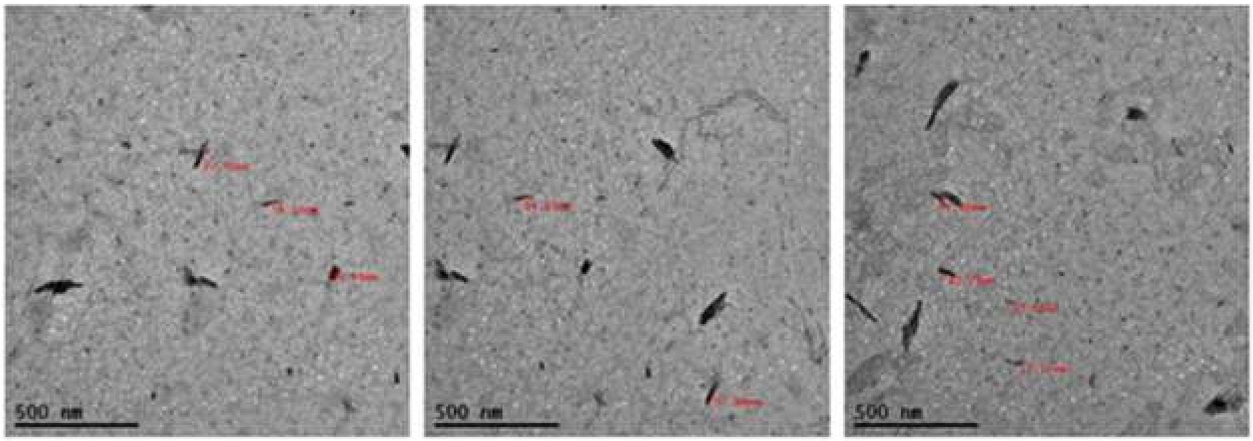


Fig. 17. Transmission electron microscopic images of cellulose nanocrystals from potato peel

Potato starch based bio-degradable nano-composite films

Potato starch based films were prepared with varying concentrations of antimicrobial agents viz. essential oils (clove and cinnamon oil) and potassium sorbate and their mechanical and antimicrobial properties were studied. Concentration of Zinc Oxide nanoparticles (ZnO-NPs) was 0.016% and was kept constant in all films except control film.

Mechanical properties: Strength of the films was measured in terms of resistance to extension (N) and extensibility (mm) and presented as elongation at break (%) and tensile strength (MPa). Tensile strength is the measure of the force or stress required to pull something (resistance to lengthwise stress) to the point where it breaks or before permanent deformation results. Higher the resistance more is the strength of the film. While more is the extensibility, higher is the tensile strength. The tensile strength of the films prepared with different concentrations of cinnamon oil ranged from 27.70 to 36.25 MPa. Tensile strength was the maximum in films prepared with 0.2% of cinnamon oil, which is even better than control film that had 31.87MPa tensile strength. Clove oil based films exhibited the tensile strength 8 to 23% lower than the control films. Potassium sorbate films have tensile strength of 20.92 to 36.25MPa. Increase in concentration of potassium sorbate resulted in decrease in tensile strength. The results showed that the overall tensile strength of the films decreased with the increase in the concentration of essential oils and potassium sorbate.The results are quite convincing and showed that potato starch can not only be used for film making, but can also be utilized as replacement of polypropylene due to its higher strength.

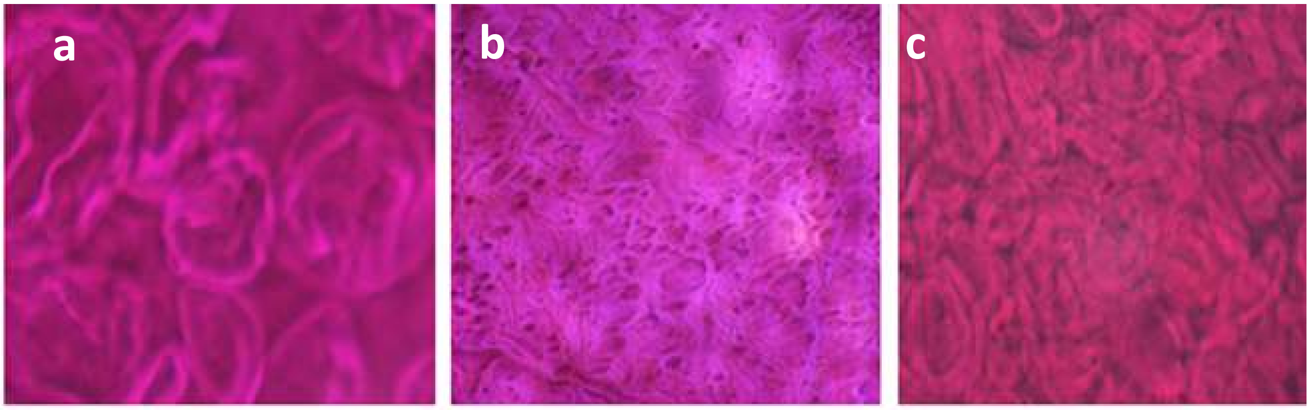


Fig. 18. Light microscopic images (40X) of (a) Control film (b) cinnamon oil incorporated film and (c) potassium sorbate incorporated film

Antimicrobial activity: The films showed antimicrobial effect against S. aureus, C. jejuni and E. coli, however, no combination was effective against the growth of S. typhi. The results revealed that the nanocomposite films incorporated with different concentration of cinnamon oil showed maximum inhibition zone against E. coli (24 to 29%) followed by S. aureus (17-24%) and C. jejuni (19-22%) (Fig).

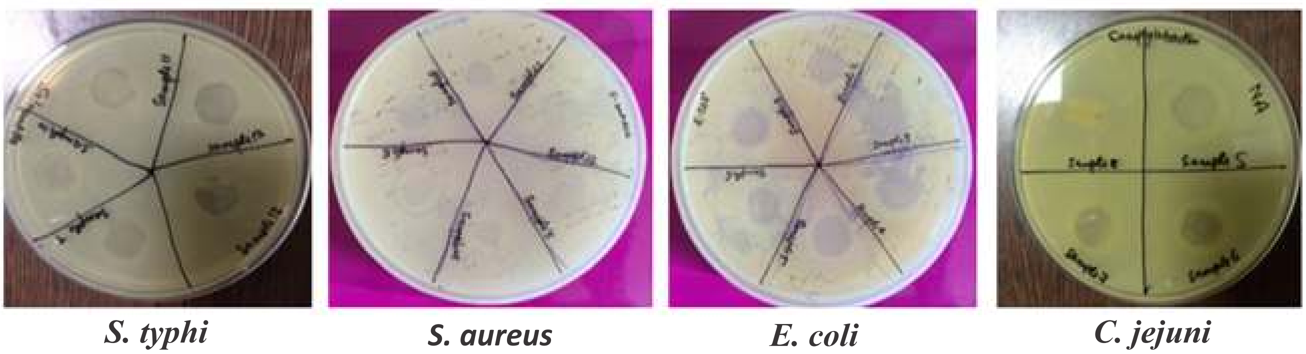


Fig. 19. Petri dishes with circular discs of films inoculated with different antimicrobial agents

Development of Nutritionally superior varieties

In breeding for development of nutrient rich potato varieties, a total of 7795 hybrid TPS were generated from 6 crosses and under generation advancement, in F1C1 generation, 40 clones were selected based on morphological (tuber) traits and in F1C2 generation of cross Barielly Red ×CP 3770, 9 clones were selected out of 19 clones based on tuber and nutritional superiority of phytonutrient content.Fifty five samples were analyzed for nutritional value (anthocyanin content in peel and flesh and carotenoids in flesh). Anthocyanin content ranged from 2.56 µg/g FW (MSP/16-272) to 124.69 µg/g FW (MSP/15-51) in peel. However, anthocyanin content varied from 0.71 µg/g FW (CP3770-(a)) to 23.57 µg/g FW (MSP/15-51) in flesh of these samples. MSP/15-51 was superior due to high anthocyanin content. Total carotenoids varied from 2.12 µg/100g FW

(MSP/16-298, MSP/16-151, MSP/16-300, MSP/16-74) to 107.14 µg/100g FW (MSP/15-26). Based on the results, hybrid MSP/15-51 may be selected for high anthocyanins and hybrid MSP/15-26 for high total carotenoids.

Fig. 20. Potatoes of MSP/15-51 and MSP/15-26

Division of Seed Technology

Programme: 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 nucleaus 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 in 2015-16 and hills 2016 along with various seed research is summarized as below:

Seed Production

A. Plains (2015-16)

A total production of 30639.74 qtls. nucleus and breeder seed was achieved from an area of 153.63 ha in plains through conventional 23273.63 qtls. in 116.56 ha and hi-tech 7366.11 qtls. in 37.072 ha. seed production system respectively. The percentage of nucleus and breeder seed from conventional system was 75.96 and 24.04 through hi-tech system.

1. Conventional Seed Production System:

Tuber indexing and Field ELISA Testing: During 2015-16, total no. of 3758 clones/samples of indexed tubers and 5074 samples of hills in stage-1 standing crop of different commercial potato varieties were tested at regional stations in the plains .The results are given in the table no. 1.

Table-1: Tuber indexing and Field ELISA Testing (Plains 2015-16)

Name of Station	Indexed Tubers		Field ELISA	
Plains (2015 -16)	No of clones/ samples tested	Healthy clones No (%)	No of clones/ samples tested	Healthy clones No (%)
Modipuram	1267	1226 (96.76)	1504	1472 (97.87)
Jalandhar	275	243 (88.00)	735	492 (66.93)
Gwalior	1875	1776 (94.72)	1778	1667 (93.76)
Patna	341	334 (97.95)	1057	951 (89.97)

Stage-I: A total production of 176.08 qtls. was achieved from an area of 2.19 ha (Table-2) with average production of 90.78, 49.15, 84.05 and 85.79 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-II: A total production of 975.64 qtls. was from an area of 6.91 ha (Table-2) with average production of 127.68, 169.16, 139.22 and 247.93 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage- III: A total production of 4314.92 qtls. was achieved from an area of 23.48 ha (Table-2) with average production of 185.37, 233.14, 152.08 and 181.43 qtls./ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-IV: A total production of 17806.99 qtls. was achieved from an area of 83.98 ha (Table-2) with average production of 249.83, 195.92, 169.41 and 199.37 qtls./ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Table -2: Station & variety wise area (ha) and production (Qts.) in Conventional system 2015-16 (Plains)

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
I. Modipuram										
K. Bahar	0.30	30.80	1.26	192.70	5.00	975.50	13.00	3356.30	19.56	4555.3
K. Pukhraj	0.02	4.07	0.23	27.50	0.70	164.00	1.60	398.85	2.55	594.42
K. Anand	0.04	2.68	0.18	23.80	0.60	108.20	1.70	376	2.52	510.68
K. Sadabahar	0.05	4.10	0.22	22.00	0.45	46.80	0.60	106.60	1.32	179.5
K. Garima	0.06	5.65	0.22	26.80	0.90	166.00	3.60	827.25	4.78	1025.7
K. Khyati	0.07	7.00	0.30	52.80	0.90	167.80	5.87	1561.50	7.14	1789.1
K. Surya	0.03	2.20	0.18	15.65	0.40	72.60	1.20	270	1.81	360.45
K. Chipsona-1	0.07	4.87	0.22	30.00	0.65	102.50	1.70	490	2.64	62737
K. Chipsona-3	0.03	2.90	0.20	16.80	0.50	72.30	1.60	368	2.33	460.00
K. Chipsona-4	0.04	1.92	0.22	15.20	0.65	113.50	2.20	486	3.11	616.62
K. Frysona	0.04	2.95	0.32	30.00	0.75	142.50	3.40	884	4.51	1059.45
K. Mohan	0.05	3.48	-	-	-	-	-	-	0.05	3.48
K.Himalini	-	-	-	-	-	-	0.13	19.10	0.13	19.1
Total	**0.80**	**72.62**	**3.55**	**453.25**	**11.50**	**2131.70**	**36.6**	**9143.6**	**52.45**	**11801.17**
II. Jalandhar										
K. CM	0.01	0.54	0.04	5.40	0.20	49.50	1.00	167.25	1.25	222.69
K. Jyoti	0.30	15.00	0.60	103.20	2.50	458.00	10.80	2111.00	14.2	2687.2
K. Badshah	0.01	0.52	0.04	8.80	0.10	18.00	0.45	177.50	0.6	204.82
K. Pukhraj	0.02	1.10	0.05	17.99	0.40	254.01	2.10	374.27	2.57	647.37
K. Pushkar	-	-	-	-	0.01	0.20	0.04	0.50	0.05	0.7
K. Chipsona-3	0.01	0.36	0.02	1.40	0.05	4.50	0.05	13.38	0.13	19.64
K. Khyati	0.02	0.77	0.05	6.50	0.40	69.50	0.90	150.58	1.37	227.35
K. Himalini	0.01	0.30	0.04	1.18	-	-	-	-	0.05	1.48
K. Surya	0.01	0.58	0.05	2.52	0.25	56.00	0.70	148.12	1.01	207.0
K. Chipsona-1	-	-	-	-	-	-	-	-	-	-
K.Shailja	-	-	-	-	0.04	11.20	-	-	0.04	11.2
Total	**0.39**	**19.17**	**0.89**	**146.99**	**3.95**	**920.91**	**16.04**	**3142.6**	**21.27**	**4229.67**
III. Gwalior										
K.Chandramukhi	0.11	11.47	0.21	46.50	0.63	72.35	2.1	280.00	3.05	410.32
K. Jyoti	0.26	17.32	0.46	68.00	1.77	216.46	5.21	833.57	7.7	1135.35

K. Sindhuri	0.16	16.17	0.56	82.50	1.77	292.50	7.13	1381.00	9.62	1772.17
K. Lauvkar	0.11	9.4	0.31	33.50	0.22	39.00	2.22	284.00	2.86	365.90
K. Chipsona-I	0.11	9.69	0.36	39.50	1.28	224.50	3.79	723.65	5.54	997.34
K. Chipsona-3	0.11	8.23	0.28	33.50	0.96	163.50	3.83	611.00	5.18	816.23
Total	**0.86**	**72.28**	**2.18**	**303.5**	**6.63**	**1008.31**	**24.28**	**4113.22**	**33.95**	**5497.31**
IV Patna										
K. Arun	0.02	1.69	-	-	0.10	14.00	1.55	221.25	1.67	236.94
K. Jyoti	0.03	3.46	0.06	13.00	0.20	46.50	2.40	382.50	2.69	445.46
K. Khyati	0.03	3.00	0.06	23.00	0.55	102.00	-	-	0.64	128.00
K. Lailt	0.01	0.80	0.06	16.90	-		-	-	0.07	17.70
K. Pukhraj	0.02	1.32	0.03	7.50	0.25	51.00	3.11	803.82	3.41	863.64
K. Sindhuri	0.03	1.74	0.08	11.50	0.30	40.50	-	-	0.41	53.74
Total	**0.14**	**12.01**	**0.29**	**71.9**	**1.4**	**254.00**	**7.06**	**1407.57**	**8.89**	**1745.48**
Plains' Total	**2.19**	**176.08**	**6.91**	**975.64**	**23.48**	**4314.92**	**83.98**	**17806.99**	**116.56**	**23273.63**

2. Hi-Tech Seed Production System:

i) Generation-1: A total production of 922.95 qtls. was achieved in G -1 from an area of 7.332 ha with average production of 191.37, 20.70, 100.89 and 180.00 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

ii) Generation-2: A total production of 6443.16 qtls. was achieved in G-2 from an area of 29.77 ha with average production of 248.98, 148.75,149.25 and 199.71qtls./ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

Table 3: Station & variety wise area (ha) and production (Qts.) in Hi-Tech system 2015-16 (Plains)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
I. Modipuram						
K. Bahar	2.6	460.00	10.00	2629.00	12.6	3089.00
K. Frysona	0.01	1.30	1.60	426.30	1.61	427.60
K. Pukhraj	0.03	5.60	0.50	124.20	0.53	129.80
K. Sadabahar	0.05	8.60	0.40	69.50	0.45	78.10
K. Himalini	-	-	0.07	10.00	0.07	10.00
K. Surya	0.11	24.55	0.70	142.50	0.81	167.05
K. Khyati	0.70	160.80	2.23	525.00	2.93	685.80
K. Chipsona-1	0.05	9.65	0.10	32.00	0.15	41.65
K. Chipsona-3	0.07	10.40	1.80	411.00	1.87	421.40
K. Chipsona-4	0.38	86.00	1.00	210.00	1.38	296.00
Total	**4.0**	**766.9**	**18.40**	**4579.50**	**22.4**	**5346.40**

II Jalandhar						
KCM	0.50	3.49	-	-	0.5	3.49
K. Jyoti	0.25	3.11	0.05	9.44	0.3	12.55
K. Badshah	0.30	0.68	0.90	85.84	1.2	86.55
K. Pukhraj	-	-	2.73	500.00	2.73	500.00
K. Pushkar	-	-	-	-	-	-
K. Chipsona3	0.09	0.73	0.10	26.50	0.19	27.33
K. Khyati	0.70	21.00	1.30	192.00	2.0	213.00
K. Himalini	0.40	24.46	0.80	60.88	1.2	85.34
K. Surya	0.35	1.31	-	-	0.35	1.31
K.Chipsona1	0.10	0.90	-	-	0.1	0.9
Total	**2.69**	**55.68**	**5.88**	**874.66**	**8.57**	**930.34**
III Gwalior						
K.Chandramukhi	-	-	-	-	-	-
K. Jyoti	-	-	-	-	-	-
K. Sindhuri	0.033	3.30	1.05	171.00	1.083	174.3
K. Lauvkar	0.144	15.00	0.96	129.00	1.104	144.00
K. Chipsona-1	0.005	0.45	-	-	0.005	0.45
K. Chipsona-3	0.005	0.34	-	-	0.005	0.34
K. Surya	0.05	0.28	-	-	0.05	0.28
Total	**0.192**	**19.37**	**2.01**	**300.00**	**2.202**	**319.37**
IV Patna						
K. Ashoka	0.10	20.50	0.70	113.00	0.8	133.50
K. Jyoti	0.02	3.50	-	-	0.02	3.50
K. Arun	-	-	0.10	20.35	0.1	20.35
K. Kanchan	0.02	2.50	0.35	57.30	0.37	59.80
K. Khyati	0.09	8.50	0.45	40.70	0.54	49.20
K. Pukhraj	0.10	23.50	0.80	216.30	0.9	239.80
K. Sindhuri	0.05	9.50	0.70	164.80	0.75	174.30
K. Chip-3	-	-	0.15	25.35	0.15	25.35
K. Surya	0.07	13.00	0.20	51.20	0.27	64.20
Total	**0.45**	**81.00**	**3.45**	**689.00**	**3.9**	**770.00**
Plains Total	**7.332**	**922.95**	**29.74**	**6443.16**	**37.072**	**7366.11**

3. Total supply of breeder seed

During 2015-16, total 24729.62 qtls. breeder seed was supplied to various government and private agencies, from plains, Table-4 (A & B).

Table-4 (A): Station and variety wise supply (qtls.) during 2015-16

Sl. No.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
1.	Kufri Jyoti	-	2143.79	833.57	373.00	3350.36
2.	Kufri Bahar	6256.24	-	-	-	6256.24
3.	Kufri Chipsona-1	531.20	-	723.65	-	1254.85
4.	Kufri Khyati	2134.10	359.76	-	38.50	2532.36
5.	Kufri Lauvkar	-	-	413.00	-	413
6.	Kufri Chipsona-3	791.20	33.04	641.00	24.25	1489.49
7.	Kufri Badshah	-	263.09	-	-	263.09
8.	Kufri Surya	419.65	146.79	-	50.50	616.94
9.	Kufri Sindhuri	-	-	1608.50	152.50	1761
10.	K. Chandramukhi	-	164.35	271.50	-	435.85
11.	Kufri Sadabahar	190.40	-	-	-	190.4
12.	Kufri Anand	389.70	-	-	-	389.7
13.	Kufri Frysona	1309.70	-	-	-	1309.7
14.	Kufri Chipsona-4	721.00	-	-	-	721
15.	Kufri Himalini	29.10	60.70	-	-	89.8
16.	Kufri Arun	-	-	-	234.25	234.25
17.	Kufri Ashoka	-	-	-	97.00	97
18.	Kufri Shailja	-	10.82	-	-	10.82
19.	Kufri Kanchan	-	-	-	56.50	56.5
20.	Kufri Garima	856.00	-	-	-	856
21.	Kufri Pushkar	-	0.70	-	-	0.7
22.	Kufri Pukhraj	545.00	894.50	-	961.07	2400.57
Total		**14173.29**	**4077.54**	**4491.22**	**1987.57**	**24729.62**

B. Hills (2016-17)

1) Multiplication of basic material maintenance of mother stock: A total no. of 22 varieties were tested with ELISA/PCR against 29 viruses Out of these only 11 varieties were found free from all the tested viruses. Later, K. Pukhraj, K. Khyati, K. Frysona, K. Surya and K. Badshah were made free from viruses by carrying out series of testing through PCR/ELISA by the taskforce and were included in the microplants multiplication and supply chain.

Seed Production (Hills): During 2016, a total production of 892.59 qtls. of nucleus and breeder seed was achieved in 5.0 ha area in the hills through conventional 724.39 qtls. in 4.2 ha (Table-5) and hi-tech 168.20 qtls. in 0.80 ha (Table-6) seed production system respectively. The percentage of nucleus and breeder seed was 81.72 through conventional system and 18.28 through hi-tech system in the hills.

1. Conventional system:

i) Tuber indexing and Field ELISA Testing: During 2015-16, of different commercial potato varieties total no. of 404 clones/samples of indexed tubers were tested and 396 (98.02%) were found healthy whereas 1352 samples of hills in stage-1 standing crop were tested and 1342 (99.26%) were found healthy at Fagu.

ii) Stage-I: A total production of 24.53 qtls. was achieved from an area of 0.14 ha with average production of 175.21 qtls/ha at Fagu.

iii) Stage-II: A total production of 49.44 qtls. was achieved from an area of 0.45 ha with average production of 109.87 qtls/ha at Fagu.

iv) Stage- III: A total production of 206.29 qtls was achieved from an area of 0.90 ha with average production of 229.21 qtls /ha at Fagu.

v) Stage-IV: A total production of 444.13 qtls of breeder seed was achieved from an area of 2.71 ha with average production of 163.89 qtls /ha at Fagu/Kufri.

Table 5: Station & variety wise area and production (Qts.) in Conventional system 2016 (Hills)

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Kufri										
K. Jyoti	0.080	8.98	0.23	22.95	0.40	98.50	1.40	221.78	2.11	352.21
K.Girdhari	0.018	4.49	0.06	8.32	0.15	28.00	0.37	72.50	0.598	113.21
K.Himalini	0.025	7.03	0.07	10.40	0.16	43.50	0.48	85.00	0.735	145.93
K.Shailja	0.008	2.27	0.05	5.16	0.14	29.40	0.28	37.20	0.478	74.03
K.Kanchan	0.005	0.95	0.04	2.61	0.05	6.89	0.18	27.65	0.275	38.01
K.Himsona	0.002	0.28	-	-	-	-	-	-	0.002	0.28
K.Giriraj	0.002	0.53	-	-	-	-	-	-	0.002	0.53
Hills' Total	**0.14**	**24.53**	**0.45**	**49.44**	**0.90**	**206.29**	**2.71**	**444.13**	**4.2**	**724.39**

1. Hi-tech system:

i) Generation-1: A total production of 26.75 qtls was achieved from an area of 0.20 ha with average production of 133.75 qtls /ha at Fagu.

ii) Generation-2: A total production of 141.45 qtls. was achieved from an area of 0.60 ha with average production of 235.75 qtls./ha at Kufri.

Table 6: Station & variety wise area and production (Qts.) in Hi-Tech system 2016 (Hills)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
V. Kufri						
K. Jyoti	0.10	9.90	0.04	11.95	0.14	21.85
K.Girdhari	0.03	3.89	0.20	42.74	0.23	46.63
K.Himalini	0.07	12.96	0.22	66.81	0.29	79.77
K. Kanchan	-	-	0.07	11.00	0.07	11.00
K. Giriraj	-	-	0.04	4.65	0.04	4.65
K.Shailja	-	-	0.03	4.30	0.03	4.30
Total	**0.20**	**26.75**	**0.60**	**141.45**	**0.80**	**168.20**

3. Supply of breeder seed from hills (2016):

During current year, a total quantity of 692.00 qtls. of breeder seed was supplied to different government and private agencies (Table-7).

Table-7: Agency and Variety-wise supply of breeder seed to the Govt./Pvt., Agencies from Kufri

Agency	Kufri Jyoti	Kufri Girdhari	Kufri Giriraj	Kufri Shailja	Kufri Himalini	Kufri Kanchan	Total
Himachal Pradesh	40.00	35.00	-	20.00	15.00	-	110.00
Jammu and Kashmir	15.05	25.05	-	-	45.05	-	85.15
Arunachal Pradesh	10.00	-	-	-	-	10.00	20.00
Uttrakhand	10.00	10.00	-	20.00	10.00	3.00	53.00
Meghalaya	15.00	-	-	-	5.00	-	20.00
West Bengal	60.00	-	-	-	10.00	10.00	80.00
ICAR/CPRI	**14.65**	**18.05**	**-**	**-**	**32.55**	**3.00**	**68.25**
Private/Farmers	120.85	38.00	4.50	24.95	52.55	14.75	**255.60**
Total	**285.50**	**126.05**	**4.55**	**65.00**	**170.10**	**40.80**	**692.00**

C. Production and supply of quality seed

At Ooty, total quality seed production of four varieties was 88.53 tons from 10.20 ha area during summer, autumn and spring season (Table-8). Out of this 52.8 tons of quality seed was supplied to the Govt./Pvt. agencies and the remaining quantity was kept for own planting. Revenue of Rs. 16,48,843/- has been generated during the year 2016-17.Under hi-tech in Generation-1, 3.65 tons production was also achieved from 0.128 ha area.

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

Sl. No.	Varieties	Summer season			Autumn season			Spring season		
		Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)
1.	Kufri Swarna	4.20	48.036	11.43	1.80	4.78	2.65	0.40	3.02	7.55
2.	Kufri Girdhari	2.30	28.501	12.39	0.10	0.23	2.30	0.04	0.05	1.25
3.	Kufri Himalini	0.60	2.36	3.93	0.50	0.22	0.44	0.12	1.012	8.33
4.	Kufri Jyoti	0.10	0.25	2.50	-	-	-	0.04	0.07	1.75
Total		**7.20**	**79.147**	**10.99**	**2.40**	**5.23**	**2.18**	**0.60**	**4.152**	**6.92**

At Shillong, total quality seed production of seven varieties was 46.25 tons from 7.46 ha area through Conventional system and High-tech system (Table-9). Out of this 26.36 tons of quality seed was supplied to the different states.

Table 9: Quality seed production and supply in Shillong

Sl. No.	Varieties	Conventional system			Hightech system			Total			Total Supply (t)
		Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)	Area (ha)	Yield (t)	Av. Yield (t/ha)	
1.	Kufri Jyoti	0.78	7.75	9.94	0.29	2.9	10.00	1.07	10.65	9.95	7.57
2.	Kufri Giriraj	1.18	7.77	6.58	0.26	3.5	13.46	1.44	11.27	7.83	6.76
3.	Kufri Girdhari	0.08	0.73	9.13	0.53	8.88	16.75	0.61	9.61	15.75	6.53
4.	Kufri Himalini	0.68	3.86	5.68	1.79	4.76	2.66	2.47	8.62	3.49	2.75
5.	Kufri Himsona	-	-	-	0.02	0.21	10.50	0.02	0.21	10.50	0.07
6.	Kufri Megha	-	-	-	1.51	4.99	3.30	1.51	4.99	3.30	2.64
7.	Kufri Kanchan	-	-	-	0.34	0.93	2.74	0.34	0.93	2.74	0.04
	Total	**2.72**	**20.1**	**7.39**	4.74	**26.15**	**9.52**	**7.46**	**46.25**	**6.20**	**26.36**

D. Supply of Microplants to Different Seed Agencies

A total 144 virus-free in vitro culture tubes of basic seed material comprising 15 different varieties viz., Kufri Jyoti, Kufri Khyati, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Pukhraj, Kufri Frysona, Kufri Chandramukhi, Kufri Lauvkar, Kufri Surya, Kufri Badshah, Kufri Himalini, Kufri Gaurav, Kufri Garima and Kufri Mohan were supplied to 25 different seed producing organizations in India (Fig.1 & Table-1) and a revenue of Rs. 7,20,000/- has been generated.

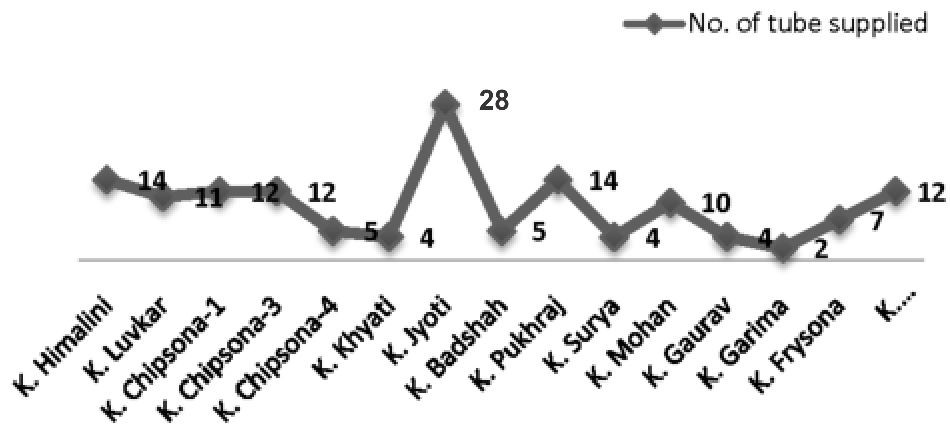


Fig 1. Variety wise supply to different seed organizations

Table 1: Microplants supply to different Seed Producing Organizations

Sr. No.	Name of the firm	Varieties supplied
1	M/s Sekhon Biotech Pvt. Ltd., Rupnagar, Punjab	K. Pukhraj, K. Chipsona-3, K. Chandramukhi, K. Frysona, K. Khyati, K.Chipsona-I, K. Surya, K. Lauvkar, K. Jyoti, K. Gaurav, K. Chipsona-4, K. Badshah
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. Lauvkar, K. Pukhraj, K. Jyoti, K. Badshah
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. Frysona, K. Pukhraj, K. Surya, K. Chandramukhi, K. Himalini, K.Chipsona-3, K. Surya
4.	M/s Sandhu Farms, VPO Udhpur, Jalandhar, Punjab	K. Pukhraj, K. Jyoti, K. Lauvkar, K. Chandramukhi, K. Frysona, K. Gaurav, K. Garima
5.	M/s GRS Bioplants, Kabirpur, Firozabad, UP	K. Lauvkar, K. Pukhraj, K. Jyoti, K. Chipsona-1
6.	Deputy Director Horticulture, Horticulture Biotechnology Centre, Shamgarh, Karnal	K Mohan
7.	M/s Neva Plantation Pvt. Ltd. Village Gopalpur, Tehsil Palampur, Distt. Kangra-176059 (H.P)	K. Chandramukhi, K. Jyoti, K. Pukhraj, K. Frysona, K. Himalini
8.	M/s Mahindra HZPC Pvt Ltd., Mohali, Punjab	K. Chipsona-3, K. Chandramukhi, K. Chipsona-4, K. Lauvkar, K. Himalini, K. Jyoti
9.	M/s Pallishree Limited, Arambagh, Hoogly (W.B.)	K. Chandramukhi
10.	M/s Sagar Biotech, Top Floor, Tip Top Complex, V.P.O Takurdwara, Tehsil Palampur, Distt. Kangra (HP)	K. Lauvkar, K. Chipsona-1, K. Chipsona-3, K. Himalini
11.	M/s Micropropagation Technology Park, TERI, Gurgaon, Haryana	K. Jyoti, K. Mohan, K. Chipsona-3, K. KhyatiK. Jyoti K. Himalini
12.	M/s AKM Sabirijman, Krishi Rasayan, Kolkata	K. Jyoti,

13.	M/s K. F. Biotech Pvt. Ltd., Bangalore	K. Himalini
14.	Assistant Director of Horticulture, Chikkaballapura, Karnataka	K. Jyoti, K. Himalini
15.	M/s Dayal Seeds Pvt. Ltd., Meerut	K. Jyoti, K. Gaurav, K. Garima, K. Mohan
16	M/s Green Agri-tech Co., Sangrur, Punjab	K. Mohan
17.	Mr. Hardev Singh, Bhtinda Punjab	K. Mohan
18.	M/s Shivalik Seeds and warehousing Pvt. Ltd., UP	K. Mohan
19.	M/s Utkal Tubers Pvt. Ltd., Bangalore	K. Jyoti, K. Chipsona-3, K. Mohan, K. Chipsona-1
20.	M/s Bagri Biotech Pvt. Ltd., Haryana	K. Pukhraj, K. Chipsona-1
21.	M/s Shashanka Agro-tech Pvt. Ltd., Ranchi, Jharkhand	K. Surya, K. Khyati, K. Frysona, K. Badshah, K. Chipson-1, K. Pukheaj
22.	M/s GMS Agritech Pvt Ltd., Kalkata	K. Jyoti, K. Chandramukhi, K. Pukhraj
23.	M/s Octave Biotechnology Pvt. Ltd., Farukhabad, UP	K. Jyoti, K. Pukhraj, K. Chipsona-1, K. Chipsona-3, K. Chipsona-4, K. Surya, K. Khyati, K. Badshah
24.	M/s Dhualadhar Bioplants, Kangra, HP	K. Jyoti, K. Pukhraj, Kufri Chandramukhi
25.	M/s JPG Agri-tech Pvt. Ltd., Jalandhar, Punjab	K. Pukhraj, K. Gaurav, K. Frysona, K. Jyoti

A total of 548 culture tubes of 16 varieties were supplied to different seed production stations/centers i.e. Modipuram, Jalandhar, Patna and Shillong (Fig.2).

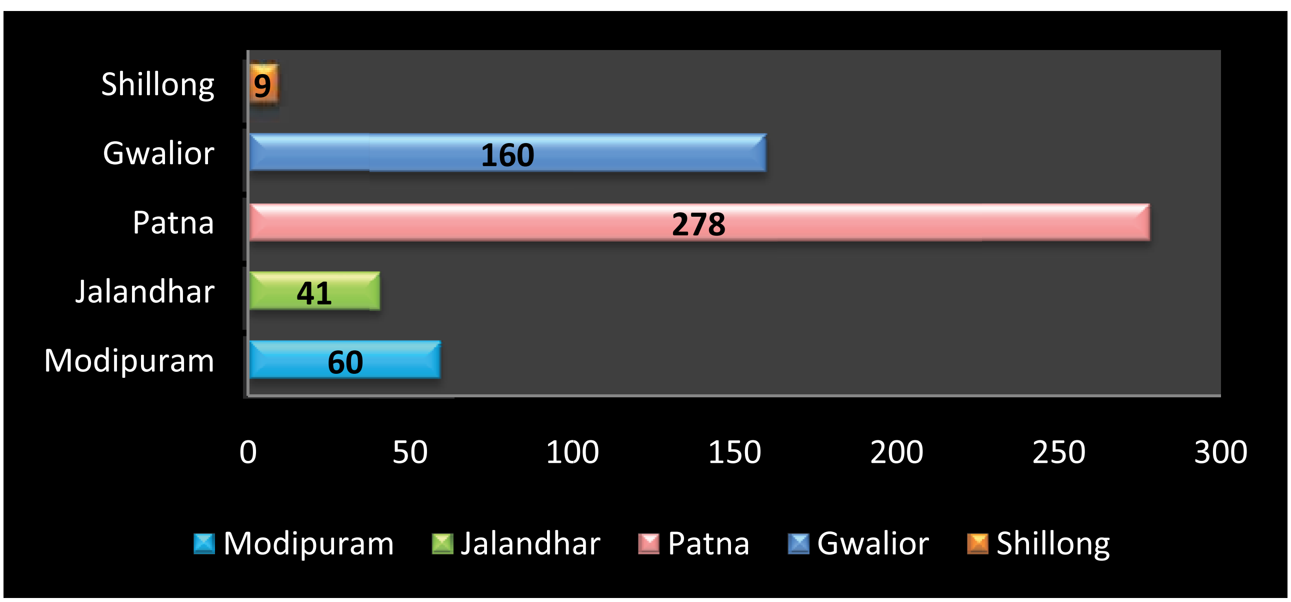


Fig. 2. Station wise supply of virus-free cultures

Table-4 (B): Station, Agency and Variety wise supply (qtls) of plains 2015-16

S. N.	Variety	Bih	HR	CG	HP	J&K	MP	Odisha	PB	UK	UP	WB	Karnataka	Rajasthan	Andhra	NSC	NHRDF	NABARD	Uni.	Auction	Pvt/ Farmer	ICAR /FOC	Total
1.	K. Anand	-	-	-	-	-	35.00	-	-	-	130.00	-	-	-	-	-	-	-	-	66.70	158.00	-	**389.70**
2.	K. Arun	34.00	-	-	-	-	-	-	42.00	-	-	136.00	-	-	-	-	-	-	0.50	-	21.75	-	**234.25**
3.	K. Ashoka	-	-	-	-	-	-	25.00	-	-	-	10.00	-	-	-	-	10.00	-	19.00	-	32.50	0.50	**97.00**
4.	K. Badshah	-	-	76.00	-	30.00	-	28.00	40.00	-	56.00	-	-	-	-	-	-	-	1.00	1.00	30.64	0.45	**263.09**
5.	K. Bahar	-	-	-	-	-	65.00	-	43.00	-	3111.00	-	-	-	-	-	194.00	-	1.80	1404.80	1422.50	14.14	**6256.24**
6.	K.CM	-	-	34.00	30.00	20.00	-	-	11.00	-	-	80.00	-	-	0.50	-	-	36.00	-	1.50	221.90	0.95	**435.85**
7.	K. Chipsona1	-	-	-	-	-	-	-	76.00	-	570.00	10.00	0.15	-	-	-	-	-	-	71.65	526.55	0.50	**1254.85**
8.	K. Chipsona-3	-	-	380.00	-	-	-	-	-	-	274.00	17.00	-	-	0.48	-	-	-	1.50	142.70	651.06	22.75	**1489.49**
9.	K. Chipsona-4	-	-	-	-	-	-	-	-		450.00	40.00	-	-	-	-	-	-	-	99.00	127.00	5.00	**721.00**
10.	K. Frysona	-	-	-	-	-	-	-	-	-	500.00	10.00	-	-	-	-	-	-	-	141.50	602.15	56.05	**1309.70**
11.	K. Garima	-	-	-	-	-	-	-	-	-	450.00	50.00	-	-	-	-	-	-	-	227.00	115.50	13.50	**856.00**
12.	K. Himalini	-	-	-	-	40.00	-	-	20.00	-	-	-	-	-	-	-	-	-	-	4.30	22.00	3.50	**89.80**
13.	K. Jyoti	-	--	-	570.00	91.00	16.00	119.00	90.90	80.00	-	713.00	4.07	3.50	0.50	96.00	47.00	70.00	32.50	3.00	1411.64	2.25	**3350.36**
14.	K. Khyati	10.00	-	-	-	-	-	-	145.00	-	980.00	40.00	-	3.50	0.50	-	400.00	-	23.50	551.20	366.41	12.25	**2532.36**
15.	K. Kanchan	20.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36.50	-	**56.50**
16.	K. Lauvkar	-	-	-	-	-	-	50.00	65.00	-	-	-	-	-	-	-	-	-	-	-	298.00	-	**413.00**
17.	K. Pukhraj	162.50	40.00	127.00	-	-	30.00	60.00	191.00	-	179.00	388.00	-	3.50	0.48	40.00	150.00	-	31.00	118.50	877.34	2.25	**2400.57**
18.	K. Pushkar	-	-	-	-	-	-	--	-	-	--	-	-	-	--	-	-	-	-	0.70	-	-	**0.70**
19.	K. Sadabahar	-	-	-	-	-	-	-	-	-	119.00	-	-	-	-	-	30.00	-	-	41.40	-	-	**190.40**
20.	K. Sindhuri	7.50	-	-	-	-	-	-	65.00	-	400.00	-	-	-	-	-	-	-	55.00	-	1222.00	11.50	**1761.00**
21.	K. Surya	-	-	-	-	-	-	45.00	38.01	-	269.00	36.00	-	3.50	0.50	-	30.00	-	25.00	37.15	119.45	13.33	**616.94**
22.	K. Shailja	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	-	0.30	10.52	-	**10.82**
	Total	**234.00**	**40.00**	**617.00**	**600.00**	**181.00**	**146.00**	**327.00**	**826.91**	**80.00**	**7488.00**	**1530.00**	**4.200**	**14.00**	**2.96**	**136.00**	**861.00**	**106.00**	**190.80**	**2912.40**	**8273.41**	**158.92**	**24729.62**

Programme: Resource optimization in potato based cropping system

Comparative performance of aeroponic, conventional and poly-house multiplied aeroponic tubers under field conditions at Fagu: Seed tubers (5-7g) of potato cv. K. Jyoti obtained from three different sources viz. aeroponic mini - tubers, poly house multiplied aeroponic tubers and conventional seed tubers from Stage III were evaluated for their production behaviour under field conditions. Significantly lower haulms weight was recorded with conventional seed tubers over aeroponic ones indicating early plant senescence in crop raised from conventional seeds. Higher haulms weight of aeroponic tubers at 120 days indicated that natural crop cycle of these tubers is comparatively longer than conventional ones. Uniform cutting of haulms in the crops raised from aeroponic and conventional tubers may limit harnessing of full production potential of crop raised from aeroponic seeds. It is therefore suggested that in seed potato production the duration of crop raised from micro-propagation based systems needs to be re-visited (Table 1).

Table 1: Effect of different seed sources on plant vigour and production potential of potato crop

Treatment	Haulms weight per plant (g)	Total tubers (000/ha)	Total Yield (t/ha)
Aeroponic mini-tuber	131.6	547.2	29.9
Aerponic tubers (one multiplication)	93.5	533.9	25.9
Conventional seed tuber	21.5	575.8	23.2
$CD_{0.05}$	23.9	17.1	2.24

Standardization of planting geometry for multiplication of small aeroponic tubers under protected conditions in high hills: An experiment was conducted to standardize the planting geometry for multiplication of extremely small aeroponic mini-tubers (<1.5 g) under poly house during autumn season in high hills (Table 2). Plant emergence varied significantly among treatments at both the stages viz. 40 and 60 DAP. Final emergence was maximum (97.1%) at 40 x 20 cm spacing and minimum (90.6%) at closest geometry i.e. 30 x 10 cm.

Table 2: Effect of planting geometry on plant vigour and production behaviour of small aeroponic tubers

Geometry (cm)	Germination (%)		Haulms wt. per plant (g)	Total tuber (m^2)	Total Yield (Kg/m^2)	Mean tuber wt. (g)
	40 d	60 d				
30 x 10	87.4	90.6	12.8	73.4	1.36	15.5
30 x 15	95.1	92.3	13.1	45.5	0.70	18.7
30 x 20	89.8	92.5	8.0	33.9	0.87	23.0
40 x 10	90.2	93.9	10.5	71.0	1.56	22.7
40 x 20	71.0	97.1	8.2	34.3	0.93	26.6
$CD_{0.05}$	5.3	4.1	NS	12.8	0.29	5.0

Production behaviour of aeroponic mini-tubers of K. Himalini under poly house at Fagu: Aeroponic tubers of potato cv. K. Himalini obtained from 3 different harvests viz. 3rd, 4th and 5th harvests were evaluated for their production behaviour under poly house conditions during Kharif season. It was found that in-spite of differences in tuber weight and number of sprouts per tuber at planting, plant vigour and production potential of aeroponic mini-tubers from three different harvests did not vary significantly. However, with delay in harvests, a gradual but non-significant increase in number and yield of potato was observed (Table 3).

Table 3: Effect of number and period of harvest in aeroponics on subsequent plant vigour and yield of potato under poly house conditions

Harvest stage	Haulms weight per plant (g)	Total tubers (m^2)	Total Yield (Kg/m^2)
3^{rd} (09/12/15)	59.5	62.1	2.0
4^{th} (17/12/15)	70.9	62.5	2.2
5^{th} (26/12/15)	73.1	73.0	2.3
CD $_{0.05}$	NS	NS	NS

Influence of BAP & CCC concentrations on in vitro tuberization: Very little information is available about influence of benzyl amino purine (BAP) and chloro choline chloride (CCC) on micro-tuberization in potato cultivars. So, a study was undertaken to determine the optimum level of BAP and CCC for getting higher proportion of large size microtubers in K. Himalini and K. Lauvkar at Shimla. The study suggested that lower concentration of BAP (5%) and CCC (200mg/l) resulted in large sized microtubers with less driage and shrinkage. As the concentration of BAP and CCC increased, there was an increase in microtuber number but it affected the size and weight, and thus, resulted in more driage and shrinkage of microtubers. BAP provided effective results with respect to microtuber size, weight, lower driage and shrinkage in both varieties (Fig. 1 & 2).

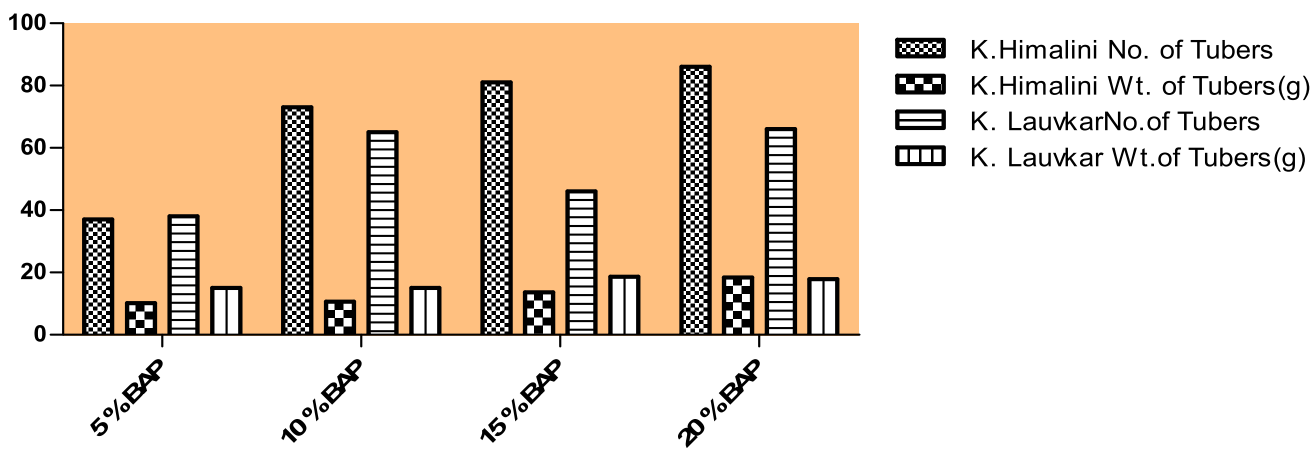


Fig. 1. Effect of BAP on in-vitro micro-tuber production of cv. K. Himalini and K. Lauvkar

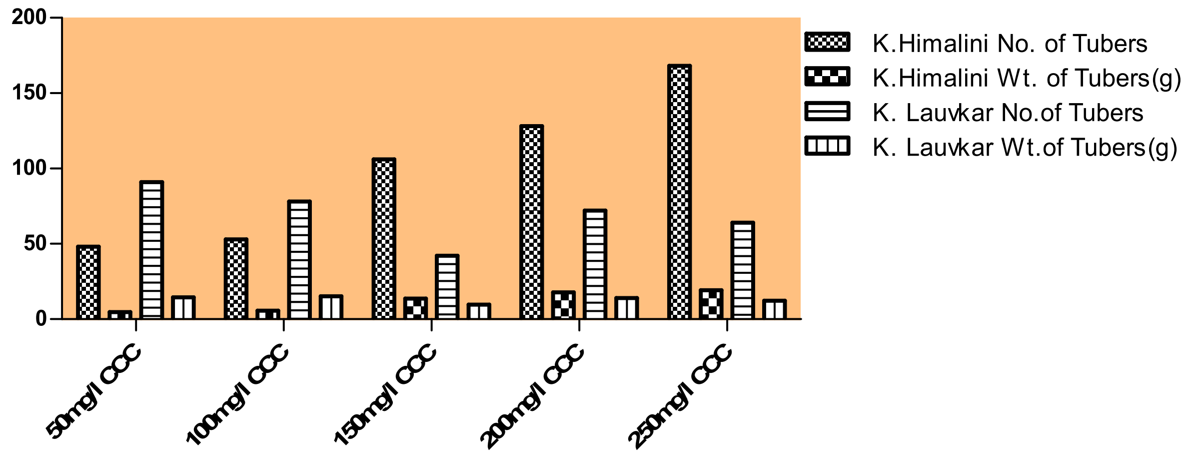


Fig. 2. Effect of CCC on in-vitro micro-tuber production of K. Himalini and K. Lauvkar

Effect of different plant sources and seasons on K. Bahar misshaping: To address the problem of misshaping in potato, an attempt was made to use all plant sources viz., *in vitro* plantlets multiplied or maintained under long day (16 hrs) & short day conditions (< 12 hrs), DUS tubers & conventional tubers which were not at all included under tissue culture and their plantlets being multiplied under two cycles of TC. Study was planned with two planting dates (main and late). Germination was at par in all the treatments. Photo period difference did not have any effect on tuber shape. Conventionally grown tubers showed the originality in varietal shape, whereas, even one-two cycle of its in vitro multiplication significantly influenced tuber shape. Therefore, K. Bahar can be considered the most sensitive variety to be taken under TC. To maintain its originality, it should be multiplied through conventional system and reasons of its sensitivity under TC need to be studied on priority basis.

Yield potential of different potato varieties in net house during autumn season at Shillong: Aeroponically produced minitubers of five potato cultivars viz. K. Megha, K. Girdhari, K. Himalini, K. Kanchan and K. Giriraj were evaluated in net house in autumn season at Shillong. Emergence of minituber on an average ranged from 43-80% for all cultivars being highest in K. Megha and least in K. Himalini. However, in terms of yield K. Himalini showed better response (Fig. 3).

Post-harvest handling of aeroponically produced mintubers at Shillong: To study post-harvest handling of aeroponically produced mintubers, three varieties viz. K. Megha, K. Himalini and K. Kanchan were subjected for curing in two different set of temperature [T1: 24 °C/80-100% RH (0day)-16 °C/40-60% RH (10days); T2 :24°C/80-100% RH (10days)-16 °C/40-60% RH (10days)] prior to final storage at 4 °C. Post-harvest handling of these mintubers have shown that curing in T2 resulted in better minitubers with reduced biomass losses (Fig. 4).

Evaluating two potato crops in net house at Jalandhar: Experiment of two crops in a year was repeated with target of *multiplying early generation potato seed fast* and efficient use of expensive net house area. Six potato varieties *K. Khyati, K. Surya, K. Chandramukhi,* K. Jyoti, K. Badshah and K. Himalini with first and second planting dates 19/09/16 (double crop early) and 2/1/17 (double crop late) respectively for dual crop, and 25/10/16 for single crop were planted. Double crop late significantly out-yield other two treatments in graded tuber yield. It implies that

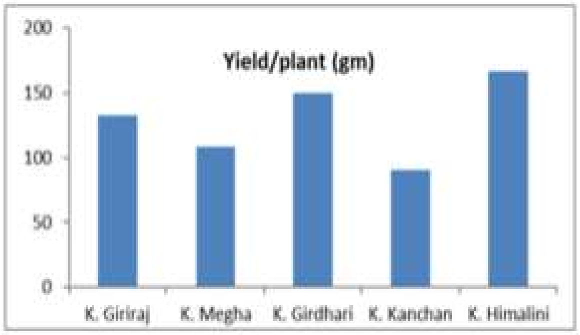


Fig. 3. Tuber yield of different varieties

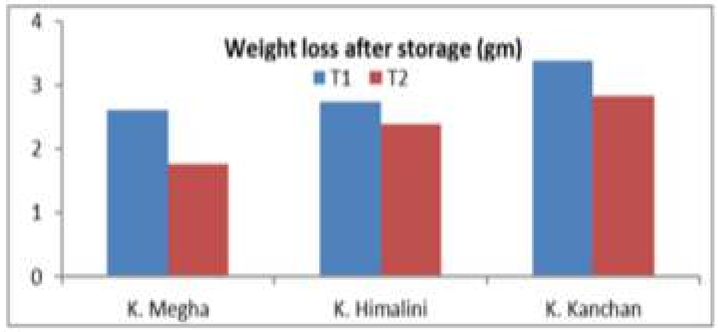


Fig. 4. Weight loss in different varieties

planting of two crops under net–house has scope of getting higher productivity per unit area over single crop. Summing the total yield for seed tubers and under size tubers, an increase in productivity of 147.5% and 101.6 % was realised. It offers future scope for planting two microplant generations or a combination of microplant and undersize mintuber in a single cropping season **(Fig. 6-7)**.

Fig. 6. Varieties planted under double cropping in net house

Evaluating two-potato crop in Aeroponics: Experiment with two varieties, K. Chandramukhi and K. Himalini was conducted at Jalandhar to evaluate performance of double crop early and late in single cropping season over conventional single crop. Tuber number per plant were at par for all the plantings, thereby inferring that double the number of tubers can be achieved with double cropping as compared to single crop in a season, which had 107% increase over single crop. Significant differences were observed for average tuber yield per plant and tuber weight of plucking. The study conclusively proves the feasibility and profitability of considering double crops in a cropping season and may be recommended for increasing seed production under aeroponics system (Fig. 8).

Comparison of Aeroponic Vs nethouse minitubers for growth and yield performance: A comparison of growth and yield parameters of aeroponic minitubers vs nethouse minitubers

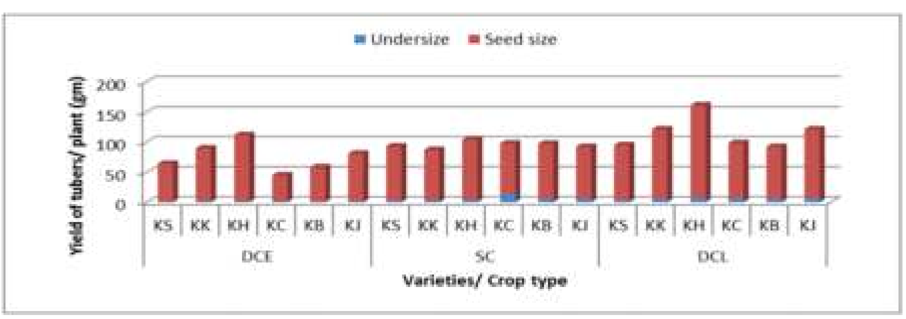


Fig. 7. Yield of undersize and seed size tubers/ plant (g) for over crop type double crop early (DCE), double crop late (DCL) and single crop (SC) in net house. Varieties are K. Surya (KS), K. Khyati (KK), K. Himalini (KH), K. Chandramukhi (KC), K. Bahar (KB) and K. Jyoti (KJ)

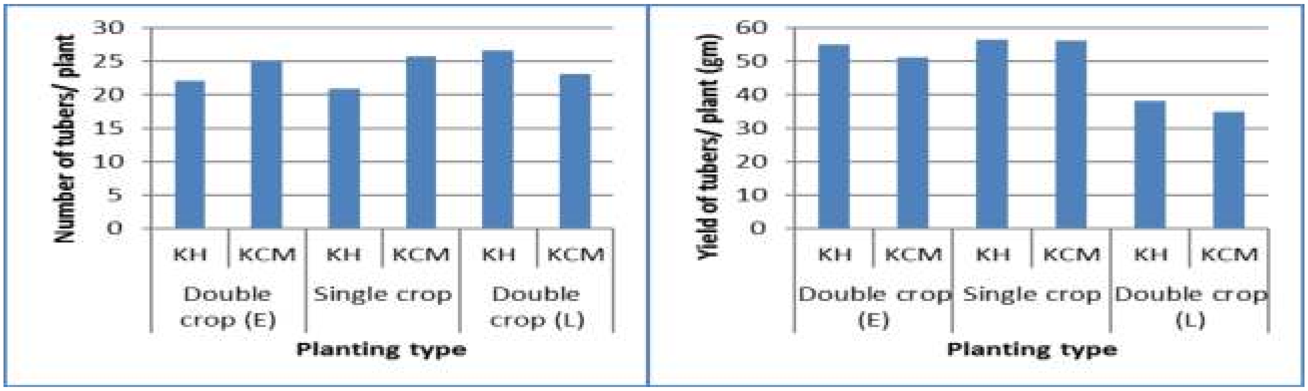


Fig. 8. Number and yield of tuber/ plant of cv. K. Himalini (KH) and K. Chandramukhi (KCM) in three crop type double crop early (E), late (L) and single crop

harvested from microplants was done for varieties K. Khyati and K. Surya at Jalandhar. Tubers with <3 g weight were demarcated as undersize, 3-25 g as seed size and >25 g as oversize. Except number of seed size tubers which were significantly higher in aeroponic minitubers, no significant differences for source of minitubers for either growth or yield traits was observed. Varietal differences were significant for all the characters except yield of seed size tubers and number of over-size tubers. In conclusion, growth and yield parameters of tissue culture and aeroponics minitubers were mostly at par (Fig. 9).

High density planting in net house for minituber production: At Jalandhar, effect of high density planting in flat bed on net house productivity was compared with ridge and furrow method in two varieties K. Chandramukhi and K. Surya. Treatments T30, T20, T15, T10 planted on flat bed had row spacing of 30, 20, 15 and 10 cm against TC (control) having ridge furrow planting at 30 cm. Plant spacing of 10 cm was kept uniform in all the treatments. The results (Fig. 10) showed significant differences for graded tuber number and undersize tubers yield with variation in spacing. However, the effect on seed size tuber yield was non-significant, implying higher smaller seed size formation under higher densities. Treatment T10 showed significantly higher yield followed by T15.

Comparing performance of photoautotrophic microplants (PAM) and tissue culture microplants (TC) in net house: Experiment was conducted at Jalandhar to analyze the performance of PAM and TC in net house for two varieties K. Chandramukhi and K. Himalini. It was observed that PAM were more vigorous than the TC and significantly higher plant height was observed at 60 days in PAM (Fig. 11 C & D). Yield parameters (Fig. 11 A & B) were slightly higher for PAM but no significant differences were found. Varietal differences were significant for growth and yield traits. The study indicated that PAM were more sturdier exhibiting better survival as compared to TC and do not require hardening during transplanting.

Effect of size of minituber on growth parameters and yield performance: At Jalandhar, morphological and yield characteristics were analysed for differently sized mintubers produced in net house. Mintubers of cv. K. Chandramukhi and K. Surya ranging in size <1.5 g (T1), 1.5-5 g (T2), 5-15 g (T3), 15-35 g (T4) and >35 g (T5) were planted in a replicated trial. Differences in canopy and plant were evident in net house. T1 showed least vigour in both varieties and increasing trend was found from T1 to T5. Significantly higher number

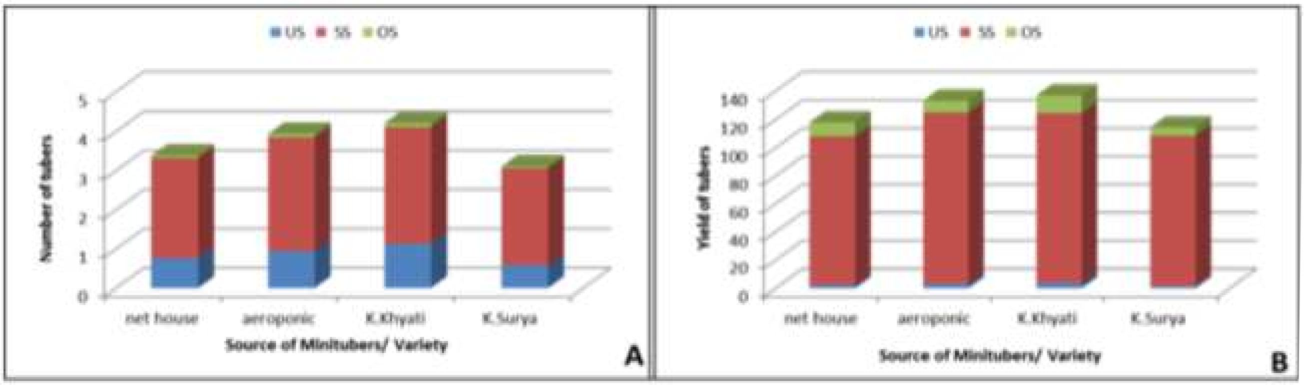


Fig. 9. Number and yield of minituber in aeroponics and net house in cv. K. Khyati and K. Surya

and yield of undersized (<3 g) and seed size (>3 g) tubers was recorded in T5 treatment (Fig. 12).

Canopy management in potato crop in net house: Three varieties (K. Pukhraj, K. Gaurav, K. Chipsona-1) with three treatments (control, single net system and double net system) were compared for canopy management in net house at Jalandhar. Number of undersized tubers (<3 g) were significantly reduced by both the treatments in comparison to control in all four varieties. In K. Pukhraj total weight of tubers in double and single net system was increased by 28.1% and by 16.7%, respectively over control. Similar trend was also observed for other genotypes.

Performance of varieties in improved aeroponic system at Modipuram: A new design of commercial scale aeroponic system was fabricated and tested to augment minituber production. System consisted of grow boxes made of bricks and concrete instead of styrofoam sheets. The system also had an improved control panel and a mechanical system for lifting the plants for tuber picking. Performance of seven potato cvs. K. Khyati, K. Mohan, K. Garima, K. Surya, K. Frysona, K. Pukhraj, K. Chipsona-1, K. Chipsona-3 and K. Chipsona- 4 was observed in this aeroponic system. Days taken for first harvest was minimum in K. Khyati (46) whereas maximum in K. Chipsona-4 (61). Maximum (63) and minimum (28) tuber number per plant were obtained in K. Chipsona-3 and in K. Khyati, respectively (Fig. 13).

Comparative performance of two different aeroponic systems: Performance of K. Khyati and K. Mohan were compared in the aeroponic

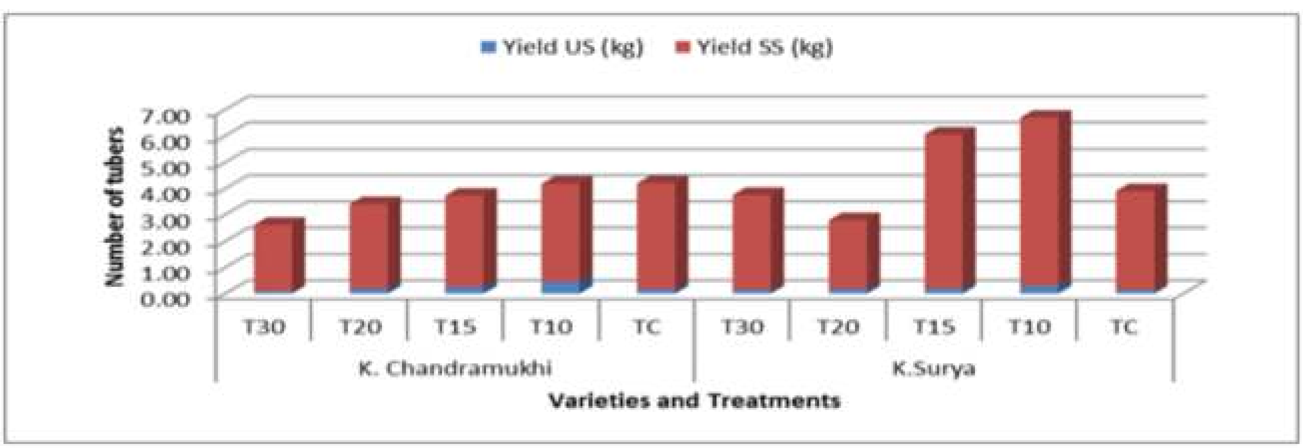


Fig. 10. Tuber yield in different seed categories, total, seed size, oversize and undersize of cv. K. Chandramukhi and K. Surya

system made of styrofoam sheet and system made of brick and concrete. Nutrient solution parameter and spray time were kept same for both varieties in both the systems. Response of two cultivars was observed in terms of mean minituber number per plant. In both the systems, it was maximum (40.7 & 64.9) in K. Mohan (Table 4).

Performance of aeroponic mini tubers grown in net house at Modipuram: Crop of aeroponically produced mini tubers of eight potato cultivars was raised in net house with standard package of practices to assess their field performance in net house. Germination of mini tubers was very good in all cultivars (>90%) except in K. Surya (87%) and K. Frysona (87%). Highest tuber yield (196.8g/plant) and number (7.1 tuber/plant) was recorded in cv. K. Pukhraj followed by K. Mohan and K. Khyati. Lowest tuber yield was recorded in cv. K. Chipsona-4 (95.4g). Biggest size (33.3g/tuber) progeny tubers were achieved from cv. K. Mohan followed by K. Frysona (32.3g). Field performance of aeroponic minitubers was very good (Table 5).

Optimizing planting time for disease free breeder seed production in West central-plains: A field experiment was conducted at Gwalior with five date of planting and three popular varieties. 31st October planted seed crop took lowest time (7.9-14.3 days) for emergence. Germination was above 90 % in all dates of planting. K. Chipsona-1 took lowest time for emergence over two other varieties. Growth parameters viz, plant height and compound leaves were highest in 10th October planting. Increasing trend was recorded for tuber number and weight with delay in planting and highest tuber number and weight was recorded in 31st October planting (Fig. 14).

Studies on planting geometry and fertilizer for higher production of seed size tubers: A field experiment was conducted with two planting distance (15 and 20cm), two crop duration (70 and 80 days), two N doses (120 and 150 kg/ha) for K. Khyati. Highest tuber number (7.07 l/ha) and yield was recorded in T7 (20cm X 80Days X 120KgN/ha) and T2, respectively (Fig. 15).

Agro-technology for aeroponic minitubers for eastern plains: An experiment was conducted at Patna for standardising the spacing and fertilizer dose for multiplication of aeroponic minitubers of cv. K. Himalini in field condition. Spacing of 30x10cm with 120:60:100 NPK kg/ha was found most suitable for production of maximum tuber number and yield.

Developing advanced soilless production system for increasing mini-tuber production

Improvement and testing of new aeroponic system: Generation II aeroponic system having improved design of grow boxes made form bricks and concrete, plant plug and jacket system for holding in vitro plants in grow boxes and crop canopy management with two layers of netting for keeping plants upright, was evaluated. In this new design there is mechanical system for lifting 300-400 plants for picking of tubers and root trimming and dressing. This has improved electrical control panel having along with displays of pH, EC, temperatures, RH and time elapsed. This is also equipped with chilling system with SS plate heat exchanger for cooling nutrient solution. Testing revealed that new grow boxes are sturdier, leak proof and temperature variation is low and slow as compared to existing polystyrene boxes. There is better compatibility of plant holding and lifting system with new grow box design. Crop lodging was nil and there was 25-30% saving on time and manpower while picking of tubers (Fig. 16).

Plug and jacket system for plant holding: Transplanting of hardened in vitro plants (with furry roots) is not possible because planting tray cups have diameter of 16-17mm only. For making transplanting possible without damaging roots a new component was developed and tested. For injection moulding of these components dies were modified. This system consists of a jacket and a pair of plugs for each plant. Five thousand pieces were tested by actually installing and raising crop. These components are useful as soft polystyrene planting sheets are not damaged, plants stems do not rot due to excessing wetting all the time, stems can easily be moved up or downwards and tubers can be taken out easily. Mature plants can be transplanted and hassle free fixing / installation and holding of cover sheets.

Evaluation of chiller performance: Performance of two chilling units installed for cooling nutrient solution, was evaluated. In first unit grow boxes are made of synthetic sheets (thickness: 50 mm) and in second unit boxes are made of brick and cement mortar (thickness: 1250 mm). Temperature variation patterns in different grow boxes and solution reservoir tanks in root zone at chiller set temperature of 13°C, was recorded. In styrofoam grow boxes (Fig. 17), average temperature was 7°C less in chilled grow box as compared to normal one. Mean temperature was 10°C less in solution tank with chiller as compared to normal tank. In concrete grow box type system (Fig. 18), average temperature of grow box and solution tank had difference of 1.7°C.

Testing of feeder unit for two corps in aeroponics: For completing two full crop cycles in aeroponic system, two feeder systems were tested for hardening and raising crop for first 20-30 days. These were installed under controlled temperature and artificial LED lights conditions. Systems were compared with four varieties viz. K. Chandramukhi, K. Himalini, K. Chipsona-1 and K. Gaurav. First unit was deep culture hydroponic system with 5 cm thick polystyrene trays (with plants) floating over 10 cm deep nutrient solution level and equipped with air bubbling and water circulation pumps. In second unit, misters were provided in grow box for supplying nutrient solution to roots intermittently with the help of timer and pump. Both units were provided light of 10000 lux for 6 days and 22000 lux onwards with LED lamps installed over the top. Aeroponic type feeder unit gave superior performance in terms of shoot and root length, and plant establishment. In this method with aeroponic type feeder system first picking could be enhanced by 20-25 days. This approach enables reducing crop period which will ultimately help in achieving the target of two crops in a season in aeroponic system.

Table 4. Comparative performance of two different aeroponic systems

Variety	New Aeroponic					Old Aeroponic				
	Crop duration	Days of 1st picking	No. of picking	Tuber /plant	Wt. /plant	Crop duration	Days of 1st picking	No. of picking	Tuber /plant	Weight /plant (g)
K. Khyati	127	43	21	28.6	83.2	121	42	20	39.6	128.5
K. Mohan	119	52	18	40.7	120.6	121	19	19	64.9	226.4

Table 5. Performance of aeroponic mini tubers in net house

Cultivars	Germination (%)	No. of tubers produced / plant	Tubers wt. (g) /plant	Mean wt. (g) of progeny tubers
K. Khyati	92	5.0	147.6	29.4
K. Mohan	95	4.5	150.4	33.3
K. Pukhraj	90	7.1	196.8	27.8
K. Surya	87	4.4	128.3	29.4
K. Chipsona1	95	4.9	139.2	28.6
K. Chipsona3	92	4.3	118.9	27.8
K. Chipsona 4	90	3.3	95.4	28.6
K. Frysona	87	3.5	113.0	32.3
Mean	91	4.7	136.0	28.9

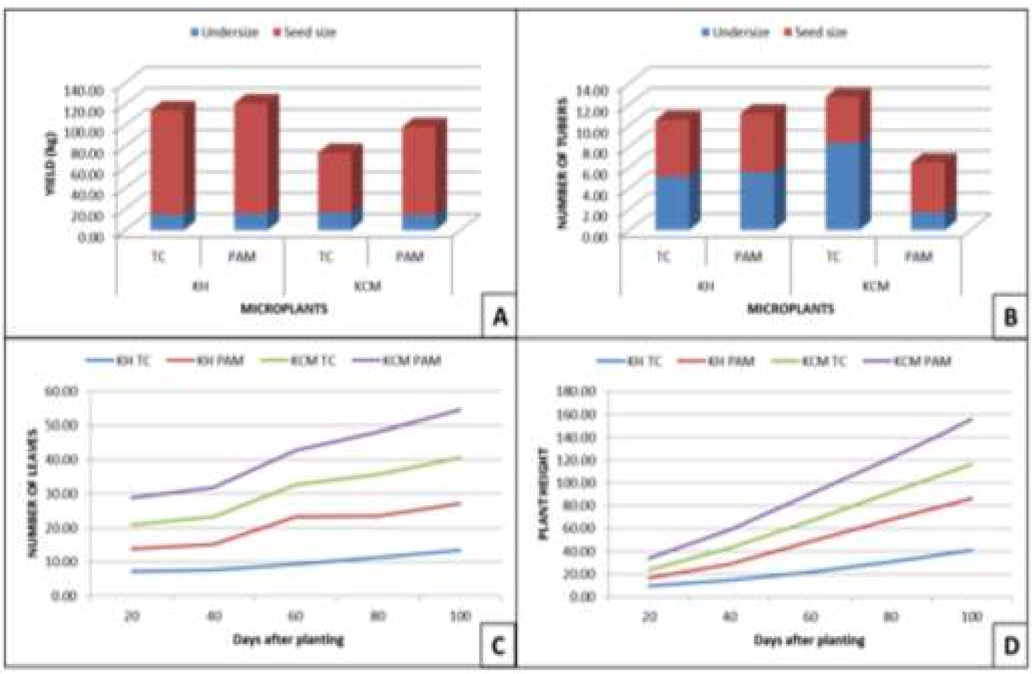


Fig. 11. Growth and yield performance of tissue culture (TC) and photoautotrophically raised microplants (PAM) in net house of cv. K. Himalini (KH) and K. Chandramukhi (KCM)

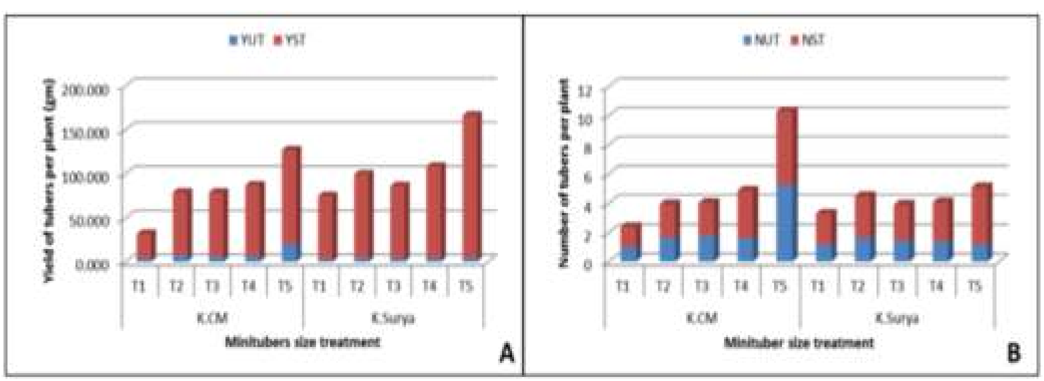


Fig. 12. Effect of minituber size on yield and number of undersize and seed size minitubers in cv. K. Chandramukhi and K. Surya (Size: <1.5 g (T1), 1.5-5 g (T2), 5-15 g (T3), 15-35 g (T4) & >35 g (T5))

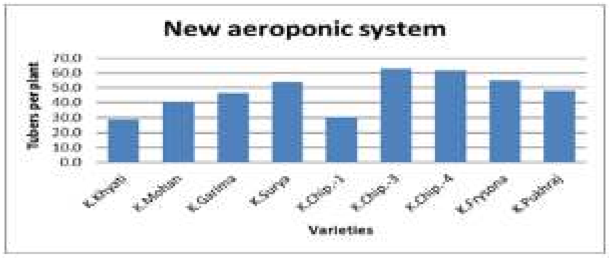


Fig. 13. Performance of varieties in aeroponic system

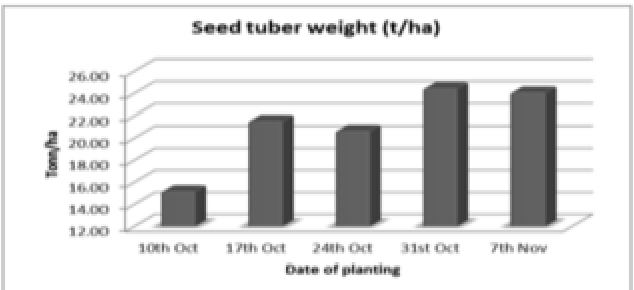


Fig. 14. Seed tuber yield as affected by date of planting

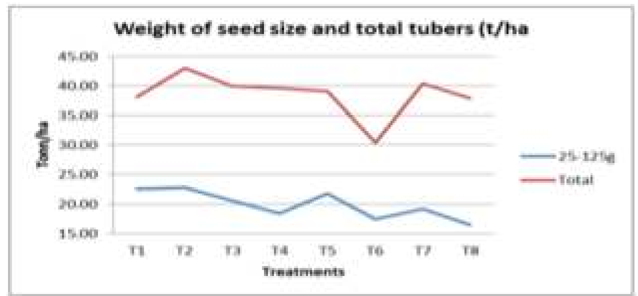


Fig. 15. Seed tuber weight as affected by plant geometry

Fig. 16. Lodged (L) plants in existing and upright (R) plants in new planting system

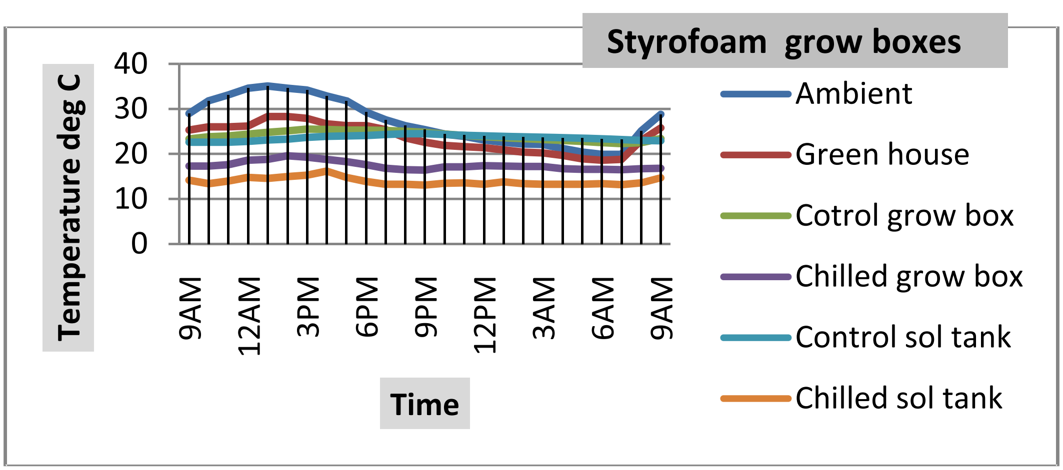


Fig. 17. Temperature variations in polystyrene grow boxes at chiller set temperature of 13^{o}C

Deep culture hydroponic system: An experimental hydroponic unit was developed and compared with two CPRI-aeroponic systems (aeroponic I-Styrofoam box type and aeroponic II -polysheet box type) for potato minituber production. Unit consisted of a brick box having 10 cm deep nutrient solution. In this system, polystyrene planting trays keep floating over the solution surface for the first 20 days. Once root length is 10 cm tray was lifted up by 5 cm after another 10 days tray was further lifted up by 5 cm. This way roots were partially dipped after 30 days of planting. In this system initial tuber formation was delayed by 20 days as compared to aeroponic systems. It was not possible to continue the crop after 80 days as there was rotting of roots and tubers. Results of this experiment indicate that this system can be used for hardening and initial growth of in vitro plants for 20-35 days (Fig. 19).

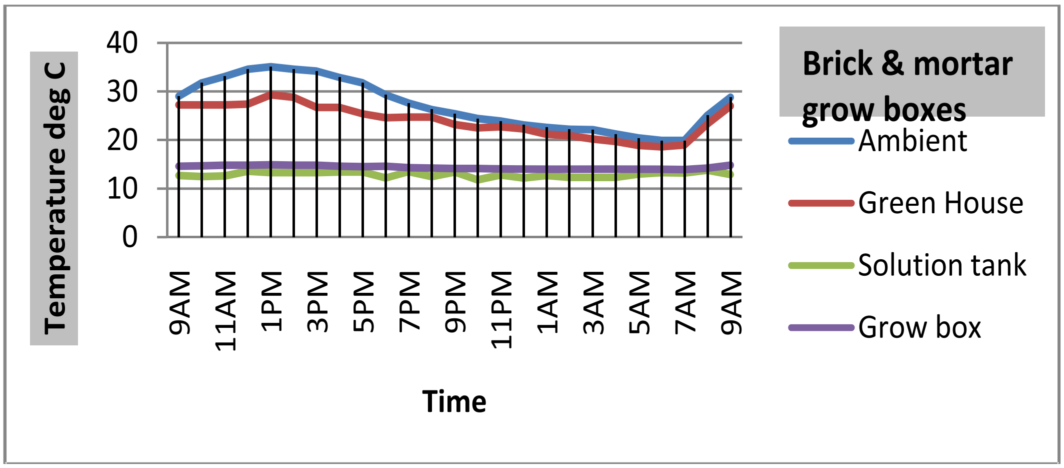


Fig. 18. Temperature variation in brick box type aeroponic system at 13°C chiller set temperature

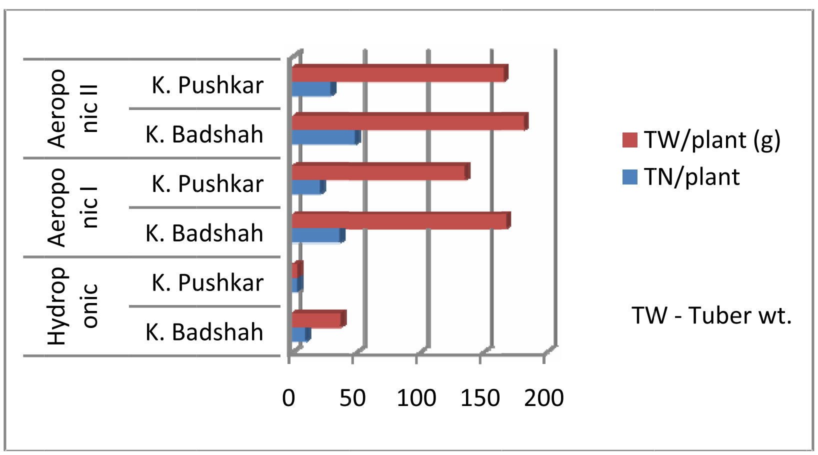


Fig. 19. Comparison of deep culture hydroponic system with aeroponic system

Division of Social Science

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

Price Spread in potato market from Shimla district during off Season

A survey of 25 farmers from higher hills of Shimla district and 10 each of wholesalers and retailers was carried out in Chandigarh to estimate price spread in potato marketed from Shimla during off season. Price spread among different components of marketing channel was worked out. It was found that most of the farmers sold their potatoes in Chandigarh market to wholesalers from which retailers purchase potato and sell them to consumers. Retailer's sale price/consumer's purchase price was ₹ 2110/- per quintal while Producer's sale price/ Wholesaler's purchase price was ₹ 1705.5/- per quintal (Table 1). Thus, price spread among different components was ₹ 714.1/qt. Net price received by producer was 66.15% of consumer price. Margin at wholesaler level was 2.18% and at retailer level was 5.96%.

Fig.1. survey of traders in Chandigarh

Table 1: Price spread of Potato from Shimla in Chandigarh market, October, 2016 (Supply Chain: Producer → Wholesaler → Retailer → Consumer)

Particulars	₹ Per qtl	% age share in consumer's price
Producer's sale price/ Wholesaler's purchase price	**1705.5**	**80.82**
Marketing cost	309.6	14.67
Net price received by farmer	**1395.9**	**66.15**
Marketing cost of wholesaler	153.4	7.27
Margin of wholesaler	46.1	2.18
Wholesaler's sale price/retailer purchase price	**1905.0**	**90.28**
Marketing cost of retailer	79.15	3.75
Margin of retailer	125.85	5.96
Retailer's sale price/consumer's purchase price	**2110**	**100.00**

Assessment of varietal adoption pattern and Cost of Cultivation in Punjab

A survey was conducted in Jalandhar, Hoshiarpur and Ludhiana district of Punjab covering 135 farmers to assess varietal adoption pattern and cost of cultivation. Variety wise proportion of total potato area in selected districts is depicted through a pie chart (Fig. 2). It was observed that Kufri Pukhraj was the most popular variety occupying more than half of area in both Jalandhar (50%) and Hoshiarpur (76%) district. Other popular varieties of Jalandhar were Kufri Jyoti, Lady Rosetta and Badshah. But, in case of Ludhiana processing varieties from private companies like Pepsico *viz.* Lady Rosetta, FC-3 and FC-5 were popular among farmers. While CPRI varities like Kufri Chipsona-1 and Kufri Chipsona-3 were also having significant area under potato. This variation in adoption pattern of potato varieties was mostly due to prevalent contract farming system of potato in Ludhiana.

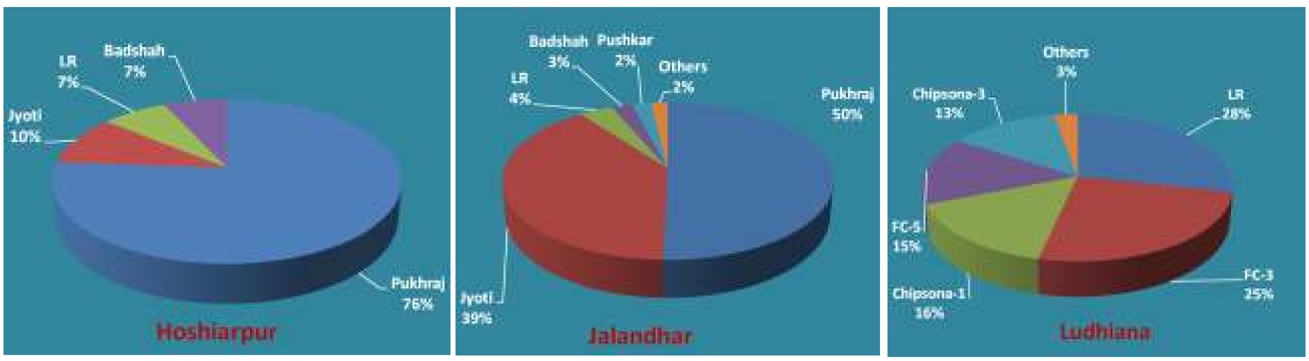


Fig. 2. Proportion of different potato varieties in selected district of Punjab

Cost of Cultivation of potato was also worked out in these three districts of Punjab. On an average, cost of potato cultivation in Punjab was found to be ₹ 122054/- per ha. The highest contribution was that of seed (56.7%) followed by human labour (23.8%) and fertilizers (11.9%). Based on average yield and selling price of potato, Gross return was worked out to be ₹ 2,64,666.7/- per ha in Punjab. The net return was ₹ 142612.5/- per ha and Benefit Cost ratio for farmers was 2.17. Thus, it can be seen that farmers from Punjab had a very good income from potato cultivation. This may be due to very high demand of potato seed from Punjab to other parts of the country which fetched them a premium price. Moreover, in Ludhiana farmers get assured price from contracting agencies thus escape from price fluctuation in market.

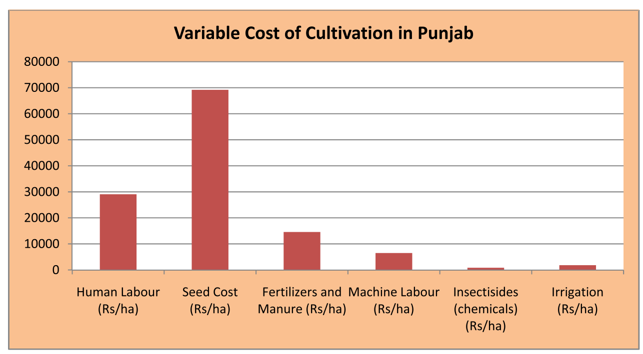


Fig.3. Graphical representation of different cost components in potato cultivation in Punjab

Economic impact of Kufri Khyati on Farmer's profitability

A total of 90 farmers (45 each growing Kufri Khyati and Kufri Pukhraj) were surveyed in different districts of western Uttar Pradesh to find out the economic impact of Kufri Khyati on farmer's profitability. All the cost components were taken into consideration for both Kufri Khyati and Kufri Pukhraj. The cost of cultivation and Gross as well as Net return were calculated for Kufri Khyati and was compared with prevailing variety Kufri Pukhraj to assess its economic impact. The variable cost of cultivation of K. Khyati (₹ 1,47,738/ha) was found to be higher than that of Kufri Pukhraj (₹ 1,38,155/ha). But, due to higher yield and higher selling price of Kufri Khyati, Gross as well as net return was higher for K. Khyati as compared to Kufri Pukhraj. The comparative economic benefits of both these varieties are given in Table 2. Net return of Kufri Khyati was ₹ 1,51,623/ha which was nearly ₹ 32000/ha higher than that of Kufri Pukhraj.

Table 2: Comparative economic benefits of Kufri Khyati over Kufri Pukhraj

Sl No.	Economic parameters (₹/ha)	Kufri Pukhraj	Kufri Khyati
1.	Variable cost of cultivation (₹/ha)	138154.30	147737.20
2.	Average Yield (q/ha)	306.00	312.24
3.	Gross return (₹/ha)	257805.00	299360.10
4.	Net return (₹/ha)	119650.70	151622.90
5.	Benefit cost ratio	1.86	**2.02**
6.	Cost of production (₹/qt)	451.5	473.1

*Average selling price of potato @ ₹ 842.5/qt for K. Pukhraj and 958.75/qt for K. Khyati

Estimation of variable cost of potato cultivation in Bihar

Bihar is the third largest potato producing state of India. Nalanda and Patna districts have the highest area under potato in the state. Therefore, the cost of cultivation of potato was estimated in these districts through survey method during 2015-16. A total of 120 farmers, 60 each from Patna and Nalanda were surveyed using an interview schedule. It was observed that Kufri Pukhraj was the most popular variety in Nalanda covering nearly 90% area. In Patna, red colour varieties like C-1, C-40, Lal Gulab and Kufri Sinduri were very popular among farmers. Results also revealed that, on an average, variable cost of potato cultivation in Nalanda was found to be ₹ 131852/- per ha. The highest contribution was that of seed (42.9%) followed by human labour (29.6%) and machine labour (10.5%). In case of Patna, the variable cost of cultivation was estimated to be ₹ 106215.2/- per ha in which maximum contribution was that of human labour (35.5%) followed by seed cost (25.7%) and fertilizers and manure (13.9%). Higher cost of cultivation in Nalanda can be attributed to its high seed rate and use of good quality seed at a higher price. In Patna, mostly farmers used seed available from local market. Based on average yield and selling price of potato, Gross return in Nalanda was worked out to be ₹ 2,11,302/- per ha which was higher than Patna where Gross return was only ₹ 149367.7/ha. The net return and BC ratio for farmers was 1.6 in Nalanda and 1.4 in Patna. Thus, it can be observed that farmers from Nalanda had good income from potato cultivation due to use of quality seed resulting in higher yield level.

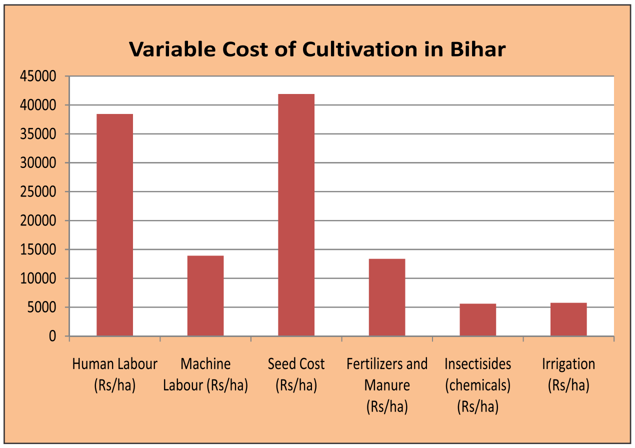


Fig.4. Graphical representation of different cost components in potato cultivation in Bihar

Estimation of variable cost of cultivation in West Bengal

West Bengal is the second largest potato producing state in the country. Variable cost of cultivation of potato was worked out in Hooghly and Bardhman districts of West Bengal through survey method during January, 2017. Altogether 130 farmers, 65 each from Hooghly and Bardhman district were surveyed using an interview schedule. Results revealed that, on an average, variable cost of potato cultivation in both Hooghly and Bardhman was found to be ₹ 143593/- per ha. The highest contribution was that of seed (39.7%). Gross and Net Return from potato was ₹ 298237 and ₹ 155009/ha (Table 3).

Table 3: Economic benefits of potato cultivation in West bengal

Sl No.	Economic parameters	Average cost
1.	Variable cost of cultivation (₹/ha)	143228.1
2.	Average Yield (q/ha)	318.8
3.	Gross return (₹/ha)	298237.3
4.	Net return (₹/ha)	155009.2
5.	Benefit cost ratio	1.92
6.	Cost of production (₹/qt)	449.27

*Average selling price of potato @ ₹ 935.33/qt.

Assessment of improved potato varieties

On-farm demonstration in Shimla district of Himachal Pradesh

Overall, 20 demonstrations were laid out in different villages of Shimla district to assess the performance of potato variety Kufri Himalini and Kufri Girdhari at farmers' field. A total of 10 varietal demonstrations were laid out to show the farmers, the superiority of new potato variety Kufri Himalini over existing cultivar Kufri Jyoti.

Fig. 5. Recording observation in demonstration plots

The average yield of demonstrated variety Kufri Himalini was found to be 19.3 t/ha which was significantly higher than the control variety Kufri Jyoti which had an yield level of only 15.4 t/ha. Thus, there was 25.3% increase in yield was recorded in demonstration plots of K. Himalini. Similarly, Late blight resistant variety Kufri Girdhari was also demonstrated to farmers using all the recommended package of practices in demonstration plots. The incidence of late blight disease was negligible (0-2%) in Kufri Girdhari as compared to Kufri Jyoti, where 20-25% infestation of disease was recorded. As a result, the demonstration plots of late blight resistant variety Kufri Girdhari gave higher yield i.e 22.0 t/ha yield as compared to existing variety Kufri Jyoti (15.4 t/ha) thus Fig 5: Recording observation in Demonstration plots having an yield advantage of 42.8 per cent (Table 4).

Table 4: Details of tuber yield of improved varieties vis-à-vis local varieties at Shimla

Sl No.	Name of variety	No. of Demonstration	Yield (t/ha)	% increase over local check
1	Kufri Jyoti (Local check)	7	15.4	-
2	Kufri Himalini	10	19.3	25.3
3.	Kufri Girdhari	10	22.0	42.8

Front Line Demonstrations of improved potato varieties developed by CPRI in Bihar

During 2016-17, 19 demonstrations were laid out in different villages of Chakia and Tetaria blocks of East Champaran district, Bihar. Three improved varieties, namely Kufri Sindhuri, Kufri Khyati and Kufri Lalit were used to assess their performance in farmers' fields. Two local varieties, namely *Lerma* which is popular in Chakia block and C-40 in Tetaria block were used as local checks. Before planting, a training programme on scientific cultivation of potato was also organized involving scientists from different divisions for successful implementation of the project. Moreover, farmers' knowledge was been strengthened through distribution of related publications, fields' visit and other extension services. The agronomic practices were supervised at farmers' fields by scientists and technical staffs at regular intervals. A total of 290 quintals of seed potato was produced from the demonstration plots of 0.974 ha. Farmers were encouraged to keep the seeds in cold store for sale at higher prices or planting in the next season.

Table 5: Detail of variety, number of demonstration, area planted and total production

Sl. No	Variety	Demo No.	Area (ha)	Total production from demonstration plots (quintal)
1	Kufri Sindhuri	9	0.381	111
4	Kufri Khyati	6	0.297	81
5	Kufri Lalit	4	0.296	98
6	**Total**	**19**	**0.974**	**290**

A comparison of potato yield between improved varieties and local varieties is presented in Table 5 & 6. It can be observed that variety Kufri Lalit attained highest yield of 334.13 q/ha which was subsequently followed by Kufri Sindhuri (285.25 q/ha) and Kufri Khyati (278.53). Table also reflected that the average yield of improved varieties (299.30 q/ha) was 51.20 per cent higher than the average yield of local varieties, which was only 197.65 q/ha.

Table 6: Details of tuber yield of improved varieties vis-à-vis local varieties

Variety	No. of Demontrations	Average tuber y ield (q/ha)		% increase in yield over local control
		Improved varieties	Local varieties	
Kufri Sindhuri	9	285.25	192.44	48.22
Kufri Khyati	6	278.53	194.25	43.38
Kufri Lalit	4	334.13	206.25	62.00
Mean		299.30	197.65	**51.20**

Farmers field demonstrations on new variety Kufri Garima in Uttar Pradesh: In order to popularize the new potato varieties developed by institute and improved cultivation practices of potato, this year also, a total of 10 field demonstration on new variety namely Kufri Garima were conducted at 10 various locations of four districts namely Meerut, Hathrus, Bulandsher and Muzaffarnagar of Uttar Pradesh at farmers' field during the year 2016-17 at an area of 0.025 ha.

Fig. 6. Recording observation at Farmer's field in UP

Table 7: Details of tuber yield of improved variety and local varieties in Uttar Pradesh

Sl No.	Name of variety	No. of Demonstration	Yield (t/ha)	% increase over local check
1	Kufri Bahar (Local check)	10	29.9	-
2	Kufri Garima	10	25.8	15.9

Quality potato seeds of Variety Kufri Garima was distributed to each farmer and necessary observations were collected during raising of crops and at harvesting time. This year in Kufri Garima variety, 15.90 % of increased in yield was recorded over yield of popular variety in these areas i.e Kufri Bahar in ten trials when crop was harvested after 90-100 days (Table 7). Average tuber yield from ten demonstrations was 29.9 t/ha in Kufri Garima under recommended practices in comparison to Kufri Bahar, which was having yield level of 25.8 t/ha under farmers practices. Average number of tubers per plant was observed at 11.58 in variety Kufri Garima and 12.73 in Kufri Bahar in these trials.

Transfer of Technology

Technology transfer activities organized by ICAR-CPRI, Shimla

The Division of Social Sciences organized a wide range of extension activities related to potato production during the year 2016-17. These included organization of training programmes for farmers and extension functionaries from different public and private sector organizations, laying out Technology and varietal demonstrations on farmers' field, putting up exhibition stall of the institute in several Agril. exhibitions and live phone in programmes on Doordarshan for farmers and other stakeholders. These kind of technology transfer activities helped in creating awareness and increasing knowledge of farmers & 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, 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 Agri./Hort. officers of different State Development Deptt. were major highlights of Technology Transfer activities during this year.

A. **Organization of trainings:** A Total of Ten (10) training programmes for scientists, farmers, extension functionaries and other stakeholders were organized at CPRI Headquarters, Shimla. Different aspects of scientific method of seed, table and processing potato cultivation *i.e* seed preparation, planting, nutrient management, intercultural operations, irrigation, water management, plant protection, harvesting, processing, storage and marketing were covered during these trainings courses. A number of methods like lectures, practical classes and film shows on above mentioned topics were used to enhance the effectiveness. Besides this, field visits to different places like CPRS, Kufri-Fagu, Directorate of Mushroom Research, Solan, YSP University of Horticulture and Forestry, Nauni etc were also organized for trainees. The details of trainings conducted during 2016-17 is given in the table below:

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

Sl. No.	Title of the Training Course	Date and Duration	No. of Farmers / Officers	Sponsoring agency
1.	Chat show on Scientific Potato Cultivation	June 10, 2016 (One day)	13	CPRI, Shimla
2.	Training & Demonstration on use of Drip Irrigation in Potato Cultivation	July 22, 2016 (One day)	33	CPRI, Shimla
3.	Potato Cultivation	August 20, 2016 (One day)	15	CPRI, Shimla
4.	*Aloo ki unnat kheti*	September 12-14, 2016 (3 days)	11	Project Director, ATMA, Kheda, Gujarat
5.	*Gunvatta yukt Beej Aloo utpadan ki taknik*	October 17, 2016 (One day)	33	NABARD, Punjab
6.	*Aloo ki unnat kheti par Krishi Prashanmanch Programme*	October27, 2016 (One day)	35	CPRI, Shimla DD Kisan, New Delhi
7.	*Vaigyanik Aloo ki kheti evam mulya samvardhan*	November 15, 2016 (One day)	32	CPRI, Shimla
8.	Model training course on Diseases and pest management in potato	December 5-12, 2016 (8 days)	22	Directorate of Extension, Govt. of India
9.	*Aloo ki unnat kheti*	March 9, 2017 (One day)	70	CPRI, Shimla CIP, New Delhi
10.	*Aloo ki unnat kheti*	March18-20, 2017 (3 days)	32	Project Director, ATMA, Mehsana, Gujarat

B. **Kisan Mela/ *Gosthies:*** ICAR-CPRI, Shimla organized following Kisan mela and Gosthi for the benefit of potato growers.

- Organized a Kisan Gosthi (Scientist-Farmer meeting) on Scientific cultivation of potato and other tuber crops" during Horti Sangam on 10th July, 2016 at Hajipur, Bihar in which nearly 500 farmers benefitted.
- Organized Training cum Kisan Mela on "Potato Seed Production" at

CPRS, Jalandhar on 15th December, 2016. Nearly 200 farmers from different part of Punjab state participated and benefitted from the exhibition.

C. **Demonstrations:** A total of 20 on-farm demonstrations were laid out in different villages of Shimla district. Out of these, 10 demonstrations were laid out for Kufri Himalini and 10 on Kufri Girdhari. Observations were taken regularly during crop season. It was observed that both Kufri Girdhari and Kufri Himalini out yielded control variety Kufri Jyoti in terms of yield/ha. Yield of Kufri Girdhari was 22.0 t/ha while Kufri Himalini yielded 19.7 t/ha. The control variety Kufri Jyoti gave yield level of only 15.4 t/ha which was far less than demonstrated varieties.

D. **Live phone in programme on Shimla Doordarshan:** Expert scientists from different discipline of from CPRI Shimla participated in live phone in programmes. They answered the queries from potato growers on aspects like planting, water management, disease and pest management, storage practices etc. during Krishi Darshan. A list of these programmes is given in Table 2.

Table 2: Live phone in programme on Doordarshan, Shimla during 2016-17

Sl. No.	Date	Topic	Name of Experts
1.	April, 2016	Varietal requirement and planting of potato in higher hills of HP	Dr. Ashwani Sharma Dr. (*Ms.*) Dalamu
2.	May, 2016	Inter-cultural operations of potato in HP	Dr. Jagdev Sharma Dr. NK Pandey
3.	June, 2016	Harvesting and storage of potato in mid hills of HP	Dr. Brajesh Singh Dr. NK Pandey
4.	July, 2016	Potato disease and pests and their management	Dr. Vinay Sagar Dr. Shridhar J.
5.	August, 2016	Intercultural operations undertaken in potato crop before harvesting	Dr. Jagdev Sharma Dr. Tanuja Buckseth
6.	September, 2016	Potato harvesting and its safe storage	Dr. Pinky Raigond Dr. Dhiraj K. Singh
7.	October, 2016	Potato varieties and planting operations in plain areas of HP	Dr. Vinod Kumar Dr. Jagesh Tiwari

8.	November, 2016	Intercultural operations and weed management in potato	Dr. Jagdev Sharma Dr. Pooja Chaukhande
9.	December, 2016	Disease and pest management in potato	Dr. Ravinder Kumar Dr. Sridhar J.
10.	January, 2017	Potato varieties, plantin g and nutrient management in mid hills of HP	Dr. Vinod Kumar Dr. Rajesh Kumar Singh
11.	February, 2017	Intercultural operations, harvesting and storage of potato in lower hills of HP	Dr. Ashwani Sharma Dr. Brajesh Singh
12.	March, 2017	Potato disease an d pest management in mid hills of HP	Dr. Sanjeev Sharma Dr. Sridhar J.

E. **Organization/Participation in agricultural fair/exhibitions:** ICAR-CPRI, Shimla participated in following exhibitions and institute stall was put to showcase varieties and production technologies of potato. A large No. of farmers visited CPRI Stall in these exhibition. List of these exhibitions is given below:

- Participated and put up stall in National Mushroom Mela at Directorate of Mushroom Research, Chambaghat, Solan on 10th September, 2016.
- Participated and put up an exhibition stall of CPRI in International Agro Tech Exhibition 2016 organized by CII during 19-22 Nov., 2016 at Chandigarh.

Activities of Agriculture Technology Information Centre (ATIC)

Sale and distribution of CPRI technical and extension bulletins: A total of 615 technical and extension bulletins were sold through ATIC. Moreover, nearly 1000 publications like CPRI profile, Crop Calendar and leaflets related to potato technologies were distributed free of cost to the institute visitors and during different exhibitions. A total of 22 CDs of PPM (Potato Pest Manager) and one CD of CAASPS (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 ₹ 33190/.

Dissemination of knowledge to visitors: A total of 2230 person visited in the institute during the period under report. The visitors included 1587 B.Sc./M.Sc./Ph.D students of various universities of different states, 460 farmers from

different states of the country and 183 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 to the visitors. A total revenue of Rs 15870/- was generated through visitors.

Extension activities at CPRI Campus, Modipuram

A. Trainings

- A one day training on Potato processing for identified women and youth of village Salakheri district Muzarfarnar on 2nd May, 2016 at CPRIC, Modipuram was organized
- A two days training on *"Maidani kshetron me beej aloo utpadan evam vipanan"* for 35 District and block levels agriculture officers and technical assistants sponsored by SAMETI, Lucknow (UP).
- One day Interface meeting and training on Promotion of processing varieties of potato for U.P. under UPKAR Project for 50 Farmers and Entrepreneurs and Cold store owners under the sponsored project UP Council of Agriculture Research, Lucknow.
- One day training on Improved Techniques of Table and Potato Seed Production for U.P. for 50 farmers of adopted villages from district Hapur (U.P.), under "Mera Gaon Mera Gaurav" programme.
- One day training on Improved Techniques of Potato Production and Recent advances in agriculture for 100 farmers under *"Mera Gaon Mera Gaurav"* programme.

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

- CPRIC, Modipuram participated in several exhibitions and showcased the potato technologies developed by the institute. The details are as under:
- Farm Field School in Nawla village of Muzafarnagar district on 30th April, 2016 organised by ICAR-IIFSR, Modipuram.

- Farm Field School in Meerapur Dalpat village of Muzafarnagar district on 6th May, 2016 organised by ICAR-IIFSR, Modipuram.
- Krishi Unnati Mela-2016 at Pt. Deen Dayal Upadhaya Dham Farah Mathura from 26-29 September 2016 organised by ICAR and Ministry of Agriculture and Farmers Welfare, GOI.
- Krishi Pradarshni at Pandara Park, New Delhi on 15-16 October, 2016 organised by I.A.S. Wives Association New Delhi.
- All India Farmers' Fair and Agro-Industrial Exhibition from 8-10 October, 2016 organised by SVBP University of Agri. & Technology, Meerut. The CPRI stall was awarded **third prize** in ICAR group.
- Krishi Pardarshini and Kisan Gosthi at KVK, Hastinapur, Meerut (UP) on 23rd December, 2016 organised by KVK Hastinapur, Meerut (UP).
- Exhibition on the occasion of International Agronomy Congress – 2017 at ICAR- IARI Campus, New Delhi from 21-23 January, 2017 organised by Indian Society of Agronomy, New Delhi.
- Northern Regional Agriculture Fair – 2017 at Muzafarnagar (U.P.) from 24-26 February, 2017 organised by ICAR-IIFSR, Modipuram.
- Pantnagar Kisan Mela and Agro-Industrial Exhibition from 4-7 March, 2017 organised by GB Pant University of Agri. & Technology, Pantnagar.
- Krishi Unnati Mela-2017 at Indian Agricultural Research Institute, Pusa New Delhi from 15-17 March 2017 organised by ICAR- IARI New Delhi.

C. **The World Soil Health Day** was celebrated on 5th December, 2016 at CPRIC, Modipuram. An interactive session was organized on this occasion in which scientist, technical officers and research fellows were acquainted with the basics of soil components and importance of soil health for agriculture by the joint Director, Dr Manoj Kumar. He also stressed upon increasing the organic matter contents in soils of Modipuram campus. Dr Anuj Bhatnagar talked about the ill effects of erratic use of insecticides and pesticides on soil health.

D. **Visitors and phones attended:** A total of 330 farmers from various districts of UP, Haryana, Rajasthan and Telangana and 248 students and trainees visited Central Potato Research Institute Campus, Modipuram to know thw potato farming activities at the campus. Along with 150 quarries of potato growers form various districts of UP, MP, Delhi, Rajasthan, Punjab, Uttrakhand, Haryana and Chhattisgarh states were answered through phone.

E. **Aloo Krishi Pathshala on "Problems and remedies of potato cultivation" at Akashwani, New Delhi**

A series of Live phone in programme on "Problems and remedies of potato cultivation" was organized by CPRIC, Modipuram in collaboration with Akashwani, New Delhi during 28th October, 2016 to 23rd January, 2017. In this programme, a total of 15 Radio Talks were delivered by the scientists of ICAR-CPRIC, Moddipuram including Director, CPRI on various aspects of scientific potato cultivation. In addition, live phone in programme on Doordarshan, New Delhi was also attended by scientists from CPRI RS, Modipuram during 2016-17.

Extension activities at CPRS, Patna

A. **Training programmes organized during 2016-17**

- A one day training on Scientific Cultivation of Kharif Crops for farmers was organised at Vaishali. A total of 100 farmers attended this training.
- A two days training on Scientific Cultivation and Processing of Potatoes for 64 NGO members and students was organised.

B. **Demonstrations:** 25 FLDs of improved varieties (Kufri Lalit, Kufri Sindhuri & Kufri Khyati) were laid out in East Champaran and Vaishali district of Bihar.

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

- Krishi Unnati Manch on 28-30 May, 2016 at ICAR-RCER, Patna.
- Horti Sangam-2016 on 9-10 July, 2016 at Hajipur, Bihar.
- *Purvanchal Krishi Pradarshani evam Goshthi* on 21-22 Oct, 2016 at Mahant Digvijay Nath Inter College Campus,


Chawkmati, Gorakhpur, UP

- Kisan Mela during 3-4 Dec, 2016 at RPCAU, Samastipur, Bihar.
- National Farmers Fair cum Vegetable Showcasing on 27 Jan 2017 at ICAR-IIVR, Varanasi (UP)
- Bihar Kisan Mela on 3-5 March, 2017 at Bihar Agriculture University, Sabour (Bihar). ICAR-Central Potato Research Station (CPRS) Patna bagged second best stall award.
- Potato Expo 2017 on 09-10 March, 2017 at Milan Ground, Kolkata.
- Bihar Divas 2017 on 22-24 March, 2017 at Gandhi Maidan, Patna.

D. Others extension activities

- The scientists from the station participated in 11 live phone in programmes telecasted from Patna Doordarshan as expert and answer the queries of the farmers of the region.
- A total of 500 farmers and 60 technocrats from various districts of Bihar and other states of India visited the station and were apprised about potato technologies by staff of CPRS, Patna.
- Hosted ETV programme "Annadata Sammah" and Improved Agricultural Sambad on 24th December, 2016 at CPRS Patna.

Extension activities at CPRS, Gwalior

A. Training

- A one day training on Soil Health Awareness for farmers was organised on 5th Dec., 2016 at the centre. A total of 34 farmers attended this training.
- A one day training on Potato Cultivation for 30 employees of NABARD was organised on 17-02-2017 in the centre.

B. Visitors attended: A total 535 farmers from various parts of Madhya Pradesh visited the station and apprised about scientific methods of potato cultivation and post-harvest activities undertaken at the centre.

Extension activities at CPRS, Jalandhar

A. Training programmes

- Two day training on "Fabrication, operation and maintenance of aeroponic systems for potato minituber production", during 9-10 Aug, 2016 at CPRS Jalandhar.
- Three day training programme on "Production of mini tubes and operation & maintenance of aeroponic system" during 4-7 Nov, 2016 at CPRS, Jalandhar.

B. Demonstration: On third week of every month a demonstration on Drip irrigation system to local farmers during potato season with the theme 'Per drop more crop' was undertaken.

C. Visitors attended: A total 653 students, 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. Demonstrations

- Eight on farm demonstration were laid out in East Khasi Hills district of Meghalaya during 2016-17. New potato variety Kufri Himalini and Kufri Girdhari were demonstrated to farmers in four villages-Mawklot, Myrkhan, Nongpiur and Mylliem.

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

- Participated and put stall in Technology Week during 14-16 December, 2016 at KVK, East Khasi Hills district, 5th Mile, Upper Shillong.
- Participated and put stall in State Agriculture Dept., 5th mile, Upper Shillong, Meghalaya on 5th December to celebrate World Soil Day.
- Participated and put stall in exhibition cum-workshop on "Indigenous farming and traditional foods of North East" from 25-27 February, 2017 at ICAR Research Complex for NEH Region, Umiam, Meghalaya.

C. Visitors attended: A total of 250 visitors visited the station during the period under report, which included, farmers and state agriculture/horticulture officer from across north eastern states. They were exposed to current advancements in varietal and technological aspects of Potato R&D.

Extension activities at CPRS, Ooty

A. Training programmes

- A Three days training on "Advances in Potato Cultivation" during 20-22 Feb., 2017 was organised at the station which was attended by 30 farmers.

B. Demonstration: Two Demonstrations on seed treatment against PTM and different farm mechanization in potato cultivation was laid at the station.

C. Exhibitions: The centre participated in following exhibitions and showcased its technologies.

- Exhibited stall during "Flower show" at Botanical garden conducted by Horticulture Department, Tamil Nadu
- Exhibited stall during NCTTC-2016 National Exhibition on Tubers crops at ICAR-CTCRI, Thiruvananthapuram, Kerala.
- Exhibited stall during foundation day of ICAR-IISWRC, Theetukal, Ooty.
- Exhibited stall during World Soil day organized by ICAR-IISWRC, Theetukal, Ooty.
- Exhibited a stall at Radio Astronomy Centre, TIFR, Muthorai, Ooty during National science day.

D. Visitors attended: A total of 536 students from different states, 130 farmers and 20 foreign delegates from neighbouring countries visited the station during the period. and were acquainted with recent potato technologies.

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 68 thousands documents and has attained the position of most sought-after library on potato R & D in India. Since its inception this library has acted as repository and clearinghouse of potato literature and information. It continually provided scientific and technical information supports and services towards attainment of research mission of the institute. Efforts were made for strengthening and developing the information resources and services through undertaking various activities given here below:

Resource Development

At the headquarter (Shimla), a total of 842 documents were purchased, procured and added to library resources. The total collection at Shimla stand at 39650 documents comprised of 16182 books, 15780 back volume of journals, 2700 serials, 2242 annual reports, 583 theses, 251 standards, 51 maps/atlases, 1663 reprints and 198 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 28409 books; journals back volumes and other documents i.e. AR/Reprints and Bulletins etc as per the details below (Table-1).

Periodicals and Serials Management

Forty three serials title i.e. advances, annual reviews, reference annuals, yearbooks and statistical data publications etc. were purchased. A total of 172 current journals comprising of 37 foreign and 135 Indian have been subscribed at Shimla. Out of which 19 foreign and 121 Indian journals were subscribed on payment basis and rest 32 on exchange or gratis. In all 984 issues of such journals were received, marked and kept in

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	4594	5823	2823	13240	10
2	CPRS, Jalandhar	3244	1591	1239	6074	-
3	CPRS, Patna	2060	1280	-	3340	-
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	14283	9278	4848	28409	49

**figure shown for CPRS Gwalior, Ooty and Shilong is for the year 2015-16* library for use. Besides, 24 titles of different journals were subscribed at CPRS libraries. 172 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, 37 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 1431 documents were circulated (borrowed and returned) for home studies and 8545 readers consulted 10375 documents within the library. Besides, 17 outside scientists and research scholars of various research organizations consulted the library resources. 5 new members were enrolled and 17 old members withdrew their library membership due to their transfer or retirement. At present 139 readers are active members of library including RAs/SRAs. Library received 8923 reference queries from the users of the library and responded to them satisfactorily. Besides, 476 job requests were received for 1,41,619 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

984 issues of journals (694 issues of national and 290 issues of international journals) were scanned for potato literature and 62 potato articles were found and recorded. Approximately, 837 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 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. 3,69,400.00 which includes the amount charged on account of rendering CDROM searching & photocopying (Rs. 4600.00), IGNOU computer practical (Rs. 17,200.00) and library discount (Rs.3,47,600.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 39,86,526.00 was spent (under Plan Rs. 35,86,526.00 and Non-Plan Rs. 4,00,000.00) on purchase of library resources like books (Rs.6,24,385.00), and subscription of journals (Rs.33,62,141.00) 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 24th July– 13th Aug, 2016 for 2 MLIS and 6 BLIS students of IGNOU Study Center, Shimla.

Institute Research Council Meeting

The Institute Research Committee Meeting (IRC), 2016 was held at ICAR-CPRI, Shimla during 7th to 9th September, 2016 which was attended by 63 scientists from the Headquarters and Stations. The basic objective of this meeting was to review the achievements of 2015-16 and finalize the work plan for 2016-17 of different research programmes.

1. Presently the wild potato accessions that are inhabitant of Chile region are being screened for identifying the sources of ToLCNDV resistance. In these accessions the resistance needs to be earmarked not only on the basis of disease symptom but also on virus load.
2. As a long term strategy, efforts should be made to conserve in-vitro all germplasm lines including tuberosum, andigena and elite wild clones.
3. The traits for which the germplasm is being screened needs to be prioritized. If possible, the concerned associate should present the screening results in the IRC.
4. Database of germplasm evaluations needs to be catalogued/ compiled and inventory should be published on priority.
5. Parental lines including advance breeding lines for heat stress tolerance should be screened at ICAR - CTCRI, Trivandrum.
6. Early maturing advanced hybrids viz., J8/85 and J8/91; medium maturing hybrid, MS/10-1529; heat tolerant hybrid, HT/07-1329; processing hybrid, MP/09-28; hybrid with combined resistance to LB and PCN viz., OS/07-14 were approved for introduction into AICRP (P) multi-location trials. Besides, red skin advanced hybrids, PS/07-07 and PS/09-9 and nutrient and water stress tolerant hybrids viz., J/93-38 and J/92-167 were also approved for introduction into AICRP (P).
7. The weightage score card for selection of advanced hybrids before introduction into AICRP (P) needs to be revisited with due weightage to consumer preference. The revised score card needs to be put on the ICAR - CPRI web page.
8. Besides other traits, the data needs to be recorded on 3 important traits viz., net yield, thermal time requirement and senescence period in all breeding projects.
9. Parental lines of breeding particularly in red skinned hybrids needs to be revisited and in each programme about 5-10 lines should be changed every year. Efforts should be made to select hybrids with deep red skin and shallow eyes.
10. In the breeding program for processing varieties texture, crispiness and other processing characters should be tested and data should be presented before introduction into AICRP.
11. Genomewide methylation in the tissue culture material of Kufri Bahar may be checked in the tubers from different sources.
12. Facility should be made to store the in-vitro transgenic material under long term conservation. A proposal in this regard may be floated.
13. Potato biotechnologists should prioritize at least 5 traits which needs molecular

intervention and are difficult to resolve through conventional approaches. A meeting in this regard need to be convened.

14. The objectives of this programme were revisited and the activities were refined/modified as given below along with the responsible associate(s):
    - Somatic hybridization in potato improvement; and molecular approaches in improving nitrogen use efficiency (NUE) in potato - Dr. Jagesh Kumar Tiwari.
    - Molecular intervention in potato tuberization; transgenics for reduced cold induced sweetening in potato; and metagenomics study - Dr. VU Patil.
    - Molecular approaches for enhancing late blight resistance in potato- Dr. Sundaresha S.
    - Mapping studies for important traits (micro/macro nutrients, late blight etc.)- Drs. Vinay Bharadwaj and Hemant Kardile.
    - Molecular approaches for abiotic stress (heat and drought) tolerance in potato - Dr. Som Dutt.
15. Activities on bacterial wilt and PCN should be reflected in the plant protection division.
16. Phytotron facility available at IARI, New Delhi can be explored for conducting experiments under raised temperature facilities.
17. Rubisco kinetics study should be carried out for potato cultivar raised under elevated CO_2.
18. One small portable aeroponic unit for rapid multiplication of Breeders' seed / Transgenic to be designed by Er. Sukhwinder, which will be fabricated at CPRI, Shimla.
19. For residue analysis studies, NRC-grapes should be consulted for laboratory facilities.
20. Good agricultural practice document shall be prepared bilingual.
21. A protocol based on organic farming to be framed by next year.
22. Possibility shall be explored to work out the Carbon foot print studies in all cropping system experiments.
23. A bulletin should be prepared and published on the basis of work carried so far in Long term Experiment.
24. Discuss about the ongoing long term experiments at CPRS, Modipuram with Project Co-cordinator, AICRP on Long term fertilizer Experiments, ICAR-IISS, Bhopal.
25. It is suggested to include one treatment of Soil test based fertilizer application in fertility experiment conducted in Ooty.
26. Late blight samples from Ooty/Hasan research fields shall be sent to CPRI, Shimla.
27. Prototype design of combine harvester shall be protected. A letter/email shall be sent to Er. Manjeet Singh for mentioning clear-cut terms for filing patent. If he agrees to conditions of CPRI for Patent filing, he may be included as one of the author. The deadline for which is 15 October, 2016.
28. High density planting should be attempted in Drip irrigation studies.
29. J.93-58 and J.92-167, two hybrids were

identified under this research activity which are proposed for AICRP introduction.

30. Pure cultures of all potato viruses and their strain prevalent in India should be maintained for antibody production.

31. Studies on comparative analysis of isolates of GBNV from Kota and Shimla hills should be undertaken.

32. LAMP based diagnostics should be developed for detection of PLRV.

33. The efficacy of Phosphorus acid @ 0.2% should be tested on susceptible and moderately resistant cultivars of potato against late blight.

34. The efficacy of Flonicamid@4g/10 litre should be tested against aphid and white fly on a large area (at least 1 acre area) at ICAR-CPRIC, Modipuram before introduction into AICRP.

35. The efficacy of Cassava leaf extract based formulation (Menma) developed by ICAR-CTCRI should be tested against white fly at ICAR-CPRIC, Modipuram.

36. Results of mineral oil can be included in IPM module against sucking pests after three years of trials.

37. The threshold limit of white fly should be re-visited and clear cut recommendation should be given.

38. Further, it was decided that stations should purchase sufficient number of pesticides spray kits to the workers.

39. The MSDS for salicylic acid and salicylaldehyde may be consulted for its negative effect, if any.

40. The work on metabolic pathway of flavouring compounds should be carried out further.

41. In-vitro protein digestibility of pulses should also be carried out along with potatoes for comparison.

42. For developing bulletins on nutritional profiling of potato, the analysis should be carried out for at least two years and the data should be statistically analysed and presented. All the concerned divisions should be consulted for identifying parameters and analysis work.

43. The cropping scheme should be prepared keeping in view the demand of breeder seed and the area should be manipulated from Stage I accordingly.

44. Reporting of seed production activities should be uniform at all the stations as per the performa to be developed and circulated by the HQ.

45. Consumer preferences for potato varieties and farmers' problem at field level should be studied by survey method. The same may be passed on to concerned scientists and breeders for development of varieties and technologies.

46. Dr PK Joshi, Regional Director, IFPRI South Asia, New Delhi may be consulted by Head, Social Sciences for impact assessment of selected potato technologies in India.

47. To increase the awareness of potato growers about new potato varieties, Front Line Demonstrations of selected varieties should be laid out in potential areas with the help of concerned breeder.

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Institute Activities 2016-17

Workshop on potato varieties at CPRIC, Modipuram

A workshop on Development and adoption of potato varieties in India was organized at CPRIC, Modipuram in collaboration with International Potato Centre (CIP) on 20th May, 2016. In this workshop, scientists of International Potato

Centre and ICAR-CPRI alongwith progressive potato growers and processors delibrated on relevant issues related to the workshop. Scientists of CIP informed the participants regarding the popularization of Indian Potato Varieties and also reasoned the non-adoption of other varieties. The outcome of the workshop was that varieties popular in Uttar Pradesh have been primarily developed by ICAR-CPRI.

Research Advisory Committee meeting -2016

The twenty third meeting of the Research Advisory Committee (RAC) was held at the ICAR-Central Potato Research Institute, Shimla during 29-30 November, 2016 under the chairmanship of Dr. PL Gautam, Vice Chancellor,

Career Point University Hamirpur. RAC members Dr SK Pandey, Ex. Director (CPRI), Dr. M.S. Palaniswami, Former Project Coordinator, AICRP on Tuber Crops, Dr. PK Mohapatra, Ex. Dean, OUAT, Bhubaneswar, Dr JP Sharma, Joint Director (Extension), IARI, New Delhi and other attended the meeting. Dr SK Chakrabarti, Director, ICAR-CPRI, Shimla, Research Programme leaders and all scientists of Headquarter also participated in this meeting. This was the 1st year for new RAC. Director, CPRI in his presentation briefed the Chairman and members of RAC about the research and developmental activities being carried out by the institute. The Chairman, Dr. PL Gautam reviewed the progress of 10 Research programmes being undertaken in the institute and guided all the programme leaders for the work plan of for year 2017-18. He also emphasized that the institute must study the impact of its existing varieties and technology in farmers field. Several important decisions were taken during the RAC for improvement of ongoing research programmes. The meeting ended with a formal vote of thanks by Dr. VK Dua, Member-Secretary, RAC.

ICAR-CPRI celebrated its 68th Foundation Day

ICAR-CPRI, Shimla celebrated its 68th Foundation Day on 20th August, 2016. Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR, graced the ocian occasion as the Chief Guest. In his foundation day lecture he emphasized on "Farmer based research to increase the production and productivity and India must be the torch bearer in potato development for the world and congratulated the Director and staff of CPRI, Shimla. Before this, Dr Mohapatra visited all the laboratories of the institute and interacted with the scientists. He was briefed about the research work being conducted in different labs and sections viz. Cell Biology, AKMU, Library, Post Harvest Technology Lab, Diagnostic lab, Tissue Culture facility, Genomics lab etc.

Dr. Mohapatra was accompanied by Dr. A.K. Singh, DDG (Extn. & Hort.) ICAR, Dr. S.K. Malhotra, Agriculture & Horticulture Commissioner, GOI & Dr. T. Janakiram ADG (Hort. Sci.) ICAR, New Delhi as Guests of Honour along with Sh. Sanjay Chauhan, Mayor, Municipal Corporation, Shimla as special guest. Dr. AK Singh, in his address highlighted the research work at CPRI and suggested that the Institute must work hard to bring out the varieties and storage technology improvement. He also advised that KVKs may be rope in for quality seed production. Two entrepreneurs from Punjab shared their experiences of aeroponic seed production technology and thanked CPRI for development of these techniques.

On this occasion, DG, ICAR gave the best worker award of the institute to selected persons under scientific, administrative, technical as well as supporting category. Smart Potato Portal was also launched by DG, ICAR for providing all decision support system developed in potato under one umbrella. Two publications on potato processing were also released by the dignitaries. Nearly 250 people attended this function.

Group meeting of AICRP (Potato) organized at CPRI, Shimla

The 34th Group Meeting of AICRP (Potato) was organized at ICAR-CPRI, Shimla during August 20-22, 2016. The meeting was attended by delegates from Indian Council of Agricultural Research, Central Potato Research Institute, State Agriculture Universities and representatives from Industries. Dr. Mohapatra, Secretary, DARE &DG, ICAR graced this occasion as the Chief Guest. Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, appreciated the significant achievements of CPRI and AICRP (Potato) for implementing need based research

which has been reflected in the country's potato production in the ascending order throughout. He emphasized on the need of market driven varietal development to meet the consumers demand as it varies from region to region not only in terms of yield but also on tuber shape, size and quality basis. He also insisted that AICRP (Potato) centres should be utilized for climate change studies by formulating a strong research programs. He appreciated the systematic and concise preparation of annual report using multi location data and bringing out technical bulletins. Dr. Mohapatra was accompanied by Dr AK Singh, DDG (Extn. & Hort.) ICAR, Dr SK Malhotra, Agriculture & Horticulture Commissioner GOI & Dr T Janakiram ADG (Hort. Sci.) ICAR, New Delhi as Guests of Honour along with Sh. Sanjay Chauhan, Mayor, Municipal Corporation, Shimla as special guest.

During the workshop the action taken on the recommendations of 33rd Group Meeting were reviewed in the presence of Dr T Janakiram ADG (Hort. Sci.), ICAR, New Delhi. The highlight of this group meeting was the release of the "Smart Potato Portal" and recommendations in the area of crop production and plant protection.

Workshop on IPR Literacy: Patent Drafting & Filing

In the present scenario, collaboration among different scientific and academic institutions is becoming a major impetus in the research arena to promote the creativity and innovation.

Recently ICAR-CPRI, Shimla has signed a memorandum of understanding (MoU) with Himachal Pradesh University on dated August 27th, 2016 to facilitate the collaborative research efforts among both the organization. As a result of which both the organizations have jointly organized a Work shop entitled "IPR Literacy: Patent Drafting & Filing" on October 2-3rd, 2016 at Department of Life Sciences, Himachal Pradesh Shimla. Experts from CPRI, Mr. Krishan Gopal, Research Associate, Institute Technology Management Unit (ITMU), and Mr. Hemant Kardile, Scientist, Crop Improvement, ICAR-CPRI, Shimla along with Dr. Hemant Sood, Assistant Professor, JUIT, Solan, delivered a talk on IPR instruments and Patent drafting & filing. The interactive workshop was the first

experiment of its kind as it forged new paths of co–operation and research between the two organizations with aim to address the current burning IPR related issues in India and was built encompassing different aspects of IPR including detailed procedure behind drafting and filing the patent application in India. The faculty, researcher and students of the HP University and Dr. YS Parmar UHF, Nauni attended the workshop and have shown great enthusiasm in knowing about the patent drafting and filing.

World Soil Health Day celebrated at CPRIC, Modipuram

The World Soil Health Day was celebrated on 5th December, 2016 at CPRIC, Modipuram. An interactive session was organized on this occasion in which scientist, technical officers and research fellows were acquainted with the basics of soil components and importance of soil health for agriculture by the joint Director, Dr Manoj Kumar. He also stressed upon increasing the organic matter contents in soils of Modipuram campus. Dr Anuj Bhatnagar talked about the ill effects of erratic use of insecticides and pesticides on soil health.

Institute Research Committee-2016

The Institute Research Committee Meeting (IRC), 2016 was held at ICAR-CPRI, Shimla during 7th to 9th September, 2016 which was attended by 63 scientists from the Headquarters and Stations. The basic objective of this meeting was to review the achievements of 2015-16 and finalize the work plan for 2016-17 of different research programmes. Dr SK Chakrabarti, Director, CPRI and Chairman, IRC in his opening remarks welcomed all participants and lauded the efforts of all the scientist for the progress made during last year. He added that CPRI is among the top institutes of Horticultural Division of ICAR. He

also expressed concern over very less international exposure of CPRI Scientists in Seminar , conferences etc.

Hindi Chetna Maas and Hindi Diwas celebration at CPRI and its centres

The institute celebrated the Hindi Pakhwada from 14 September to 13 October, 2016. Several competitions related to essay writing, Hindi word knowledge, Hindi typing, quiz etc were held in which many staff of CPRI participated. Hindi pakhwada was also celebrated at CPRI Stations viz. Modipuram, Jalandhar, Patna, Gwalior, Ooty and Shillong.

At CPRI, Shimla, Hindi Diwas was celebrated on 14 September, 2016. Dr. Mast Ram Sharma, Secretary, Himachal Pradesh Sanskrit Academy (Higher Education), Shimla graced the occasion as Chief Guest of the function. Dr. S.K

Chakrabarti welcomed him and felicitated him. In the beginning, Dr. Rakesh Mani Sharma, Incharge Rajbhasha of the institute addressed the gathering and informed the house that the institute has progressed in use of Hindi language and currently 72% of the work in institute is being done in Hindi. Dr. S.K. Chakrabarti in his address, emphasized on use of Hindi during day to day work by the staff. Chief Guest, Dr Mast Ram Sharma talked about the origin of Hindi from Sanskrit language and Raj bhasha policy of Govt. of India.

Swachh Bharat Abhiyan at CPRI, Shimla and its adopted villages

During the National Cleanliness Drive as a part of Swachh Bharat Abhiyan, the cleaning work was done in the Institute campus and nearby public places on 2nd October, 2016. Swacchta Abhiyan was also organized in adopted villages of Cheog Panchayat of Shimla district by CPRI, Shimla on 27 October, 2016 under *Mera Goan Mera Gaurav* program. Scientific and Technical staff of institute cleaned the market area, state ayurvedic hospital and primary school and locality of the panchayat. The function was well supported by the Pradhan of Cheog Panchayat Mrs. Uma Chandel, students and local villagers. 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 "Disease and Pest Management in Potato"during 5-12 December, 2016. The major objectives of this training was to enhance the knowledge and skills of trainees regarding latest plant protection technologies adopted to mange pest and diseases in potato. A total of 22 Agriculture/Horticulture officers from different State Development Deptt. working in the field of potato R&D participated in this programme. Different training methods viz. lecture-cum-discussion, practical sessions, skill demonstration and field visits were used during MTC. Emphasis was given on proper diagnosis of potato disease and pest by various lab methods and their proper management. Field visits to CPRS farm at Kufri-Fagu, and DMR, Solan were also organized during the course.

Professor Dr. R. B. Singh visited CPRIC, Modipuram (Meerut)

Professor R.B. Singh former Vice Chancellor Central Agricultural University, Imphal and former President NAAS, New Delhi visited CPRIC, Modipuram, on 17 February, 2017. Joint Director, Dr. Manoj Kumar welcome him and briefed about the recent Research work under taken in Potato by the campus. He also visited tissue culture lab and aeroponic unit and lauded the effort of scientists in potato research.

Agriculture Education Day celebrated at ICAR-CPRIC, Modipuram

Agriculture Education Day was celebrated at CPRIC Modipuram on December 03, 2016. On this occasion 49 students from various schools participated in the function and were acquainted on importance and employment opportunity in agriculture sector. An essay competition on “Importance of Agriculture Education” was also organized for the students among this function. Prizes were distributed to the students. The whole function was chaired by Dr. Manoj Kumar. Professor Gaya Prasad, Hon'ble Vice Chancellor SVP University of Agriculture and Technology Meerut, Chief Guest of the function stressed upon commercialization of Agriculture for farmers profitability and motivated students to take interest in agriculture education.

ICAR-CPRI Shimla participated in 5th India International Potato Expo 2017 at Milan Ground, Kolkata

ICAR-Central Potato Research Institute, Shimla participated in 5th India International Potato Expo 2017 at Milan Ground, Kolkata from 09-10 March, 2017. The Expo was jointly organized by the Indian Chamber of Commerce with the active support of Ministry of Agriculture, Government of India, Ministry of Commerce & Industry, Government of India & Government of West Bengal. The event consisted of two-day Exhibition & Technical Conference along with Buyer Seller Meet and Potato Growers Meet. The aim of the event was to provide best advantages to all potatoes producers, equipment manufactures and other stakeholders in potato sector.

ICAR-Central Potato Research Station (CPRS) Patna participated and put up an exhibition stall during the event. Various technologies of the institute like improved varieties, integrated disease & pest management, integrated nutrient management, post-harvest technologies, aeroponic system, True Potato Seeds (TPS), etc. were displayed through posters, live samples, virus testing kits and literature, etc. A large number of farmers, scientists, policy makers, manufactures, companies, NGO members, women entrepreneurs and other stakeholders in agriculture and allied activities visited the stall and they were made aware about various technologies of the institute.

Meeting on Doubling Farmers Income in HP organized at ICAR-CPRI, Shimla

The Coordination Committee Meeting on **"Doubling Farmer's Income in Himachal Pradesh"** was organized at ICAR-CPRI, Shimla on 17th March, 2017. The meeting was chaired by Dr. H.C. Sharma, Hon'ble VC, YS Parmar University of Horticulture & Forestry, Nauni and convened by S.K Chakrabarti, Director, CPRI Shimla. It was also attended by Dr. Ashok Sarial, VC, CSK HPKV, Palampur, Representative of different line departments like Agri / Horti / Fisheries/Animal Husbandry & other delegates and all heads of Divisions of CPRI Shimla. Discussions were held on How to double income of farmers by 2022. Interventions like Crop diversification, provisioning of irrigation, introduction of new varieties & technologies etc were discussed in length by the Chairman and members of the Committee. The committee has been given responsibility to prepare road map for Doubling Farmer's Income in Himachal Pradesh by taking into consideration views of all the stake holders involved in agriculture development in this state.

National Productivity week 2017 celebrated at ICAR-CPRI, Shimla

Under the National Productivity Council, Ministry of Commerce and Industries, Govt. of India; National Productivity week – 2017 has been celebrated across the country during 12-18 February, 2017 through organization of various training programmes, awareness camp, workshops, seminars etc. On the theme of National Productivity week celebration i.e. **"From Waste to profit through Reduce, Recycle and Reuse"**, ICAR-CPRI, Shimla organized a training cum awareness programme on 17th February, 2017. All categories of staff from ICAR-CPRI, Shimla participated in this event. At the outset, Director, ICAR-CPRI, Shimla welcome two guest speakers Dr. DP Singh, Project Manager, Municipal Corporation, Shimla and Dr. Ravi Sharma Sr. Scientific Assistant, State Council for Science Technology & Environment, Govt. of HP. In his welcome address Dr. Chakrabarti talked about three Rs i.e. Reduce, Recycle & Reuse for waste management & motivated employees of the institute to keep the premises clean by proper adoption of waste management practices. Guest speakers Dr. DP Singh & Dr. Ravi Sharma talked about Plastic & Solid waste management in Himachal Pradesh. They highlighted the achievements of State Govt. through programmes like"Polythene Hatao, ParyawaranBachao". Concepts of disposal, Recycle & Reuse of municipal waste was also talked about by the speakers. About 150 staff of ICAR-CPRI, Shimla participated and benefitted from this event.

Union Minister of Agriculture and Farmers Welfare visited CPRI stall at Agro Tech Exhibition, 2016

ICAR-CPRI, Shimla participated in 12th Agro Tech. 2016, India's Premier Biennial Agro Technology& Business Fair, organized by Confederation of Indian Industry (CII) at Chandigarh during 19-22 November, 2016. Inauguration of Agro tech exhibition was done by the Chief Guest Hon'ble President of India, Sh. Pranab Mukherjee and Guest of Honuor, President of Israel, Mr. Reuven Rivlin on 20th November, 2016.

CPRI put up an exhibition stall to showcase institute production technologies to visitors. Live demonstration on preparation of French Fries was also shown to visitors. Hon'ble Union Minister of Agriculture and Farmer's Welfare, Govt. of India, Sh. Radha Mohan Singh also visited the institute stall. Several publications were sold and extension bulletins, folders and leaflets were distributed free of cost to the farmers and others stakeholders. More than 5,000 farmers & other stakeholders associated with potato R&D benefitted from this exhibition. Many National and International delegates also visited CPRI stall during Agro tech 2016.

Sh Chhabilendra Roul, Additional Secretary (DARE) & Secretary (ICAR) and Dr. A.K. Singh, DDG (Agri. Ext. & Hort. Sc.) visited CPRI Campus, Modipuram

Additional Secretary (DARE) & Secretary (ICAR) Sh Chhabilendra Roul and Dr AK Singh, DDG (Agricultural Extension and Horticultural Sciences) visited CPRI Campus, Modipuram on 20 December, 2016. Dr. SK Chakrabarti, Director, CPRI, Shimla welcomed the hounarable guests and gave details of research activities being conducted at the Campus. During their visit guests inspected Potato Breeder Seed Production Unit at Machhari. Director and Joint Director briefed to the guests about various stages of potato breeder seed production, the guests showed their keen interest in the process and they appreciated the contribution of the campus in the meeting demand of potato seed to the country. Thereafter, Secretary, ICAR and DDG visited Tissue Culture Lab, Farmers training Hall and potato processing unit. Secretary, ICAR and DDG took a meeting with Director, CPRI and Staff members of the Campus, Directors and Scientists of IIFSR, Meerut and CIRC, Meerut. Secretary, ICAR discussed in detail about the policies of ICAR for bringing efficiency, compatibility and transparency in the official activities by implementing electronic methods. He stressed for all the transactions through E-payments methods using online transactions and swipe machines. He also stressed for installing solar panels and maximizing of Non-conventional methods of energy and emphasized on "Swachh Bharat Abhiyan". Dr AK Singh, DDG motivated the Scientists present in the meeting to link the research with farmers by doubling the income of farmers. The meeting ended with the vote of thanks. Secretary and DDG also visited the Indian Institute of Farming Systems Research and Central Institute of Research on Cattle in Meerut and reviewed their research activities.

The 5th Potato Stakeholders' meet held at Jalandhar

The 5th Potato Stakeholders' meet was held at Central Potato Research Station, Jalandhar on 28th February 2017 under the chairmanship of Dr S.K. Chakrabarti, Director, Central Potato Research Institute, Shimla. Eighteen scientists and 62 progressive potato seed growers, potato industry persons, and related government officials participated in the meeting. During the meet an interactive discussion ensued among the scientists and the stakeholders where several issues including seed production systems, quality of potato seed, seed producing areas etc. were discussed. The meeting was an important forum to sensitize the stakeholders about the challenges faced by potato seed industry and producers and become aware of the issues faced by the potato-based producers and industry to carry out future need based research. An extension folder entitled "Maintaining Seed Potato Quality under Net House: A Boon to Farmers" was also released on the occasion.

National Science Day at CPRS, Jalandhar

National Science day-2017 with the theme "Science and Technology for the Specially Abled Persons" was also celebrated concurrently. On this occasion Mr. Harnek Singh, Block Agriculture Officer, Moga was honoured and felicitated as a specially abled guest, who has been proactive in the region for promoting green technologies irrespective of his ability and has made several landmark achievements in the past.

IJSC Meeting

Institute Joint Staff Council meetings was organized during 30th August 2016 at CPRI, Shimla. The meeting was chaired by the Director CPRI, Dr SK Chakrabarti. Agenda items related to different issues of staffs of CPRI, Shimla and other regional stations were discussed. Decisions on creation of indoor facility for badminton, fabrication and electrification of lower lab, construction of parking etc were taken during this meeting.

Vigilance Awareness Workshop organized at ICAR-CPRI, Shimla

As per the instructions issued by Central Vigilance Commission, New Delhi, ICAR-CPRI, Shimla has observed Vigilance Awareness Week w.e.f 31.10.2016 to 5th November, 2016. During this week, many activities for promoting integrity in official work has been performed. On 5th November, 2016, a workshop/Seminar Vigilance Awareness has been organized in the

Institute. All the staff members of the Institute participated in the said workshop. Sh. Arvind Sharda, Deputy Inspector General, State Vigilance and Anti-Corruption Bureau, HP was the Chief Guest of this Seminar cum Workshop. During the workshop, Dr. SK Chakrabarti, Director, ICAR-CPRI, Shimla addressed the CPRI Staff and stressed upon being vigilant of all laws, rules and compliance mechanism in the conduct of our official work. Sh. Arvind Sharda, in his address, conveyed that we shall promote ethical work practices and should commit to good governance based on transparency and fairness. He also detailed various aspects relating to vigilance and how to keep ourselves away from corruption while working in any concerns. In the end, Dr. Brajesh Singh, Institute Vigilance Officer, in his address, told the staff that we should aware of the don'ts while working in the Institute and we should neither take bribe nor offer bribe. Every citizen should be vigilant and commit to uphold high standards of honesty and integrity.

Diwali Mela organized at CPRI, Shimla

Annual Diwali mela was organized at CPRI Shimla on 24th October, 2016. All the staff of CPRI, Shimla along with their family participated in this mela. Several stall related to games, fooding, cloths etc were organized during this mela. Mrs. Piyali Chakrabarti was the chief guest of this function. Several games viz. slow motorcycle race, tambola, lucky seven, musical chairs etc

were organized during this event. Childrens also participated in these games and enjoyed a lot.

Prizes were distributed to lucky winners by the chief guest on this occasion.

Training and Capacity Building

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

Sl. No	Name & Designation	Training Programme	Date & Venue
1.	Dr. Manoj Kumar, Dr. Sanjay Kumar Yadav, Scientist, Dr. Murlidhar J Sadawarti, Scientist, Dr. SP Singh, PS	Global Conference on "Perspective of Future Challenges and Options in Agriculture"	May 28 – 31, 2016 at Jalgaon, Maharashtra
2.	Dr. Shashi Rawat, Sr. Scientist	Training programme on "PHP/MySQL"	May & June for six weeks at NIELIT, Shimla
3.	Dr. S Roy, Head, CPRS, Gwalior	Training programme on "Management development program on Leadership Development (a Pre-RMP programme)"	June 07 – 18, 2016 at NAARM, Hyderabad
4.	Sh. DP Gautam, Technical Officer	Training programme on "Competence Enhancement Programme on Soft Skill and Personality Development"	June 01 – 10, 2016 at NAARM, Hyderabad
6.	Dr. Brajesh Nare, Scientist	Training Course on "Intellectual Property and Technology Management for Researchers"	June 13 – 18, 2016 at NAARM, Hyderabad
7.	Dr. Sushil Kumar, ACTO	Training programme on "Agrometeorological data collection, analysis and management"	July 25 to August 06, 2016 at CRIDA, Hyderabad
8.	Sh. Kulwinder Singh, Tech. Asstt. and Smt. Asha Thakur, Tech. Asstt.	Training programme on "Food processing, packaging and value addition of agricultural and livestock produce"	July 29 – August 12, 2016 at CIPHET, Ludhiana

9.	Sh. Tilak Raj, Sr. TO and Sh. Rakesh Kumar Patiyal, Tech. Asstt.	Training programme on "Microbial culture handling and maintenance"	August 02 – 11, 2016 at NBAIM, Mau Nath Bhanjan, UP
10.	Sh. CP Sharma, AF&AO	Training programme on "Behaviour in Government"	August 01 – 05, 2016 at ISTM, New Delhi
11.	Dr. Sanjay Kumar Sharma, Sr. TO and Sh. Mahesh Kumar, ACTO	Training programme on "Use of maintenance of advanced instruments in soil and plant analysis"	August 08 – 13, 2016 at IISS, Bhopal
12.	Sh. Kapil Kumar Sharma, ACTO and Sh. Akhilesh Kumar Singh, Sr. TO	Competency enhancement programme	August 17 – 23, 2016 at NAARM, Hyderabad
13.	Dr. Ashish Dhangar, AF&AO	Workshop on "Internal Finance Officers"	October 06 – 07, 2016 at ISTM, New Delhi
14.	Dr. G Vanishree, Scientist	Training on "Cryo preservation methods"	October 17 – 22, 2016 at NBPGR, New Delhi
15.	Dr. VK Dua, PS	Workshop on "Liaison Officer for SCs/Sts/OBCs"	October 20 – 21, 2016 at ISTM, New Delhi
16.	Er. Sukhwinder Singh, Scientist (SG)	Interaction meet on "Engineering interventions for production & processing of horticultural crops"	October 24 – 25, 2016 at CIAE, Bhopal
17.	Dr. Sukhwinder Singh, Scientist – SG	Training course on "Agro – Ecotourism: An emerging enterprise for agricultural diversification"	October 31 – November 09, 2016 at CCARI, Goa
18.	Dr. Dhiraj Kumar Singh, Scientist	Training programme on "Impact assessment of agricultural technology"	November 08 – 28, 2016 at IARI, New Delhi
19.	Sh. Islam Ahmed, CTO	Training programme on "Introduction to Bioinformatics"	November 08 – 21, 2016 at IASRI, New Delhi
20.	Sh. Yogesh Kumar Gupta, Sr. Tech. Officer	Training programme on "Post – harvest management of Agriculture produce"	November 21 – 28, 2016 at CIPHET, PAU Campus, Ludhiana

21.	Dr. Dhruv Kumar, PS & Dr. Divya K Lekshmanan, Scientist	National workshop on "Recent advances in weed management strategies"	November 29 – 30, 2016 at NIPHM, Hyderabad
22.	Dr. Priyand H Mhatre, Scientist	Training programme on "Pest Risk Analysis"	December 05 – 09, 2016 at NIPHM, Hyderabad
23.	Sh. Jaswinder Singh, Sr. TO	Workshop on "Exploring Krishikosh Repository to Disseminate Agricultural Knowledge"	December 06 – 07, 2016 at CCSHAU, Hisar, Haryana
24.	Sh. Sunil Kumar Singh, Sr. Technician Sh. Som Dutt, Sr. Tech. Asstt.	Training programme on "Operation and maintenance of improved implements for Technical Officers of ICAR Institute"	December 12 – 17, 2016 at CIAE, Bhopal
25.	Sh. Mahesh Kumar, Asstt. Chief Tech. Officer	Training programme on "Fundamental concepts and methodologies for agricultural water management"	December 19 – 24, 2016 at IARI, New Delhi
26.	Sh. Avinash Chaudhary, Sr. Tech. Officer	Training programme on "Organic farming for sustainable agriculture"	January 02 – 07, 2017 at MANAGE, Hyderabad
27.	Mrs. Shelly Chopra, Asstt.Chief Tech. Officer	Training programme on "Trace level analysis of pesticides, phytochemicals, sugars and organic acid"	January 23 – 30, 2017 at IARI, New Delhi
28.	Sh. B Suresh, Technical Assistant	Training programme on "Good Agricultural Practices (GAPs) for enhancing resource – use efficiency and farm productivity"	February 14 – 27, 2017 at IARI, New Delhi
29.	Dr. Dalamu, Scientist Sh. Dharminder Verma, ACTO	Training programme on "Analysis of Experimental Data"	February 20 – 25, 2017 at NAARM, Hyderabad
30.	Sh. Ashok Kumar, Technical Assistant, Driver	Training programme on "Automobile Maintenance, Road Safety and Behavioural Skill"	February 20 – 24, 2017 at CIAE, Bhopal

31.	Sh. Dinesh Singh, Sr. Technical Officer	Training programme on "ICAR – ERP"	March 20 – 25, 2017 at IASRI, New Delhi
32.	Dr. Vinod Kumar, PS and Dr Dhiraj K Singh	Workshop on "CIP-CPRI collaborative study on varietal relsease and adoption of potato varieties in India"	May 20, 2016 at CPRIC, Modipuram
33.	Technical Staff: Mr. Akhilesh kumar Singh Mr. Kapil Kumar Sharma Mr. Narendra Kumar Mr. R. Lakshmanan Mr. Murarilal Scientific Staff: Dr. Ashwini Kumar Dr. RatnaParti Kaur Dr. Mohanmmad Abbas Shah Dr. R.K. Singh Dr. Bappi Das Dr. Clarissa Challam Dr. Divya K. Lekshmanan	Training programme on "EM Serological and Molecular Detection of Potato virus"	------- At CPRI, Shimla

Education, Awards and Honours

Conference/Seminar/Symposium/attended by ICAR-CPRI Staff

Sl. No	Name & Designation	Conference/Seminar/Symposium etc.	Date & Venue
1.	Dr. SK Luthra, Dr. Vinod Kumar, Dr. DK Singh	workshop on 'Tracking potato improved cultivars adoption in Uttar Pradesh'	May 20, 2016 CPRI Campus, Modipuram, Meerut
2.	Er. Sukhwinder Singh	Zonal workshop and arise launch pad	9th June, 2016 at IARI New Delhi, on
3.	SK Chakrabarti, Director, VK Dua, Vinay Bhardwaj, Sanjeev Sharma, NK Pandey, Brajesh Singh, RK Singh, Sridhar Jandrajupalli, PM Govindakrishnan, Raja Shankar, Dharminder Verma, Nirmala Chauhan, Sita Ram, Devender Kumar, Name Singh, (Mrs) Kamlesh Malik, Sanjay Rawal, SK Luthra, VK Gupta, Vinod Kumar, JS Minhas, Raj Kumar, Prince, Manoj Kumar, Shambhu Kumar, SK Yadav, Satyajit Roy, SP Singh, Murlidhar Sadawarti, Bapi Das, Pradeep Kumar, EP Venkataslam, Dr Sudha, Divya K Laxmanan	34th GROUP MEETING OF AICRP (Potato)	August 20-22, 2016 at CPRI, Shimla
4.	SK Chakrabarti, Director, PM Govindakrishan, NK Pandey, Brajesh Singh, VK Dua, Rajesh Kumar Singh, Sanjeev Sharma, Vinay Bhardwaj, Jagdev Sharma, Shashi Rawat, Vinay Sagar, Som Dutt, Raja Shanker, Jagesh Kumar Tiwari, VU Patil, Jeevlatha, Basawaraj R, Pinky	Brain Storming on Climate Change	23rd August, 2016 at CPRI, Shimla

	Raigond, Dhiraj Kumar, Sundaresha, Dalamu, Ravinder Kumar, Vallepu Vankateswarlu, G. Vanishree, Tanuja, Hemant Balasaheb Kardile, Chaukhande Pooja Baldeo, Maharishi Tomar, Vinod Kumar, Ashwani Kumar Sharma, Devendra Kumar, Kamlesh Malik, Sanjay Rawal, SK Luthra, VK Gupta, JS Minhas, Raj Kumar, Prince, Manoj Kumar, Shambhu Kumar, SK Yadav, Rahul Bakade, SP Singh, Murlidhar Sadawarti, Bapi Das, Pradeep Kumar, EP Venkataslam, R. Sudha, Divya K. Lekshmanan		
5.	Dr. Baswaraj, Dr. Pinky Raigond, Sh. Hemant B Kardile, Dr. EP Venkatsalam	International Conference on "Agricultural Sciences and Food Technologies for Sustainable Productivity and National Security"	August 25 – 27, 2016 at UAS, Bangalore
6.	Dr. Babita Chaudhary	International conference on "Global initiatives in applied sciences and green technologies"	September 09 – 11, 2016 at Modinagar, Ghaziabad
7.	Dr. G. Vanishree	International conference on "Biodiversity: Current Scenario and Future Strategies"	October 06 – 08. 2016 at St. Bede's College, Shimla
8.	Dr. Anuj Bhatnagar	National Entomologist Meet	October 07 – 08, 2016 at IIHR, Bengaluru
9.	Er. Sukhwinder Singh	Brain storming session cum interaction meet on "Engineering Interventions for Production and Processing of Horticultural Crops"	October 24-25, 2016 at CIAE Bhopal.

10.	Dr. Ratna Preeti Kaur, Dr. Dalamu	"International Agrobiodiversity Congress"	November 06 – 09, 2016 at NASC Complex, New Delhi
11.	Dr. Shashi Rawat,	International conference on "Intergrated Land use Planning for smart agriculture"	November 10 – 13, 2016 at NBSS&LU, Nagpur
12.	Dr. SK Chakrabarti, Dr. VK Dua, Dr. RK Singh, Dr. Ratna Preeti Kaur, Dr. Tanuja Buckshet, Er. Sukhwinder Singh	International meet of Indian Horticulture Congress	November 15 – 18, 2016 at New Delhi
13.	Dr. Raja Shankar	International conference on "Statistics & Big Data Bioinformatics in Agricultural Research"	November 21 – 23, 2016 at ICRISAT, Hyderabad
14.	Dr. VK Dua, Dr. SP Singh, Dr. SK Yadav	International agronomy congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge"	November 22 – 26, 2016 at IARI, New Delhi
15.	Dr. Dhiraj Kumar	National conference on "Information and Communication Management Concerning Climate Smart Agriculture for Sustainable Development and Poverty Alleviation"	November 28 – 30, 2016 at RVSKVV, Gwalior
16.	Dr. Kamlesh Malik	International Conference on "Climate Change and Biodiversity Ecological Sustainability and Resource Management for Livelihood Security"	December 08 – 10, 2016 CIARI, Port Blair

17.	Dr. Babita Chaudhary	National conference on "Innovative and Current Advance in Agriculture and Allied Science"	December 10 – 11, 2016 at JTSAU, Rajendranagar, Hyderabad
18.	Dr. Anuj Bhatnagar, Dr. Kamlesh Malik	National Hindi Vigyan Samelan	December 16 – 17, 2016 at Jaipur
19.	Er. Sukhwinder Singh	National workshop on "Hydroponics-A soilless culture for urban farming"	19 Dec, 2016 at UHF, Nauni, HP
20.	Dr. Aarti Bairwa	National conference on "Climate Smart Agriculture for Nematode Management'	January 11 – 13, 2017 at CCARI, Old Goa, Goa
21.	Dr. SK Yadav, Dr. Sarla Yadav	International conference on "Agriculture and food for inclusive growth and development"	January 14 – 15, 2017 at NBRI, Lucknow
22.	Er. Sunil Gulati	National Symposium on "Agricultural Engineering for Sustainable and Climate Smart Agriculture"	February 16-18 at CCSHAU, Hisar, Haryana
23.	Dr. Prince Kumar, Er. Sukhwinder Singh	National consultative Workshop on "Protected Cultivation to Meet Future Challenges (with special reference to Soilless Cultivation, Hydroponics and Aeroponics)"	February 17 – 18, 2017 at University of Agriculture Science, Dharwad, Karnataka
24.	Dr. SP Singh, Dr. Murlidhar J Sadawarti, Dr. Raja Shankar	XIIIth Agriculture Science Congress – 2017	February 21 – 24, 2017 at Bengaluru, Karnataka

Awards, Honours and Recognition

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

S.No.	Name of the the Person	Category	Award	Year
1.	Dr. Devendra Kumar, PS & Dr. VK Gupta, PS, CPRIC, Modipuram.	Scientific	CPRI Best Worker Award	2016
2.	Sh. Yashpal Sharma, TA, Smt. Sumita Sharma, Sr. TO, CPRI, Shimla, Sh. Yogesh Kumar Gupta, Sr. TO, CPRS, Jalandhar & Dr. Ashok Kumar, ACTO, CPRIC, Modipuram.	Technical	CPRI Best Worker Award	2016
3.	Sh. AD Sharma, AO & Sh. Jai Ram Thakur, Asstt. CPRI, Shimla.	Administrative	CPRI Best Worker Award	2016
4.	Sh. Amar Nath, SSS & Smt. Manjit, SSS, CPRI, Shimla	Supporting	CPRI Best Worker Award	2016

Other awards and Honours

- Dr S Ramanujam award (2012-2015) for team work on Genetic enhancement of Solanum gene pool through conventional and molecular approaches (Potato Research and Development in India)-Dr. Vinod Kumar, Dr. Vinay Bhardwaj, Dr. Jagesh Kumar Tiwari, Dr. Satish Kumar Luthra and Dr. Raj Kumar on 20.08.2016 at CPRI, Shimla.

- Indian Society Extension Education (ISEE) Young Scientist Award 2016 conferred to Dr Dhiraj Kumar Singh, Scientist, Social Sciences, CPRI, Shimla during National Seminar on 'Information and Communication management concerning Climate Smart Agriculture for Sustainable Development & Poverty Alleviation' at RVSKVV, Gwalior from Nov.28 to 30, 2016.

- The CPRIC Modipuram stall was awarded **third prize** in ICAR group in All India Farmers' Fair and Agro-Industrial Exhibition from 8-10 October, 2016 organised by SVBP University of Agri. & Technology, Meerut.

- ICAR-Central Potato Research Station (CPRS) Patna bagged second best stall award in Bihar Kisan Mela on 3-5 Mar, 2017 at Bihar Agriculture University, Sabour (Bihar).

- Dr Baswaraj Raigond awarded with **best paper presentation (oral)** on "Standardization and validation of a quantitative RT-PCR technique for specific detection of Potato virus A" in "International Conference on Agricultural Sciences and Food Technologies for Sustainable Productivity and Nutritional Security" held at GKVK, UAS, Bangalore, during 25-27 August 2016.

- Best poster paper award entitled "Aeroponics: A novel system could revolutionize seed potato production'' authored by Tanuja Buckseth, RK Singh, Ashwani K Sharma and SK Chakrabarti. 2016. Presented in the International Meet *7th Indian Horticulture Congress* on "Doubling farmer's income through Horticulture" held at New Delhi, India on dated 15-18th November, 2016.
- Ratna Preeti Kaur Awarded Best Poster Award for the poster entitled Photoautotrophic Micropropagation as a Potential Potato Seed Production System'' in Abstracts of 7th Indian Horticulture Congress

Promotions/Retirements/Transfers/Deaths

Scientific Staff

Appointment/New Joining

1. Sh. Gaurav Verma, Scientist(Plant Pathology)- 11.04.2016(FN).
2. Dr. Rajesh Kumar Singh, Head, Division of Seed Technology-03.05.2016 (FN).
3. Dr. Manoj Kumar, Head, CPRS, Patna joined as Joint Director, CPRIC, Modipuram-23.08.2016.
4. Dr. Salej Sood, Scientist , Genetics and Plant Breeding at CPRI, Shimla- 27.03.2017 (FN).
5. Dr. Arvind Kumar Jaiswal, Scientist, Food Science and Technology at CPRS, Jalandhar-22.03.2017.
6. Dr. Subhash Katare, Sr. Scientist, Agril Entomology at CPRS, Gwalior-15.03.2017 (FN).

Retirements/Transfer/Promotions

1. Dr. PM Govindakrishnan, PS & PC, CPRI, Shimla retired on 31.08.2016.
2. Dr. JS Minhas, PS, CPRS, Jalandhar retired on 28.02.2017.
3. Dr. (Mrs.) Ashiv Mehta, PS, CPRS, Jalandhar retired on 31.03.2017.
4. Dr. M Nagesh, PS & Head, Plant Protection transfered to NBAIR, Bengluru on 13.05.2016.
5. Dr. Rajender Prasad Pant, PS, CPRIC, Moduipuram transferred to IARI, New Delhi on 15.06.2016.
6. Dr. TK Bag, PS, CPRS, Shillong transferred to IARI, New Delhi on 04.06.2016.
7. Dr. Rajendra Singh, Sr. Scientist, CPRI, Shimla transferred to CPRIC, Modipuram on 25.07.2016.
8. Dr. Vallepu Venkateswarlu, Scientist, Entomology, CPRI, Shimla transferred to Central Tobacco Research Institute, Rajamundry on 26.12.2016.
9. Dr. MA Khan, PS, Agril. Chem., CPRIC, Modipuram transferred to IARI, New Delhi on 07.03.2017.
10. Dr. Sanjay Kumar Yadav, Scientist, Agronomy, CPRS, Patna transferred to ISRI, Lucknow on 07.03.2017.
11. Dr. Rajendra Singh, Sr. Scientist, Gen. & Plant Breeding, CPRIC, Modipuram transferred to IARI, New Delhi on 14.03.2017.
12. Dr. (Smt.) R. Sudha, Scientist, Fruit Science, CPRS, Ooty transferred to CPCRI, Kasaragod on 07.03.2017.
13. Dr. Vijay Kishore Gupta, Sr. Scientist , CPRIC, Modipuram promoted to the next grade to PS w.e.f. 7.12.2014.
14. Dr. Vinay Bhardwaj, Sr. Scientist, CPRI, Shimla promoted to the next grade to PS w.e.f. 22.11.2014.
15. Dr. Ashwani Kumar Sharma, Sr.Scientist, CPRS, Kufri promoted to the next grade to PS w.e.f. 01.09.2014.

Study Leave

1. Sh. Rahul Bakade, Scientist, Plant Pathology, CPRS, Patna w.e.f. 22-08-2016 to 21-08-2019 for Ph.D.
2. Sh. VU Patil, Scientist, Biotechnology, CPRI, Shimla w.e.f. 11.01.2017 to 10.01.2019 for Ph.D.

Technical Staff

Promotion

1. Sh. Madan Pal, Technician, CPRI-RS Modipuram promoted to Sr. Technician
2. Smt. Asha Thakur, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
3. Smt. Manjeet Syal, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
4. Sh. Ram Singh, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
5. Sh. Hari Kishore, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
6. Sh. Dharminder Kumar Gupta, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
7. Smt. Madu Bala, Tech. Asstt., CPRI, Shimla promoted to Sr. Tech. Asstt.
8. Sh. Onkar Singh, Tech. Asstt.(Driver), CPRI, Shimla promoted to Sr. Tech. Asstt. (Driver)
9. Sh. Yash Pal, Sr. Tech. Asstt., CPRI, Shimla promoted to Technical Officer.
10. Sh. Harvinder Singh, Tech. Officer, CPRI, Shimla promoted to Sr. Tech. Officer.
11. Sh. Shyam Kumar Gupta, Tech. Officer, CPRS, Patna promoted to Sr. Tech. Officer.

Transfer

1. Sh. Vijay Kumar, Tech. Asstt. CPRI, Shimla to CPRS, Jalandhar.

Retirements

1. Sh. Vijay Kumar Rai, Sr. Technician(Tractor Driver), CPRS, Jalandhar on 30.4.2016
2. Sh. Balak Ram Singh, Asstt. Chief Tech. Officer, CPRIC, Modipuram on 31.7.2016
3. Sh. Onkar Singh, Sr. Tech. Asstt.(Driver), CPRI, Shimla on 31.12.2016

Administrative Staff

Promotion

1. Sh. Prem Chand Sharma, Assistant, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 08.04.2016
2. Smt. Chandni Bhagta, UDC, CPRS, Kufri promoted to the post of Asstt. w.e.f. 08.06.2016
3. Smt. Sonia Chauhan, LDC,CPRI, Shimla promoted through LDCE to the post of UDC w.e.f. 06.08.2016 (AN)
4. Sh. Deep Ram, UDC, CPRI, Shimla promoted to the post of Asstt. through LDCE w.e.f 16.01.2017 (AN)
5. Smt. Poonam Jyoti, LDC, CPRI, Shimla promoted to the post of UDC w.e.f 28.01.2017 (AN)
6. Sh. Sandeep, Asstt.,CPRIC, Modipuram promoted to the post of AAO through LDCE w.e.f 16.01.2017 (AN)

Inter-Institutional Transfer

Sh. Sanjib Kumar, Asstt., Indian Veterinary Research Institute, Izatnagar joined at CPRS, Patna w.e.f. 27.01.2017

Deputation Basis

1. Sh. Dileep Kumar, Assistant, National Research Centre on Litchi, Muzaffarpur joined to the post of Asstt. Admn. Officer at CPRS, Patna w.e.f.01.03.2017 on deputation basis.

Granted financial up gradation under MACP Scheme

1. Sh. Suresh Kumar, PA, CPRI, Shimla, Granted 2nd MACP w.e.f. 11.04.2016 in the PB Rs. 9300-34800+4600 GP

2. Sh. Sandeep Verma, UDC, CPRI, Shimla, Granted 2nd MACP w.e.f. 15.03.2016 in the PB Rs. 5200-20200+ Rs. 2800 GP

3. Sh. Deep Ram, UDC, CPRI, Shimla, Granted 2nd MACP w.e.f. 15.03.2016 in the PB Rs. 5200-20200 + Rs. 2800GP

Transfer within Institute

1. Sh. Kamal Chand Verma, UDC transferred from CPRS, Gwalior and he joined at CPRI, Shimla w.e.f 01.07.20162.

2. Sh. Jagbir Singh, AAO transferred from CPRS, Patna and joined at CPRI RS, Modipuram w.e.f. 14.03.2017

Reverted

1. Sh Akhilesh Singh, LDC, CPRS, Patna reverted to the post of Skilled Support Staff w.e.f. 18.06.20162.

2. Sh. Padam Chand, LDC, CPRI, Shimla reverted to the post of Skilled Support Staff w.e.f. 09.08.2016

Retirement

1. Sh. KC Chopra, AAO, CPRI, Shimla retired on 30.04.2016

2. Sh. Miraj Ul Haq, AAO, CPRIC, Modipuram retired on 30.06.2016

3. Sh. Dhani Ram, AAO, CPRI, Shimla retired on 31.10.2016

Skilled Support Staff

Probations & Confirmation

1. Late Sh. Sohan Pal, Ex. SSS, CPRIC, Modipuram.

2. Sh. Ramphal, SSS, CPRIC, Modipuram.

3. Sh. Mukesh, SSS, CPRIC, Modipuram.

4. Sh. Murari, SSS, CPRIC, Modipuram.

5. Sh. Rajpal Singh, SSS, CPRIC, Modipuram.

Retirement

1. Sh. Narain Dass, Skilled Support Staff, ICAR-CPRI, Shimla (30.6.2016)

2. Sh. Hans Raj, Skilled Support Staff, ICAR-CPRS, Jalandhar (30.6.2016)

3. Sh. Manjinder Singh, Skilled Support Staff, ICAR-CPRS, Jalandhar (31.7.2016)

4. Sh. Karnail Singh, Skilled Support Staff, ICAR-CPRS, Jalandhar (31.8.2016)

5. Sh. Ram Parkash, Skilled Support Staff, ICAR-CPRS, Jalandhar (30.9.2016)

6. Smt. N. Rajamma, Skilled Support Staff, ICAR-CPRS, Muthorai (30.11.2016)

7. Sh. Bat Bok Kharir, Skilled Support Staff, ICAR-CPRS, Shillong (31.12.2016)

8. Sh. Suraj Singh, Skilled Support Staff. ICAR-CPRIC, Modipuram (31.1.2017)

9. Smt. Kamla Devi, Skilled Support Staff, ICAR-CPRI, Shimla (28.2.2017)

Station –wise Staff Sanctioned

Scientific Staff at ICAR-CPRI, Shimla and its Regional Stations as on 31.3.2017

Director

Dr. SK Chakrabarti

AICRP (Potato) Unit

1. Dr. Raja Shankar, Sr. Scientist

Division of Crop Improvement

2. Dr. Vinay Bhardwaj, Pr. Scientist & officiating Head
3. Dr. Jagesh Kumar Tiwari, Scientist (SS)
4. Sh. Virupakshagauda U Patil, Scientist
5. Dr.(Ms) Dalamu, Scientist
6. Dr.(Mrs.) G Vanishree, Scientist
7. Sh. Hemant Balasaheb Kardile, Scientist
8. Dr. Salej Sood, Scientist

Division of Seed Technology

9. Dr. Rajesh Kumar Singh, PS & Head
10. Dr. (Mrs.)Tanuja Buckseth, Scientist

Division of Crop Production

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

Division of Social Sciences

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

Division of Plant Protection

16. Dr. Sanjeev Sharma, Sr. Scientist and Officiating Head
17. Dr. Vinay Sagar, Sr. Scientist
18. Dr.(Ms) Jeevalatha A, Scientist
19. Dr. Baswaraj R., Scientist
20. Dr. Sundaresha S, Scientist
21. Dr. Ravinder Kumar, Scientist
22. Dr. Shridhar Jandrajupalli, Scientist
23. Dr. Gaurav Verma, Scientist
24. Dr.(Ms.) Aarti Bairwa, Scientist

Division of Crop Physiology, Biochemistry & Post-Harvest Technology

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

ARIS Cell

29. Dr. Shashi Rawat, Sr. Scientist

CPRS RS, Modipuram

30. Dr. Manoj Kumar, Principal Scientist & Joint Director
31. Dr. Devendra Kumar, Principal Scientist
32. Dr. (Mrs.) Kamlesh Malik, Principal Scientist
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. Sanjay Rawal, Principal Scientist
38. Dr. Dhruv Kumar, Principal Scientist
39. Dr. Vijai Kishore Gupta, Principal Scientist
40. Dr. Babita Chaudhary, Sr. Scientist
41. Dr. Mehi Lal, Scientist (SS)
42. Dr.(Ms) Bandna, Scientist

CPRS, Jalandhar

43. Dr. Raj Kumar, Principal Scientist & officiating Head
44. Er. Sukhwinder Singh, Scientist (SG)
45. Er. Sunil Gulati, Scientist (SG)
46. Dr.(Ms) Ratna Preeti Kaur, Scientist
47. Dr. Prince Kumar, Scientist
48. Dr. Mohd. Abas Shah, Scientist
49. Dr.(Mrs.) Sugani Devi, Scientist
50. Sh. Brajesh Nare, Scientist
51. Dr. Arvind Kumar Jaiswal, Scientist

CPRS, Gwalior

52. Dr. S Roy, Principal Scientist & Head
53. Dr. Shiv Pratap Singh, Principal Scientist
54. Dr. Murlidhar .J.Sadawarti, Scientist
55. Dr. Subhash Katare, Sr. Scientist

CPRS, Shillong

56. Ms. Clarissa Challam, Scientist & Officiating Head
57. Sh. Bappi Das, Scientist

CPRS, Muthorai

58. Dr. EP Venkatsalam, Sr. Scientist & Incharge
59. Mrs. Divya K Lekshmanan, Scientist
60. Dr. Mhatre Priyank Hanuman, Scientist

CPRS, Kufri

61. Dr. Ashwani Kumar Sharma, Principal Scientist & Incharge
62. Dr. Vinod Kumar, Principal Scientist

CPRS, Patna

63. Dr. Shambhu Kumar, Principal Scientist & officiating Head
64. Dr. Raj Kumar, Sr. Scientist
65. Sh. Rahul R Bakade, Scientist
66. Sh. Pynbianglang Kharumunid, Scientist
67. Dr. Sarla Yadav, Scientist

Technical staff at ICAR-CPRI, Shimla and its Regional Stations as on 31.3.2017

Sr. No.	Name & Designations	Sr. No.	Name & Designations
1.	Dr. Rakesh Mani Sharma, Asstt. Chief Tech. Officer	26.	Smt. Asha Thakur, Sr. Tech. Asstt.
2.	Dr. Sushil Kumar, Asstt.Chief Tech. Officer	27.	Sh. Hari Kishore, Sr. Tech. Asstt.
3.	Smt. Tarvinder Kochhar, Asstt. Chief Tech. Officer	28.	Sh. Ram Singh, Sr. Tech. Asstt.
4.	Sh. Dharminder Verma, .Asstt. Chief Tech. Officer	29.	Sh. Dharminder Kumar Gupta, Sr. Tech. Asstt.
5.	Smt. Shelly Chopra, Asstt. Chief Tech. Officer	30.	Sh. Rajinder Kumar, Tech. Asstt.
6.	Sh. Rajdeep Bux, Sr. Tech. Officer	31.	Sh. Rakesh Kumar Patyal,Tech. Asstt.
7.	Dr. Sumita Sharma, Sr. Tech. Officer	32.	Sh. Roop Lal, Tech. Asstt.
8.	Sh. Pravesh Jassal, Sr. Tech. Officer	33.	Sh. Ravinder Kumar, Tech. Asstt.
9.	Sh. Kameshwar Sen, Sr. Tech. Officer	34.	Sh. Naresh Kumar, Tech. Asstt.
10.	Sh. Avnish Kumar Atrey, Sr. Tech. Officer	35.	Sh. Ranjesh Bhardwaj, Tech. Asstt.
11.	Sh. Chander Mohan Singh Bist, Sr. Tech. Officer	36.	Sh. Ashok Kumar, Tech. Asstt.
12.	Sh. Yogesh, Sr. Tech. Officer	37.	Sh. Deep Ram, Tech. Asstt.
13.	Sh. Harvinder Singh, Sr. Tech. Officer	38.	Sh. Rakesh Kumar, Tech. Asstt.
14.	Smt. Shruti Gupta, Tech. Officer	39.	Sh. Prithi Raj, Tech. Asstt.
15.	Sh. Vinod Kumar, Tech. Officer	40.	Smt. Jitender Kaur Arora, Tech. Asstt.
16.	Sh. Tilak Raj, Tech. Officer	41.	Sh. Jagdish Chand ,Sr. Technician (Welder)
17.	Sh. Dharm Prakash Gautam, Tech. Officer	42.	Sh. Jagdish Chand, Sr. Technician (Blacksmith-cum-Carpenter)
18.	Sh. Kana Singh Chauhan, Tech. Officer	43.	Sh. Dev Raj, Sr. Technician
19.	Sh. Sheesh Ram, Tech. Officer	44.	Sh. Ram Dayal, Sr. Technician
20.	Sh. Yashpal Sharma, Tech. Officer	45.	Sh. Parmesh Dutt, Sr. Technician
21.	Sh. Naresh Kumar Sharma, Sr. Tech. Asstt.	46.	Sh. Anil Kumar Dubey, Sr. Technician
22.	Sh. Sushil Singh, Sr. Tech. Asstt.	47.	Sh. Neem Chand, Sr. Technician
23.	Sh. Naresh Chand Sharma, Sr. Tech. Asstt.	48.	Sh. Sita Ram, Technician
24.	Smt. Manjeet Syal, Sr. Tech. Asstt.	49.	Sh. Laiq Ram, Technician
25.	Smt. Madhu Bala, Sr. Tech. Asstt.	50.	Sh. Surinder Pal, Technician
		51.	Sh. Vinod Gir, Technician
		52.	Sh. Mansha Ram, Technician

Sr. No.	Name & Designations	Sr. No.	Name & Designations
53.	Sh. Arjun Dass, Technician	77.	Sh. Dinesh Singh , Sr. Tech. Officer
CPRS Kufri		78.	Sh. Pushpender , Sr. Tech. Officer
54.	Sh. Kedar Singh, Tech. Asstt.	79.	Dr. Sanat Kumar, Sr. Tech. Officer
55.	Sh. Ajit Singh,Tech. Asstt.	80.	Sh. Udaivir Singh, Tech. Officer
56.	Sh. Ram jivan, Tech. Asstt.	81.	Sh. Naresh Kumar Sood, Tech. Officer
57.	Sh. Mohan Lal, Sr. Technician	82.	Sh. Vijay Kumar Yadav, Tech. Officer
CPRI RS, Modipuram		83.	Sh. Ved Singh, Tech. Officer
58.	Sh. Islam Ahmed, Chief Tech. Officer	84.	Sh. Kehar Singh , Sr. Tech. Asstt
59.	Sh. Ram Kumar Verma, Chief Tech. Officer	85.	Sh. Krishan Pal Singh ,Tech. Asstt
60.	Sh. Mahesh Kumar, Asstt. Chief Tech. Officer	86.	Sh. UP Paudel, Tech. Asstt.
		87.	Sh. Pawan Kumar Malik, Tech. Asstt.
61.	Sh. Mahipal Singh Bharti, Asstt. Chief Tech. Officer	88.	Sh. Mahesh Pal, Sr. Technician
		89.	Sh. Narayan Singh , Sr. Technician
62.	Sh. Ramesh Chand, Asstt. Chief Tech. Officer	90.	Sh. Vipin Kumar , Sr. Technician
63.	Sh. Harvir Singh, Asstt. Chief Tech. Officer	91.	Sh. Rambir Singh, Sr. Technician
64.	Dr. Ashok Kumar, Asstt. Chief Tech. Officer	92.	Sh. Madan Pal, Sr. Technician
		93.	Sh. Kamal Singh, Sr. Technician
65.	Sh. Krishan Pal Singh, Asstt. Chief Tech. Officer	94.	Sh. Satpal Singh, Technician
		CPRS Jalandhar	
66.	Sh. Satender Kumar, Sr. Tech. Officer	95.	Sh. Kapil Kr. Sharma, Asstt. Chief Tech. Officer
67.	Sh. Om pal, Sr. Tech. Officer		
68.	Mrs. Kusum Singh, Sr. Tech. Officer	96.	Sh. Munna Lal, Asstt. Chief Tech. Officer
69.	Sh. Harvir Singh, Sr. Tech. Officer	97.	Sh. Jaswinder Singh, Sr. Tech. Officer
70.	Sh. Santosh Kumar, Sr. Tech. Officer	98.	Sh. Yogesh Kumar Gupta, Sr. Tech. Officer
71.	Sh. Murari Lal, Sr. Tech. Officer	99.	Sh. Akhilesh Kumar Singh, Sr. Tech. Officer
72.	Sh. Omvir Singh , Tech Officer	100.	Sh. Gurdev Singh, Tech. Officer
73.	Sh. Subhash Chand, Sr. Tech. Officer	101.	Sh. Praveen Kumar , Sr. Tech. Asstt.
74.	Dr (Mrs.) Vineet Sharma, Sr. Tech. Officer	102.	Sh. Som Dutt, Sr. Tech. Asstt.
75.	Sh. Avinash Chaudhary , Sr. Tech. Officer	103.	Sh. Narinder Mayer, Sr. Tech. Asstt.
76.	Sh. Jasvir Singh , Sr. Tech. Officer	104.	Sh. Kulwinder Singh, Sr. Tech. Asstt.

Sr. No.	Name & Designations	Sr. No.	Name & Designations
105.	Sh. Anil Kumar Chandel, Tech. Asstt.	123.	Sh. Rakesh Srivastava, Tech. Officer
106.	Sh. Pradeep Kumar Upadhaya, Tech. Asstt.	124.	Sh. Anil Kumar, Sr. Tech. Asstt.
107.	Sh. Vijay Kumar, Tech. Asstt.	125.	Sh. Alekh Narain, Sr. Tech. Asstt.
108.	Sh. Bhag Singh, Tech. Asstt.	126.	Sh. SDA Rizvi , Tech. Asstt
109.	Sh. Pawan Kumar, Technician	127.	Sh. Narinder Kumar, Sr. Technician
CPRS Gwalior		128.	Sh. Lal Babu Dass, Sr. Technician
110.	Dr. Yogendra Pal Singh, Sr. Tech. Officer	129.	Sh. Sunil Kumar Singh, Sr. Technician
111.	Sh. Sanjay Kr. Sharma, Sr. Tech. Officer	130.	Sh. Parvesh Kumar Yadav, Technician
112.	Sh. Shyam Kumar Gupta, Sr. Tech. Officer	**CPRS, Shillong**	
113.	Sh. Rajinder Kumar Samadhiya, Sr. Tech. Officer	131.	Sh. Bosterwell Langstieh, Sr. Tech. Asstt.
114.	Sh. Surendar Singh, Sr. Tech. Asstt,	132.	Sh. Hesting Jyrwa, Sr. Tech. Asstt.
115.	Sh. Radha Kishan, Tech. Asstt.	133.	Sh. PR Khongbuh, Tech. Asstt.
116.	Sh. Nihal Singhk Tech. Asstt.	134.	Sh. Ram Dass Rai ,Tech. Asstt.
117.	Sh. Bijendra Singh, Technician	135.	Sh. S. Nongrum, Sr. Technician
118.	Sh. Tara Chand, Technician	**CPRS Muthoroi (Ooty)**	
119.	Sh. Chet Ram, Technician	136.	Sh. V Rajendran, Tech. Officer
120.	Sh. Parkash Ram, Technician	137.	Sh. R Lakshmanan, Tech. Asstt.
CPRS Patna		138.	Sh. B Suresh, Technician
121.	Sh. Arun Kumar Singh, Asstt. Chief Tech. Officer	1.	Sh. Ratnesh Kumar, Chief Admn. Officer
122.	Sh. Arjun Kumar Sharma, Sr. Tech. Officer	2.	Sh. AD Sharma, AO
		3.	Sh. Sandeep Singh Dudi, AO

Administrative Staff at ICAR-CPRI, Shimla and its Regional Stations as on 31.3.2017

Sr. No.	Name & Designations	Sr. No.	Name & Designations
Establishment Section		8.	Sh. Om Parkash, Asstt.
4.	Sh. Joginder Singh Thakur , AAO	**Bill & Cash Section**	
5.	Smt. Poonam Sood, Asstt.	9.	Sh. Prem Chand Sharma, AAO/DDO
6.	Smt. Meena Verma, Asstt.	10.	Sh. Amar Chand, Asstt.
7.	Smt. Sunita Thakur, Asstt.	11.	Ms. Reeta Walia, Asstt.

Sr. No.	Name & Designations	Sr. No.	Name & Designations
12.	Sh. Ashwani Gupta, UDC Cum Cashier		**PME Cell**
13.	Sh. Tej Singh, UDC	38.	Sh. Deep Ram, Asstt.
14.	Sh. Raghubir Singh, LDC	39.	Sh. Sachin Kanwar, UDC
	Audit Section	40.	Sh. Rakesh Negi, LDC
15.	Sh. Tej Singh Bhati, FAO		**Vigilance Section**
16.	Sh. Chander Prakash, AF&AO	41.	Sh. Shashi Thakur, Personal Secretary
17.	Dr. Ashish Dhangar, AF&AO	42.	Smt. Nirmala Chauhan, UDC, AICRP (Potato) Unit
18.	Smt. Babli Bhawani, Asstt.		**Engineering Section**
19.	Sh. Jai Ram Thakur, Asstt.	43.	Smt. Kanta Rani, Asstt.
20.	Sh. Jagdish Chand, Asstt.		**Plant Protection Divn.**
21.	Miss Prawartika Das, Asstt.	44.	Sh. Gurjeet Singh, Pvt. Secy.
22.	Smt. Shyam Lata Beakta, Asstt.		**Director Cell**
23.	Sh. Sandeep Verma, UDC	45.	Sh. Ram Chand, Pvt. Secy.
24.	Sh. Kamal Chand Verma, UDC		**Hindi Section**
25.	Smt. Geeta Devi, UDC	46.	Sh. Suresh Kumar, PA
26.	Smt. Sonia Chauhan, UDC		**CPRS, Kufri**
	Estt.II Section	47.	Smt. Chandni Bhagta, Asstt.
27.	Smt. Urmila Verma, Asstt.		**CPRIC, Modipuram**
28.	Sh. Narender Paul, LDC	48.	Sh. Jagbir Singh, AAO
29.	Smt. Punam Jyoti, UDC	49.	Sh. Sandeep, AAO
30.	Sh. Pawan Kumar, UDC	50.	Sh. Santosh Kumar, UDC
	Store Section	51.	Smt. Sneh Lata, LDC
31.	Sh. Chanda Ram, AAO	52.	Smt. Seema Verma, LDC
32.	Sh. Jagdish Chand, Asstt.	53.	Sh. Ashok Kumar, LDC
33.	Sh. Krishan Lal, Asstt.	54.	Sh. Rajesh Kumar, PS
34.	Sh. Hans Raj, UDC		**Jalandhar**
35.	Sh. Kundan, LDC	55.	Sh. Jeevan Kumar, AAO
36.	Sh. Mohinder Singh, LDC	56.	Sh. Suresh Kumar Verma, PA
37.	Sh. Gokal Ram, LDC		

Sr. No.	Name & Designations	Sr. No.	Name & Designations
57.	Sh. Sukhpal Sharma, Asstt.		**Muthorai**
58.	Smt. Sandhya Kapila, Asstt.	68.	Smt. IC Dharmapaul, Asstt.
59.	Sh. Rakesh,UDC	69.	Smt. M. Rani, Asstt.
60.	Smt. Bimla Salhotra, UDC		**Patna**
61.	Smt. Daishey Tuli, LDC	70.	Sh. Dileep Kumar, AAO (on deputation as on 01.03.2017)
62.	Sh. Naresh Kumar, LDC	71.	Sh. Surender Singh, Asstt.
63.	Sh. Daljeet Singh, LDC	72.	Sh. Sanjib Kumar, Asstt.
	Gwalior	73.	Sh. Ramesh Kumar Gupta, UDC
64.	Sh. Krishan Lal, AAO		**Shillong**
65.	Sh. Pradhuman Kumar Sarswat, UDC		NIL
66.	Sh. Ashish Kalyan, LDC		
67.	Sh. Shri Krishan, LDC		

Skilled Supporting Staff at ICAR-CPRI, Shimla and its Regional Stations as on 31.3.2017

Sr. No.	Name & Designations	Sr. No.	Name & Designations
	CPRI, Shimla	14.	Sh. Sanjeevan Kumar, SSS (SS Gr. II)
1.	Sh. Maharaj Singh, SSS (SS Gr. III)	15.	Sh. Ashok Kumar, SSS (SS Gr. I)
2.	Sh. Khem Chand, SSS (SS Gr. III)	16.	Sh. Narender Kumar, SSS (SS Gr. I)
3.	Sh. Charan Dass , SSS (SS Gr. III)	17.	Smt. Kajal, SSS (SS Gr. I)
4.	Sh. Roshan Lal, SSS (SS Gr. III)	18.	Sh. Padam Dev , SSS (SS Gr. I)
5.	Sh. Kanhiya Prasad, SSS (SS Gr. III)	19.	Sh. Roshan Lal, SSS (SS Gr. I)
6.	Sh. Bir Bhadur, SSS (SS Gr. III)	20.	Smt. Manjit, SSS (SS Gr. I)
7.	Sh. Piar Chand, SSS (SS Gr. III)	21.	Sh. Amar Nath, SSS (SS Gr. I)
8.	Sh. Subhash Chand, SSS (SS Gr. III)	22.	Sh. Hira Singh, SSS (SS Gr. I)
9.	Sh. Mansa Ram, SSS (SS Gr. III)	23.	Sh. Rajinder Singh, SSS
10.	Sh. Babu Ram, SSS (SS Gr. III)	24.	Sh. Padam Chand, SSS (SS Gr.I)
11.	Sh. Ramesh Kumar, SSS (SS Gr. III)		**CPRI Cantten Staff.**
12.	Sh. Rajinder Kumar, SSS (SS Gr. II)	1.	Sh. Nand Lal, Wash Boy
13.	Sh. Kulwant Singh, SSS (SS Gr. II)		

Sr. No.	Name & Designations
	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. Mangtey , SSS (SS Gr. III)
2.	Sh. Satya Pal Singh, SSS (SS Gr. II)
3.	Sh. Amiruddin, SSS (SS Gr. II)
4.	Sh. Jagtey, SSS (SS Gr. II)
5.	Sh. Som Pal, SSS (SS Gr. II)
6.	Sh. Krishan Pal, SSS (SS Gr. I)
7.	Sh. Mani Ram, SSS (SS Gr. I)
8.	Sh. Rajpal, SSS (SS Gr. I)
9.	Sh. Rajvir Singh, SSS (SS Gr. I)
10.	Sh.Raj Kumar, SSS (SS Gr. I)
11.	Sh. Sudesh Pal, SSS (SS Gr. I)
12.	Sh. Tej Bir Singh, SSS (SS Gr. I)
14.	Sh. Ramphal, SSS(SS Gr. I)
15.	Sh. Mukesh, SSS (SS Gr. I)
16.	Sh. Murari, SSS (SS Gr. I)
17.	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. Satnam Singh, SSS (SS Gr. II)
5.	Mrs. Passo, SSS (SS Gr. II)
6.	Smt. Rashpal Devi, SSS (SS Gr. II)
7.	Sh. Ram Lubhaya, SSS (SS Gr. II)
8.	Sh. Sukhwinder , SSS (SS Gr. II)
9.	Sh. Subhash, SSS (SS Gr. II)
10.	Sh. Jagai Ram, SSS (SS Gr. II)
11.	Sh. Paramjit Singh, SSS (SS Gr. II)
12.	Sh. Ram Sarup, SSS (SS Gr. I)
13.	Sh. Joginder Pal, SSS (SS Gr. I)
14.	Sh. Ram Nath, SSS (SS Gr. I)
15.	Sh. Jagan Nath, SSS (SS Gr. I)
16.	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)
8.	Sh. Akhilesh Singh, 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 (SS Gr. II)

Sr. No.	Name & Designations	Sr. No.	Name & Designations
7.	Sh. Ram Singh, SSS (SS Gr.II)	26.	Sh. Munna Singh, SSS (SS Gr. I)
8.	Sh. Jagdish, SSS (SS Gr. II)	27.	Sh. Kali Charan, SSS (SS Gr. I)
9.	Sh. Ram Rattan, SSS (SS Gr. II)	28.	Sh. Tilak Singh, SSS (SS Gr. I)
10.	Sh. Shyam Singh, SSS (SS Gr. II)	29.	Sh. Net Ram, SSS (SS Gr. I)
11.	Sh. Parkash Tomar, SSS (SS Gr. II)	30.	Sh. Mangal, SSS (SS Gr. I)
12.	Sh. Virendra Singh, SSS (SS Gr. II)	31.	Sh. Jandel Singh, SSS (SS Gr. I)
13.	Sh. Ranbir Singh, SSS (SS Gr. II)	32.	Sh. Bhagirath, SSS (SS Gr. I)
14.	Sh. Kallu, SSS (SS Gr. II)	33.	Sh. Ramdin, SSS (SS Gr. I)
15.	Sh. Ashok Kumar, SSS (SS Gr. II)	34.	Sh. Sikander Singh, SSS (SS Gr. I)
16.	Smt. Vimla Devi, SSS (SS Gr. I)	**CPRS Shillong**	
17.	Sh. Jaswant Singh, SSS (SS Gr. I)	1.	Sh. Ram Ekbal Rai , SSS (SS Gr. III)
18.	Sh. Kedar, SSS (SS Gr. I)	2.	Smt.Theibet Thawmuit, SSS (SS Gr. III)
19.	Sh. Sonpal, SSS (SS Gr. I)	3.	Mrs. Tellinora, SSS (SS Gr. III)
20.	Sh. Parasu Ram, SSS (SS Gr. I)	4.	Km. Thapa , SSS (SS Gr. III)
21.	Sh. Punjab Singh, SSS (SS Gr. I)	**CPRS Muthorai**	
22.	Sh. Ram Parkash, SSS(SS Gr. I)	1.	Sh. K. Ramasamy, SSS (SS Gr. I)
23.	Sh. Bharat Singh, SSS (SS Gr. I)	2.	Sh. J. Bhojan, SSS (SS Gr. I)
24.	Sh. Munnu Singh, SSS (SS Gr. I)	3.	Smt. S Pankajam, SSS (SS Gr. I)
25.	Sh. Lala Ram, SSS (SS Gr. I)	4.	Smt. M, Anagamma, SSS

Sanctioned, Filled and Vacant position of Scientific Staff on 31.3.2017

Position as on 31.03.2017 as per latest Cadre Strength received from the Council													
		Scientist			Sr. Scientist			Principal Scientist			Overall Scientific position		
Sl.No.	Discipline	SS	**IP**	V	SS	**IP**	V	SS	**IP**	V	SS	IP	V
1.	Agricultural Biotechnology	3	**3**	0	1	**0**	1	0	**0**	0	4	3	1
2.	Agricultural Economics	3	**0**	3	0	**0**	0	0	**1**	-1	3	1	2
3.	Agricultural Entomology	6	**3**	3	2	**2**	1	0	**0**	0	8	5	3
4.	Agricultural Extension	2	**2**	0	0	**0**	0	1	**0**	1	3	2	1
5.	Agricultural Microbiology	3	**0**	3	0	**0**	0	0	**0**	0	3	0	3
6.	Agricultural Statistics	1	**0**	1	0	**0**	0	0	**0**	0	1	0	1
7.	Agricultural Meteorology	1	**0**	1	0	**0**	0	0	**0**	0	1	0	1
8.	Agril. Process Engineering	1	**0**	1	0	**0**	0	0	**0**	0	1	0	1
9.	Agronomy	4	**4**	0	1	**0**	1	1	**1**	0	6	5	1
10.	Com. Application in Agril.	1	**1**	0	0	**0**	0	0	**0**	0	1	1	0
11.	Farm Machinery & Power	3	**3**	0	0	**0**	0	0	**0**	0	3	3	0
12.	Flexi Discipline	0	**0**	0	2	**0**	2	0	**0**	0	2	0	2
13.	Food Technology	2	**1**	1	0	**0**	0	0	**0**	0	2	1	1
14.	Genetic & Plant Breeding	10	**7**	3	2	**2**	0	1	**0**	1	13	9	4
15.	JD(CPRS Modi.) Non-RMP	0	**0**	0	0	**0**	0	1	**1**	0	1	1	0
16.	Nematology	2	**2**	0	0	**0**	0	1	**0**	1	3	2	1
17.	Plant Biochemistry	2	**2**	0	1	**1**	0	0	**0**	0	3	3	0
18.	Plant Pathology	10	**7**	3	1	**2**	-1	1	**1**	0	12	10	2
19.	Plant Physiology	6	**2**	4	0	**0**	0	0	**1**	-1	6	3	3
20.	Seed Science & Technology	5	**3**	2	0	**1**	-1	1	**0**	1	6	4	2
21.	Soil Science	5	**1**	4	0	**0**	0	0	**0**	0	5	1	4
22.	Vegetable Science	14	**11**	3	2	**1**	1	4	**1**	3	20	13	7
	Total	**84**	**52**	**32**	**12**	**9**	**3**	**11**	**6**	**5**	107	67	30

Sactioned Filled and Vacant Position of Technical Category as On 31.3.2017, 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	29	5	3	8	6	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	12	2	2	3	2	-	-	-	-	**31**	**28**	**03**
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**
Cat. III Computer programmer T-6	1	-	-	-	-	-	-	1	-	-	-		-	-	-	-	**1**	**1**	**-**
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**
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	2	2	1	2	1	2	3	2	-	2	1	-	-	-	-	**13**	**8**	**5**
Tractor Driver	1	1	1	1	1	-	4	2	3	3	1	-	1	-	-	-	**12**	**7**	**5**
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**	**53**	**08**	**05**	**22**	**15**	**42**	**37**	**13**	**11**	**19**	**10**	**05**	**03**	**08**	**04**	**178**	**138**	**40**

List of Administrative Staff (Sanctioned & Filled as on (31.03.2017)

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	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	**01**	**-**
*FAO (**in lieu of Sr. Fin. & A/Cs Officer)***	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	**01**	**-**
Admn. Officer	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	**02**	**-**
Asstt. Admn. Officer	5	3	1	1	2	2	1	1	-	-	-	-	1	1*	-	-	10	**08**	**02**
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	16	1	2	3	-	1	-	2	-	1	1	1	2	1	2	30	**23**	**07**
UDC	05	11	3	2	3	1	1	1	1	-	1	-	2	1	1	-	17	**16**	**01**
LDC	14	06	2	3	3	3	1	2	1	-	-	-	2	-	1	-	24	**14**	**10**
Total	**61**	**47**	**08**	**09**	**12**	**7**	**5**	**4**	**4**	**0**	**2**	**1**	**7**	**4**	**3**	**2**	**102**	**74**	**29**

1. *One post filled through deputation as AAO at CPRS, Patna.
2. One post of UDC earmarked for ST downgraded as LDC advertised for CPRS, Shillong..
3. Requisition for filling up four Stenographer Grade-III in lieu of PA already sent to ICAR

List of sanctioned, filled and vacant Skilled Supporting Staff as on 31.03.2017

Grade	Sanctioned	Filled	Vacant
SS Grade -I	82*	57	25
SS Grade -II	65	38	27
SS Grade -III	39	21	18
SS Grade -IV	18	-	18
Sub Total	**204**	**116**	**88**
Canteen Staff			
Cook	1	0	1
Tea Maker	1	0	1
Wash Boy	1	1	0
Grand Total	**207**	**117**	**90**

Station / Grade-wise list of the Skilled Supporting Staff 31.03.2017

Station	Sanctioned Strength	Grade IV	Grade III	Grade II	Grade I	Total
Shimla	75	-	11	03	10	24+1* Canteen staff
Kufri	12	--	02	02	05	09
Modipuram	42	--	01	04	12	17
Jalandhar	26	--	01	10	05	16
Patna	20	-	02	04	02	08
Gwalior	12	-	-	15	19	34
Shillong	12	-	04	-	-	04
Muthorai	08	-	-	-	04	04
Total	**207**	**-**	**21**	**38**	**57**	**116+1=117**

1. ***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

Classified Abstract of Expenditure of Plan, Non-plan and Receipt

Details of Plan Expenditure

(Amount in Rupees)

S.NO	Head	RE Allocation	Expenditure
1	2	3	4
	Grants in Aid-Capital Works		
A.1	Land	0.00	0.00
B.1	Office Buildings	4134000 .00	4134313 .00
B.2	Residential Buildings	2239000 .00	2238880 .00
B.3	Other Works	0.00	0.00
	Total: Works	**6373000 .00**	**6373193 .00**
	Other Capital Expenditure		
C.	Equipments	33385000 .00	33384823 .00
D.	Information Technology	2889000 .00	2889268 .00
E.	Library Books and Journals	377100 0.00	3771245 .00
F.	Vechicles and Vessels	0.00	0.00
G.	Livestock	0.00	0.00
H.	Furniture & Fixtures	6600 .00	66379 .00
I.	Others	0.00	0.00
	Total: Other Capital Expenditure	**40111000 .00**	**40111715 .00**
	Total Grant In Aid Capital	**46484000 .00**	**46484908 .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 Allowances	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	2649000.00	2648761.18
B.	Foreign TA	0.00	0.00
	Total: Travelling Allowances	**2649000.00**	**2648761.00**
	Research and Operational Expenses		
A.	Research Expenses	29421000.00	20165671.00
B.	Operational Expenses	0.00	8777419.00
	Total: Research and Operational Expenses	**29421000.00**	**28943090.00**
	Administrative Expenses		
A.	Infrastructure	0.00	91399.00
B.	Communication	0.00	33579.00
C.1	Repairs/Maintenance-Equipments, Vehicles & others	0.00	4208.00

C.2	Repairs/Maintenance- Office Building	0.00	331495.00
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	16658.00
	Total: Administrative Expenses	**0.00**	**477339.00**
	Miscellaneous Expenses		
A.	HRD	446000.00	445793.00
B.	Other Items (Fellowships, Scholarships etc.)	0.00	0.00
C.	Publicity & Exhibitions.	0.00	0.00
D.	Guest House - Maintenance	0.00	0.00
E.	Other Miscellaneous	0.00	0.00
	Total: Miscellaneous Expenses	**0.00**	**445793.00**
	Total Grant in Aid- General	**32516000.00**	**32514983.18**
	Grand Total : Capital + Revenue + (salaries) + Revenue (General)	**79000000.00**	**78999891.18**

Revenue Receipts

SI.No.	Particulars	Amount (₹)
1	Sale of Farms Produce	12355306.39
2	Sale of Fish & Poultry	0.00
3	Sale of Land	17666848.00
4	Sale of Building	0.00
5	Sale of Vehicle, other Machine Tools	34500.00
6	Sale of Live Stocks	0.00
7	Income from Royalty, Sale of Publications and Advertisement	34620.00
8	Licence Fee	1135917.00
9	Interest earned on Loans and Advances	1235095.63
10	Leave Salary and Pension Contribution	0.00
11	Receipts from Schemes	0.00
12	Analytical and Testing Fee	8000.00
13	Pre-shipment Fee	0.00
14	Application fee from candidates	1200.00
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	1858531.98
19	Income generated from Internal Resource Generation	1664872.00
20	Net profit in Revolving Funds-	23156125.00
21	Recoveries of Loans and Advances	1700396.00
22	Miscellaneous Receipts	999036.63

Break up:	:	**Grand Total**	**15538198.63**
Revenue Receipts:	:	3863545.37	
Loan Recoveries:	:	1700396.00	
Sale of Assets:	:	17701348.00	
		15538198.63	

Details of Non-Plan Expenditure

SI. 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	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		1500000.00	0.00	1500000.00	1489058.00	0.00	1489058.00
D, Information Technology		0.00	0.00	0.00	0.00	0.00	0.00
E. Library Books and Journals		400000.00	0.00	400000.00	399793.00	0.00	399793.00
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		200000.00	0.00	200000.00	198919.00	0.00	198919.00
I. Others		0.00	0.00	0.00	0.00	0.00	0.00
Total: Other Capital Expenditure		**2100000.00**	**0.00**	**2100000.00**	**2087770.00**	**0.00**	**2087770.00**
Total Grants in Aid - Capital		2100000.00	0.00	2100000.00	2087770.00	0.00	2087770.00
Grants in Aid - Salaries							
Establishment Expenses							
A.1 Establishment Charges		269400000.00	0.00	269400000 .00	265616750 .25	0.00	265616750 .25
A.2 Wages		1900000.00	0.00	1900000.00	1783602.00	0.00	1783602.00
A.3 Overtime Allowance		0.00	0.00	0.00	0.00	0.00	0.00
A.1 Establishment Charges		269400000.00	0.00	269400000 .00	265616750 .25	0.00	265616750 .25
A.2 Wages		1900000 .00	0.00	1900000.00	1783602.00	0.00	1783602.00
A.3 Overtime Allowance		0.00	0.00	0.00	0.00	0.00	0.00
Total: Establishment Expenses		**271300000.00**	**0.00**	**271300000.00**	**267400352.25**	**0.00**	**267400352.25**
Total Grants in Aid - Salaries		271300000.00	0.00	271300000.00	267400352.25	0.00	267400352.25
Grants in Aid - General							

Pension and Retirement Benefits						
A. Pension & Other Retirement Benefits	167664000 .00	0.00	167664000 .00	167661846 .00	0.00	167661846 .00
Total: Pension and Retirement Benefits	**167664000.00**	**0.00**	**167664000.00**	**167661846.00**	**0.00**	**167661846.00**
Travelling Allowances						
A. Domestic TA / Transfer TA	1300000 .00	0.00	1300000 .00	1299268 .00	0.00	1299 268 .00
B. Foreign TA	0.00	0.00	0.00	0.00	0.00	0.00
Total: Travelling Allowances	**1300000.00**	**0.00**	**1300000.00**	**1299268.00**	**0.00**	**1299268.00**
Research and Operational Expenses						
A. Research Expenses	17000000 .00	0.00	17000000 .00	16980253 .00	0.00	16980253 .00
B. Operational Expenses	10000000 .00	0.00	10000000 .00	9999399 .00	0.00	9999399 .00
Total: Research and Operational Expenses	**27000000 .00**	**0.00**	**27000000 .00**	**26979652 .00**	**0.00**	**26979652 .00**
Administrative Expenses						
A. Infrastructure	18000000 .00	0.00	18000000 .00	17886888 .00	0.00	17886888 .00
B. Communication	1000000 .00	0.00	1000000 .00	999885 .00	0.00	999885 .00
C.1 Repairs/Maintenance - Equipments,Vehicles& Others	4195000 .00	0.00	4195000 .00	4194214 .00	0.00	4194214 .00
C.2 Repairs/Maintenance - Office building	2737000 .00	0.00	2737000 .00	2736627 .00	0.00	2736627 .00
C.3 Repairs/Maintenance - Residential building	2017000 .00	0.00	2017000 .00	2017250 .00	0.00	2017250 .00
C.4 Repairs/Maintenance - Minor Works	551000 .00	0.00	551000 .00	550927 .00	0.00	550927 .00
D. Others (excluding TA)	9400000 .00	0.00	9400000 .00	9397443 .75	0.00	9397443.75
Total: Administrative Expenses	**37900000 .00**	**0.00**	**37900000 .00**	**37783234.75**	**0.00**	**37783234.75**
Miscellaneous Expenses						
A. HRD	500000 .00	0.00	500000 .00	499885 .00	0.00	499885 .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	95605 .00	0.00	95605 .00
D. Guest House – Maintenance	100000 .00	0.00	100000.00	100294 .00	0.00	100294 .00
E. Other Miscellaneous	100000.00	0.00	100000.00	97326 .00	0.00	9732 6.00
Total: Miscellaneous Expenses	**800000.00**	**0.00**	**800000.00**	**793110 .00**	**0.00**	**793110 .00**
Total Grants in Aid - General	**234664000 .00**	**0.00**	**234664000 .00**	**234517110.75**	**0.00**	**234517110 .75**
Grand Total : Capital + Revenue (Salaries)+	**508064000 .00**	**0.00**	**508064000 .00**	**504005233 .00**	**0.0 0**	**504005233.0 0**
Loan and Advances		1300000.00	1300000.00		617500 .00	617500 .00