

ANNUAL REPORT 2017-18



ICAR-Central Potato Research Institute
Shimla - 171001 (HP)



ICAR-CPRI Annual Report 2017-18

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Preface

It is a matter of great honor and pride for me to present the Annual Report (2017-18) of ICAR-Central Potato Research Institute, Shimla. The fact that India emerged as the second largest potato producer in the world today speaks volume about research accomplishment and technological competence of this institute. Nevertheless, doubling farmers' income by 2022 and sustainable production of ~ 125 million metric tonnes of potato annually by the year 2050 are the two guiding short- and long-term R4D objectives of this institute today.

The present report gives an overview of the salient achievements of prioritized R&D activities undertaken during the period by the institute. Germplasm is the backbone of any crop improvement program and the institute has been making continuous efforts to enrich its potato germplasm repository which constitutes > 4,300 accessions. This year 5 elite genetic stocks were registered with the NBPGR, New Delhi. Three new potato varieties namely Kufri Ganga, Kufri Neelkanth and Kufri Lima were recommended for release. Based on consistently good performance over the years, 10 advanced hybrids including six for table purposes, two for chips, one each for heat stress and drought tolerance were identified. Nutritionally superior clones MSP/16-272 possessing high Zn, Fe, Ca, Mg and carotenoids; and MSP/15-51 with high anthocyanin, ascorbic acid, Zn and Fe in the flesh were identified. For deeper understanding and better utilization of the genetic constitution of the dihaploid potato the whole genome of potato dihaploid C-13 was sequenced. Also, advanced progenies of somatic hybrids were developed and functional genomics for improving nitrogen use efficiency in potato was investigated. In continuation of the efforts for improving the pathogen diagnostics, Loop Mediated Isothermal Amplification (LAMP) assay for detection of PVX, PLRV and *P. infestans*, dipstick kit for detection of PVX using commercial antibodies, PCR based diagnostics for phytoplasma, multiplex RT-PCR for PVA, PVX & PVS and others were developed. Comparative transcriptomics studies revealed the involvement of various genes in ToLCNDV-potato plant interaction. In continuing our efforts for studying the climate change impacts on potato, calibration of WOFOST crop growth model was completed for potato cultivars Kufri Lalit and Kufri Arun. The assessment of post-harvest losses in potato showed mean total losses of 8.6 % during harvesting, and 4.0% at curing, sorting, grading and packaging stages. Potato based gluten free cookies were developed by replacing wheat flour with other cereal flours and potato matrix. Potato starch was used for the development of bio-degradable disposable table wares e.g. plates, bowls. The institute produced 2860.96 metric tonnes of nucleus and breeder seed through conventional and hi-tech (tissue culture cum aeroponics) systems. Institute conducted several national and international training programmes of different duration including Summer School training and Model Training courses. Many exhibitions, fairs, celebration of important days, chat shows, etc. were also organized. Expert scientists from different discipline of ICAR-CPRI participated in various live phone-in programmes on Doordarshan.

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 R4D activities and bringing out the results in time. I would also thank Chairperson and members of RAC who guided us and gave direction to the research activities. 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 Mohapatra, Secretary, DARE and Director General, ICAR, for his constant support and guidance. I would also place on record my thanks for DDG (Horticultural Science) and ADG (HS-II) for providing necessary direction, guidance and suggestions.

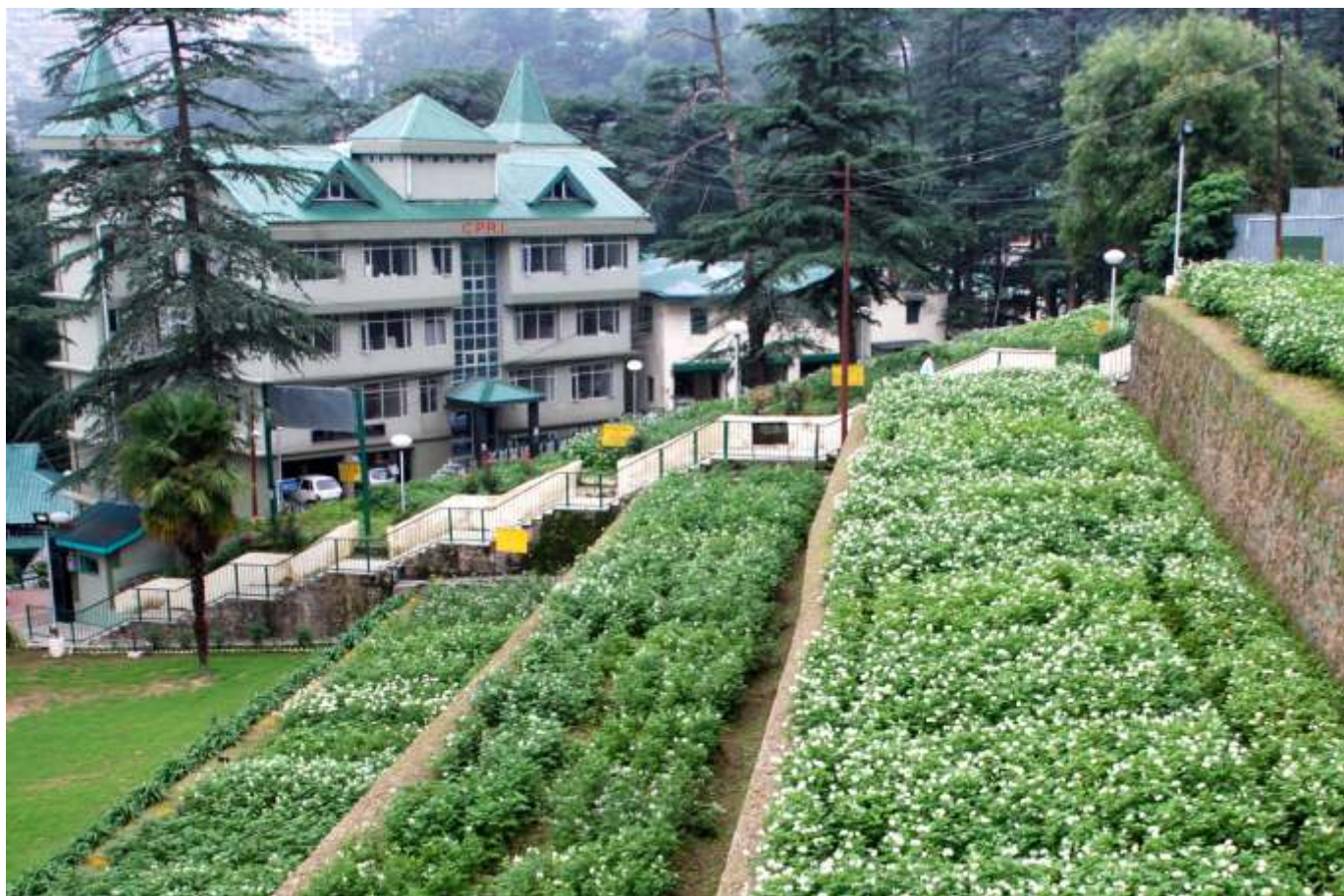


(SK Chakrabarti)
Director

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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. Modipurma (UP), Kufri Fagu (HP), Jalandhar (Punjab), Gwalior (MP), Patna (Bihar), Shillong (Meghalaya) and Ooty (Tamil Nadu) to cater the need for location specific research and extension activities.

The institute 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 66 scientists, 130 technical staffs and 71 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.

The 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 11 well defined research programmes and one service project on potato seed production. In addition to regular research programmes, a total of 11 externally funded research projects sponsored by different agencies *viz.* ICAR, DBT, PPV & FRA, CIP, IASRI, NASF, NEC and UPCAR are also

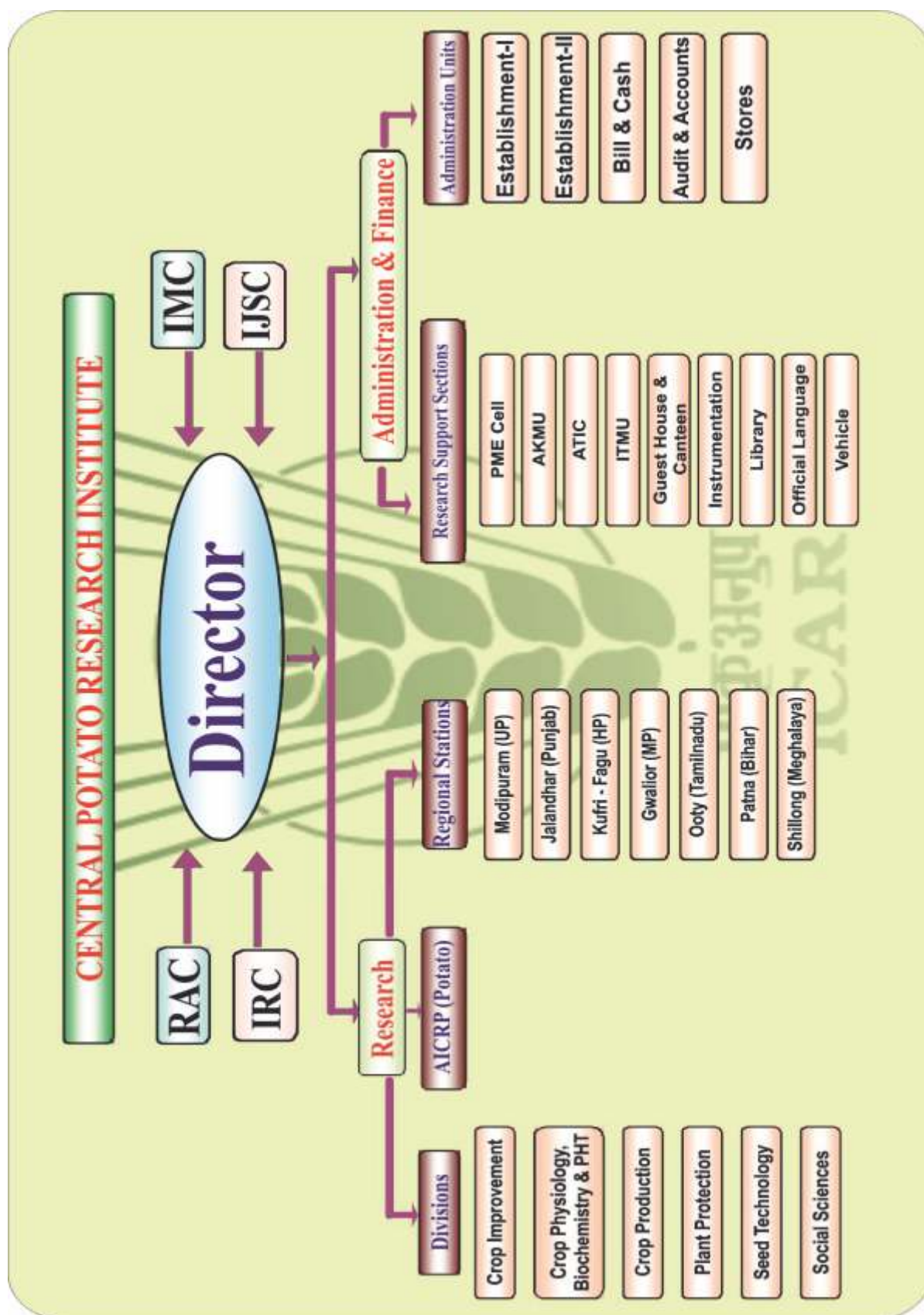
under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

Staff, Finance & Facilities

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 31.03.2018 was 374 including 66 scientific, 130 technical, 70 administrative and 108 supporting staffs. The expenditure of the institute for the year was Rs 65.42 crores and receipts Rs. 2.47 crores. 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.

The institute has 521 ha farm lands distributed over 15 units for conducting field experiments and undertaking breeders' seed production. Recently, Aeroponic facility was created in CPRI, Shimla, CPRIC, Modipuram, CPRS, Patna and CPRS, Shillong for soil less disease free seed potato production. A BPD Unit has been established at CPRS, Jalandhar for commercialization of potato technologies developed by the institute. The institute library is the second largest library in the world. Besides, the institute has well-equipped AKMU cell, ATIC, museum, auditorium, conference hall, committee room at the hqrs. and similar facilities have been provided at the regional stations. The institute is well equipped to organize training programmes with the facilities like audio-visual aids, projector, Guest house, farmers' hostels etc.



The Organogram of ICAR-CPRI

Executive Summary

Division of Crop Improvement

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 prebreeding. During the year, 44 accessions were imported including 8 accessions were from The Netherlands, 32 from USA and 4 from Canada and the present collection is > 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. Five elite genetic stocks were registered with the ICAR-NBPGR, New Delhi.

In Breeding programme, three new improved potato varieties namely Kufri Ganga, Kufri Neelkanth and Kufri Lima were recommended for release in 35th group meeting of ACIRP (Potato) held during 16-18 September, 2017 at BCKV, Kalyani, West Bengal. Based on consistently good performance over the years, 10 advanced hybrids namely J/10-91, J/10-148, MS/12-2116, MCIP/12-185, PS/11-47 and PS/11-86 (table purposes); MP/9-45, MP/9-73 (chips), HT/10-1554 (heat stress) and WS/7-113 (drought tolerance) were identified. Nutritionally superior clones were identified and MSP/16-272 possessed high Zn, Fe, Ca, Mg and carotenoids in flesh, and MSP/15-51 possessed high anthocyanin, ascorbic acid, Zn and Fe in flesh. Advanced hybrids MS/11-664 (table purpose), MP/10-172 (Chips) and HT/11-3 (heat tolerance) were introduced in AICRP for multi-location testing. Optimum NPK requirement (kg/ha) of varieties/advanced hybrid namely Kufri Ganga (261N, 80P, 132), Kufri Neelkanth (240N, 40P, 50K) and MP/6-39 (240N, 40P, 100K) were worked out. Processing quality of 13 genotypes during storage at 10-12°C with CIPC identified MP/9-45 recorded best processing quality throughout the storage period of 180 days. SSR alleles 201 and 229 bp- specific to parent Bareilly Red were identified for likely association with purple flesh colour.

In Biotechnology programme following research work were completed: whole genome sequencing of potato dihaploid C-13, development of advanced progenies of somatic hybrids and SSR alleles, sequence variation

analysis of genes involved in nitrogen use efficiency (NUE), development of CAPS marker of nitrate reductase gene, investigating NUE variables and genes in potato grown with variable N supplies under aeroponics, field evaluation of NUE mapping population under low N, development of SSR markers for identification of Indian potato varieties, development of modified and rapid protocol for ploidy estimation potato, identification of SNP level differences in the late blight responsive SWEET promoter, expression analysis of Rubisco activase isoforms under the heat stress conditions in potato, cloning and characterization of potato annexin gene (StAnn1) for exploring its potential in providing heat stress tolerance, CDF1.2 candidate gene for enhancing earliness in potato, functional screening of heat tolerant genes in response to tuberisation, F-Box mediated Auxin signalling maintains defence against *Phytophthora infestans* in *Solanum demissum* and genotyping-by-sequencing analysis in potato.

Division of Plant Protection

Late blight severity was insignificant this year. Isolates of *Phytophthora infestans* were observed sensitive to new molecules (cymoxanil, dimethomorph and fenamidone). Generated 220 Mb data of *P. infestans* A2 (Ib mt DNA haplotype) using nano pore platform and generated enough reads to cover the whole genome and assembled. Developed Loop mediated isothermal amplification (LAMP) assay for detection of PVX, PLRV and *P. infestans*; simplified nucleic acid release protocol for RT-PCR based detection of potato viruses; dipstick kit for detection of PVX using commercial antibodies; PCR based diagnostics for phytolasma, multiplex RT-PCR for PVA, PVX & PVS, and sequence specific real-time detection of PVA, PVM, PVX, PVS & PSTVd. The Indo-Blightcast model was used to predict the appearance of late blight across the agro-ecologies and it predicted late blight accurately across the country and accordingly agro-advisories were issued to respective regions. Transcriptome analysis of differentially expressed genes (DEGs) in Kufri Bahar and Kufri Pukhraj upon ToLCNDV-potato infection revealed the role of genes involved in biological process, molecular function and cellular component. Effect of viruses infection on development of late blight revealed that development of late blight is affected by virus infection and virus-infected plants had less development of *Phytophthora infestans* (except PVS) than were healthy ones. However, interaction depends

on host genetic background too. Application of dimethomorph (0.2%), ametoctradin + dimethomorph (0.2%), azoxystrobin + tebuconozol (0.1%), mandipropamid (0.1%) and phenomidon + mancozeb (0.3%) was found effective against late blight. Application of phosphorous acid reduced blight severity considerably (20-23%) and reduction was more in susceptible than moderately resistant cultivar. Some bacterial endophytes have shown promising results against *P. infestans* and *Streptomyces scabies* under *in-vitro* conditions.

Aphids, whiteflies, leafhoppers and mites were monitored at Gwalior, Jalandhar and Modipuram on seed and ware potato crop. At Jalandhar, the population of leaf hoppers, *Empoasca fabae* Harris and *Amrasca biguttula biguttula* (Ishida) was initially high and declined overtime. At Modipuram, the yellow sticky traps data revealed that maximum aphids, whitefly and hoppers were recorded in 51st, 48th and 47th standard week of the year 2017, respectively. The draft whole genome sequence data of *Aulacorthum solani* (Kaltenbach) was completed. To control the sucking pests/vectors knockdown and residual toxicity of Potassium silicate (technical grade), Flonicamid, Clothianidin and Imidacloprid to *M. persicae* and adult whiteflies and the subsequent reduction in viral disease incidence were evaluated. Screening of ten varieties including newly released varieties Kufri Neelkanth, Kufri Ganga and Kufri Lima and three genotypes -MS/7-645, MS/8-1148 and MS/0042 against whiteflies in net house indicated least preference to MS/0042. Regarding identification studies on nematode, *Globodera rostochiensis* (Gr-LAMP) and Gp-Cyt and Gp-Cytb for the detection of *Globodera pallida* (Gp-LAMP) was developed and validated. *S. sisymbriifolium* was found to have high degree of resistance against both the species of PCN as no PCN females were observed on roots. The native strains/species of EPNs *Steinernema* CPRSUS01 were extracted and identified. Studies on Dazomet revealed that Dazomet @ 30 g/m² showed highest yield with significant reduction in PCN population.

Division of Crop Production

In Climate change programme research were completed on calibration of WOFOST crop growth model for potato cultivars Kufri Lalit and Kufri Arun, carbon footprints of potato production, effect of water levels and mulching on potato under drip irrigation, effect of water levels and mulching on potato under sprinkler irrigation, soil moisture content and soil temperature as influenced by water levels & mulch under micro-irrigation, evaluation of drip and

sprinkler irrigation methods with or without mulch, identification of climate resilient potato cultivars in relation to rising CO₂ level and temperature, potential impact of climate change on potato late blight outbreak in Punjab using Indo-Blightcast model, appearance of late blight and insect-pests in climate analogues, effect of different dates of planting on late blight development in varieties having varying degree of resistance, and periodic generation of data on arrival and build-up of aphid and whitefly population on potato.

In Resource optimization programme, major output was in seed potato production, micro-propagation potential of potato cultivars, yield gap analysis, Indian good agricultural practices (GAP) for production of potatoes, organic potato production, potato based cropping systems, long term plant nutrition studies, agro-techniques of potato cultivars for *kharif* season in southern Karnataka and mechanical technologies for potato cultivation.

In Nutrient management programme, real time N management by fine tuning top dressing using leaf SPAD value, experiments for validation and calibration of QUEFTS model, omission plot experiments, optimization of phosphorus dose in potato, optimizing fertilizer requirement for potato cultivars Kufri Girdhari and Kufri Himalini, microbial consortium, effect of zinc and iron sources on tuber content, developed variety specific water and nutrient management schedule under limited water availability and worked out N requirement of newly released potato variety through drip fertigation.

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) in Bihar. Mean total losses of 8.6 and 4.0% were recorded during harvesting and at curing, sorting, grading and packaging stages, respectively. Mean losses during storage by following the farmers' practice ranged between 6.2 to 6.5%. Losses were the minimum (2.53%) when potatoes were stored at 10-12°C up to three months followed by 4.02% at 2-4°C. At wholesalers, retailers and consumers level also the potatoes treated with CIPC showed lower losses compared to 2-4°C stored potatoes. Large scale studies to evaluate volatile compounds for sprout suppression in potatoes revealed that menthol effectively controlled sprouting in Kufri Chipsona-1 at 12°C up to 6 months of storage without any adverse effect on

processing quality, taste and flavour of tubers. A significant negative correlation could be established between thickness of periderm and total weight loss at 30 and 60 days. Antihypertensive compounds in form of ACE (angiotensin converting enzyme) inhibitors were detected in six potato varieties and out of these three varieties had antidiabetic properties as well in their tubers. To detect the rancidity development, different oils and multiple fryings were performed and it was found that free fatty acids development was the least with olive oil with minimum rancidity in form of thiobarbituric acid (TBA). However, the free fatty acids remained less than 3%, which means that the tested oils are safe for up to five fryings. A process for thermally processed ready to eat steam cooked potatoes was standardized, which can be used for long term storage and finally utilized for cooking when desired. Potato based gluten free cookies were developed by replacing wheat flour with other cereal flours and potato matrix. Potato starch was used for the development of biodegradable disposable table wares e.g. plates, bowls. The strength of table wares was good since they are starch based, it is expected that they are safe in terms of environment creating an avenue for potato waste utilization.

Division of Seed Technology

In Seed production, a total production of 28609.62 qtls nucleus and breeder seed was achieved from an area of 138.834 ha. Out of which, 23241.73 qtls production from 114.671 ha was through conventional and 5367.89 qtls from 24.163 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from conventional system was 81.24 and 18.76 through hi-tech system. During 2016-17, total 22385.59 qtls breeder seed was supplied to various government and private agencies, from plains. During 2017, a total production of 1019.49 qtls of nucleus and breeder seed was achieved from 5.01 ha area in hills. A total quantity of 764.75 qtls breeder seed was supplied to different government and private agencies from hills. A total 263 virus-free *in vitro* culture tubes of basic seed material of 14 varieties were supplied to 30 different seed producing organizations in India. A total of 87000 aeroponic minitubers of different varieties were produced under aeroponics. A total of Rs. 8.9 crores/- has been generated by the sale of breeder seed/ microplants/ aeroponic minitubers under Revolving Fund Scheme.

In Seed research, the results revealed that aerial aeroponic tubers can also be used as a source of seed like aeroponic minitubers without doubt. Increases in crop duration beyond 120 days in hills may result in higher productivity. Significant interaction between

pH levels and genotype for number of nodes was observed suggesting the need for standardizing variety/ genotype specific pH levels of the media. Highest tuber number/m² was produced with 15x10cm spacing, followed by 15 x 15 cm in spring-summer crop under Shimla conditions. Under-size tubers in K. Chandramukhi reduced by 21.0% in double net over control. Similar was pattern in K. Gaurav and K. Himalini. Electrical conductivity of less than 3dS/m (EC 1) throughout the crop period was found to be superior.

Division of Social Sciences

During this year, a survey for assessing varietal adoption pattern and cost of cultivation of potato in Madhya Pradesh was conducted by interviewing 100 farmers of Indore, Ujjain and Dewas districts of Madhya Pradesh. The results revealed that Kufri Jyoti was the most popular variety in Indore (49 %) and Dewas (48 %) districts and Kufri Chipsona-1 (51 %) and Chipsona-3 (41 %) in Ujjain. The average cost of potato cultivation was found to be ₹ 1, 08,085/- per ha during 2016-17. A survey from 85 farmers of Bulandshahr and Meerut districts of UP for estimation of the adoption level of farmers revealed that majority of farmers (76.47 %) had medium level of adoption, which was followed by low (12.94 %) and high (10.59 %). The technologies like use of improved varieties, maintenance of plant to plant and row to row spacing, optimum seed rate, pre-sprouting of tubers, irrigation interval and late blight management were followed by majority of farmers. In a survey conducted in Vaishali and Saran districts of Bihar, *Bhura aloo* and C-1/C-40 were the major varieties covered more than 55 % of the total potato area. For estimation of consumers' preferences for potatoes, in Jalandhar (Punjab), Meerut (UP) and Shimla (Himachal Pradesh) following was observed: taste > shelf life =tuber size > cooking time > skin color > shape > flesh color > skin smoothness > texture > aroma >eye's depth. A survey for identifying productivity constraints showed that farmers were lack of seeds of HVVs, irrigation water, labor, disease infection (especially late blight) and poor quality seeds. Moreover, a total of 93 FLDs were laid out in various districts of UP, Bihar, HP, Meghalaya and Tamil Nadu. The Division also conducted several national and international training programmes of different duration (1-21 days) which include Summer School training and Model training course at the headquarter and also at regional stations. Many exhibitions, fairs, celebration of important days, chat shows, etc were also organized by the Division. Expert scientists from different discipline of CPRI Shimla participated in 9 live phone-in programmes on Doordarshan Shimla.

Research Programmes

Institute Research Programmes, PIs and Co-PIs

1.	Management and enhancement of potato germplasm HORTCPRICIL201500100 12	PI: Dr. Vinod Kumar. Co-PIs: Drs. Vinay Bhardwaj, SK Luthra, Raj Kumar, JK Tiwari, Dalamu, G. Vaneshree, Tanuja Buckseth, Shambu Kumar, RP Kaur, Sanjeev Sharma, Salej Sood, Baswaraj R, Jeev Latha, Ravinder Kumar, Kamlesh Malik, S Roy, Arvind Kumar Jaiswal, Bandana, EP Venkatasalem, DK Lekshmanan, PH Mhatre, Name Singh, Jagdev Sharma, Som Dutt and Clarissa Challam
2.	Breeding to evolve trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses HORTCPRICIL201500200 130	PI: Dr. SK Luthra. Co-PIs: Drs. VK Gupta, Raj Kumar, Babita Chaudhary, RP Kaur, Shambu Kumar, Sarla Yadav, Mehi Lal, Sanjay Rawal, Bandana, AK Jaiswal, Vinay Bhardwaj, Salej Sood, Dalamu, G. Vanishree, Vinod Kumar, EP Venkatasalam, DK Lekshmanan, Sanjeev Sharma, S. Sundaresha, R Baswaraj, Ravinder Kumar, Aarti Bairwa, PH Mhatre, Clarissa Challam, Brajesh Singh, Devendra Kumar, Name Singh, Som Dutt, Kamlesh Malik, JK Tiwari, Pinky Raigond, VK Dua, Jagdev Sharma, Manoj Kumar, Prince Kumar and Hemant Kardile
3.	Genetic enhancement of potato through molecular and genomic tools. HORTCPRICIL201500300 131	PI: Dr. Jagesh Kumar Tiwari. Co-PIs: Drs. S Sundaresha, Vinay Bhardwaj, Hemant Kardile, Brajesh Singh, Sanjeev Sharma, Som Dutt, G Vanishree, Clarissa Challam, VK Dua, RP Kaur, Shashi Rawat, SK Luthra, Tanuja Buckseth, RK Singh, Devendra Kumar, Vinod Kumar, Salej Sood, EP Venkatasalem and PH Mhatre
4.	Impact, adaptation and management strategies for climate resilient potato production HORTCPRICIL201500200 139	PI: Dr. VK Dua. Co-PIs: Drs. Sanjay Rawal, Devendra Kumar, Jagdev Sharma, Shashi Rawat, Name Singh, SP Singh, Prince Kumar, Paresch Chaukhande, Sunayan Saha, Sanjeev Sharma, Mehi Lal, Kamlesh Malik, Anuj Bhatnagar, VK Gupta, Vinay Sagar, Som Dutt, Hemant Kardile, Brajesh Nare, Mohd. Abbas Shah, Sushil Kumar, Subhash Katare, 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 HORTCPRICIL500500133	PI: Dr. Manoj Kumar. Co-PIs: Drs. VK Dua, Name Singh, Jagdev Sharma, Raj Kumar, Prince Kumar, SP Singh, Bapi Das, Shashi Rawat, Pooja Mankar, DK Lekshmanan, Dalamu, VU Patil, Sarla Yadav, Sushil Kumar and Yogesh
6.	Biology, epidemiology, modeling and management of insect pests, vectors and cyst nematodes of potato. HORTCPRICIL201500600 134	PI: Dr. (Mrs.) Kamlesh Malik. Co-PIs: Drs. Anuj Bhatnagar, Sridhar Jandrajupalli, Aarti Bairwa, Jeevalatha A, Baswaraj R, 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, Priyank Matre and Subhash Katare

7.	Re-defining epidemiological parameters and management approaches for potato pathogens. HORTCPRICIL201500800135	PI: Dr. Sanjeev Sharma. Co-PIs: Drs. Vinay Sagar, A Jeevalatha, Baswaraj R, S. Sundaresha, Ravinder Kumar, Gaurav Verma, S Roy, Mehi Lal, Shashi Rawat, Anuj Bhatnagar, PH Mhatre, Mohd. Abbas Shah, EP Venkatasalam, J Sridhar, Kamlesh Malik, Subhash Katare, Prince Kumar, MJ Sadawarti, Subhash Chand and Islam Ahmad
8.	Post-harvest management and nutritional enhancement of potatoes HORTCPRICIL201500800136	PI: Dr. Brajesh Singh. Co-PIs: Drs. Jagdev Sharma, SK Luthra, Vinay Bhardwaj, Vinay Sagar, Som Dutt, Pinky Raigond, Baswaraj Raigond, Bandana, S Sundaresha, RP Kaur, Dalamu, Dhiraj K Singh, Sanjay Rawal, Hemant Kardile, Pynbianglang Kharumunid, AK Jaiswal, Alka Joshi (IARI), Vineet Sharma, Yogesh Gupta and Shelly Chopra
9.	Resource optimization in potato based cropping system HORTCPRICIL201500900137	PI: Dr. Sanjay Rawal. Co-PIs: 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, Murlidhar Sadawarti, Mehi Lal, RP Kaur, Sugni Devi, Bandana, Tanuja Buckseth, Pooja Mankar, Prince Kumar, Clarissa Challam, , Pynbianglang Kharumunid, DK 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. Co-PIs: Drs. RK Singh, Pynbianglang Kharumunid, Dhiraj Kumar Singh and Ashok Chauhan
11.	Production of breeder seed of potato through conventional and hi-tech system HORTCPRICIL201501100132	PI: Dr. RK Singh. Co-PIs: Drs Tanuja Buckseth, Ashwani Kumar Sharma, Manoj Kumar, Vinay Singh, Dhruv Kumar, Raj Kumar, Prince Kumar, RP Kaur, S Roy, SP Singh, Subhash Katare, MJ Sadawarti, Shambhu Kumar, RK Singh, Clarissa Challam, EP Venkatasalem, Sugani Devi, Mohd. Abbas Shah, Parvesh Jassal, Sumita Sharma, RK Verma, Balak Ram Singh, KP Singh, Harveer Singh, NK Sood, Jasvir Singh, Santosh Kumar, Pushpender Kumar, Satinder Kumar, Kapil Kumar Sharma, Akhilesh Kumar, Arun Kumar Singh, YP Singh, Surinder Singh, RK Samadhiya and Sanjay Sharma

PI and Co-PIs are based on the Institute Activity Milestones 2017-18.

Division of Crop Improvement

Programme: Management and enhancement of potato germplasm

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 44 accessions were imported including 8 from the

Netherlands, 32 from USA and 4 from Canada. The present germplasm collection at CPRI consists of more than 4300 accessions of cultivated and wild species imported from 30 countries.

Table 1. Potato germplasm holding at CPRI, Shimla

Material	No. of accessions				No. of donor countries
	Tuber	<i>In vitro</i>	True seed	Total	
a) Tuberosum (Cultivars / parental lines)					
Indian					
Cultivars bred at CPRI	56	56		56	
Advanced hybrids	86	50	-	96	
Indigenous varieties	51	107	-	107	
Indigenous samples	97	42		97	
Exotic	1837	2550	-	2625	30
b) Andigena	758	77	-	762	5
c) Wild/ semi-cultivated sps.	123 (40 species)	58 (15 species)	340 (71 species)	482 (125 species)	5
Total germplasm				4322	

Conservation

Field conservation: One thousand five hundred and eighty six Tuberosum accessions, 758 Andigena accessions and 69 indigenous samples were maintained in fields at Jalandhar. Nearly 1425 Tuberosum accessions and 90 indigenous samples including 3 dihaploids were maintained in fields at Kufri. In wild species, 352 clones of 123 accessions representing 40 *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

***In vitro* conservation:** Nearly 2550 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. During this year, 6

advance hybrids / varieties namely MS/06-1947, MS/08-1565, MS/4-578, MS/9-723, MS/09-91 and Kufri Lima were found free from all viruses.

Pollen cryopreservation of potato germplasm: The extracted pollen grains of varieties K. Chipsona 1, K. Pukhraj, K. Pushkar and K. Lauvkar were cryo preserved after packing in gelusil capsules, kept in cryo-vials and immersed in liquid nitrogen cryocan for future use. The proportion of the viable pollen types varied in fresh pollen samples of varieties i.e. 14.32 % in K. Chipsona 1, 15.51% in K. Pukhraj, 14.27% in K. Pushkar and 1.71 % in K. Lauvkar. The viability of one and two year old samples stored at -20° C and -80°C were also recorded. Viability of pollen grains was confirmed in two-year and three-year old samples of K. Himalini, K. Himsona and K. Girdhari stored at -80° C. However, for storage of pollen at -20° C viability was ascertained in two-year old samples but not in three-year old samples. These pollen grains were also utilized for making crosses, where berries were observed to be formed for two and three year old samples stored at -80°C and two year old samples stored at -20°C.

Evaluation: As in previous years, a large number of accessions were evaluated for various biotic and abiotic stresses and also for adaptability and

physico-biochemical qualities. Promising accessions identified in these evaluations are listed in Table 2.

Table 2. Evaluation of potato germplasm

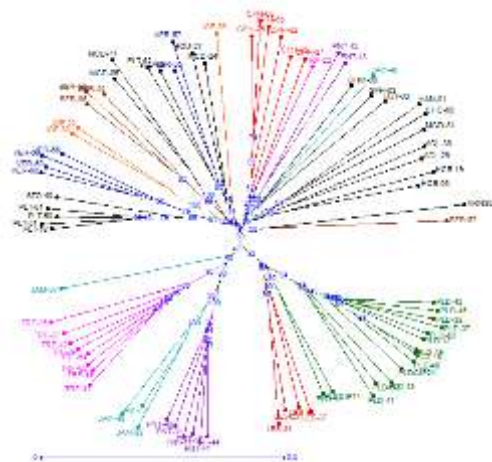
Character	Location	No. of accessions evaluated	Promising accessions*
Adaptability	Kufri	150	CP 3036, CP 2468, CP 4430, CP 4428 and CP 4429
	Jalandhar Spring	100	CP 4393 and CP 4399 out yielded the best control Kufri Jyoti (380 g/plant)
	Modipuram Autumn (early)	76	Kufri Garima, MCIP/12-286, MP/12-415, MS/0-3740 and MS/0-3808
	Autumn (Main)	93	CP 4517, K. Garima, CP 4507, Kufri Mohan Rajendra -3, JX-455, CP 4506 and CP 4504.
Late blight Foliage	Kufri (field)	115	10-HR; 7-R; 45-MR (Promising CP Nos. 2402, 3168, 3170, 3183, 3197, 3203, 4387, 4428, 4429 and 4430)
	Shillong (field)	407	21-HR; 8-R; 37-MR (Promising CP Nos. 1012, 1187, 1324, 1736, 1750, 2012, 2075, 2161, 3765, 3768, 3770, 3774, 4051, 4065, 4106, 4118, 4138, 4174, 4220, 4221 and 4228)
	Shimla (Lab)	63	15-R (CP Nos. 2072, 2103, 3022, 3512, 3762, 3773, 3845, 3850, 3888, 3961, 3984, 4402, 4429, 4430 and 4508) and 28-MR
Tuber	Shimla (Lab)	63	8-HR (CP Nos. 2103, 3845, 3850, 3888, 4080, 4269, 4393 & 4430); 13-R and 9-MR
Viruses: PVX & PVY	Shimla	54	Twenty-one accessions namely CP Nos. 1326, 1418, 1584, 1766, 3322, 3421, 3454, 3470, 3582, 3710, 3772, 3968, 3982, 4086, 4221, 4393, 4370, 4387, 4393, 4411 and 4517 had combined resistance to PVX and PVY
PSTVd	Shimla	100	32 accessions were infected.
Leaf hopper and Mites	Modipuram	184	11 genotypes (CP Nos. 3619, 3635, 3639, 3641, 3647, 3673, 3678, 3681, 3687, 3689 and 3699) had <5% burn for both mite and leaf hopper.
Cyst nematodes	Ooty	55 (A) + 191 (T)	7 Andigena (A) accessions and 36 Tuberosum (T) accessions were found resistant to both the species of PCN, <i>G. rostochiensis</i> and <i>G. pallida</i> .
Keeping quality	Jalandhar	69	20 accessions (CP 4490, CP 4512, CP 4514, CP 4519, U-325/1, U-576/36, U-521/21, U-414/23, U-568/7, U-327/24, U-552/6, U-

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

Genetic enhancement of Tuberosum: With the objective to select early maturing late blight resistant clones, 71 advanced clones were evaluated for late blight at Kufri and for foliage maturity at Patna. Clones viz., TE.12-09, TE. 12-13, TE. 12-64, TE. 13-03, TE.13-24 & TE.13-26 were found to have resistance to late blight and early foliage maturity.

Wild Species

Diversity analysis of wild potato species by SSR markers Allelic variation in wild potato (*Solanum*) species using SSR markers was investigated. SSR



allelic profiles showed high polymorphism and distinctness in the wild species using 14 markers. Cluster analysis of 82 accessions of 22 wild species based on the Jaccard's coefficient by UPGMA method distinguished all the accessions. To save the resources, a three-markers-set (STM0031, STM1106 and STM0037) was identified to distinguish the accessions.

Screening for Late blight resistance: In order to diversify the sources of resistance to late blight in

potato breeding programmes, under natural epiphytotic conditions at Shimla, 80 clones of 42 accessions of 21 different wild potato species were screened for foliar late blight resistance. Based on AUDPC values 21 clones of 10 species were highly resistant, while 2 clones of 2 species viz., *S. spegazinii* and *S. chacoense* were resistant (Table 3). Ten clones of 7 species were moderately resistant. Remaining 47 clones (58.7% of total clones evaluated) were susceptible.

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

Level of resistance	Promising Clones (Species)
Highly resistant	1724-30 (<i>S. sparsipillum</i>), 1847-02, 1848-17, 1848-21, 2425-01 (<i>S. demissum</i>), 2169-06 (<i>S. bulbocastanum</i>), 2267-03, 2619-03, 2619-04 (<i>S. spegazinii</i>), 2379-01, 2686-13, 2781-21 (<i>S. tuberosum</i> ssp. <i>andigena</i>), 2710-12 (<i>S. stoloniferum</i>), 2846-0 (<i>S. berthoultii</i>), 2937-01, 2937-02 (<i>S. chacoense</i>), 3005-16, 3005-16, 3005-21, 3006-04 (<i>S. kurtizianum</i>), 3102-01 (<i>S. iopetalum</i>).
Resistant	1725-26 (<i>S. spegazinii</i>), 2937-0 (<i>S. chacoense</i>)
Moderately resistant	2279-02, 2610-02 (<i>S. microdontum</i>), 2379-0, 2781-11, 2781-24, (<i>S. tuberosum</i> ssp. <i>andigena</i>), 1725-0 (<i>S. spegazinii</i>), 1825-11 (<i>S. cardiophyllum</i>), 1847-05 (<i>S. demissum</i>), 2713-07 (<i>S. stoloniferum</i>), 2894-0 (<i>S. brevicaule</i>).

Table 4. Screening of wild potato species for foliar blight resistance in open condition

Sl.	Germplasm	Registration Number	Salient features
1.	VMT 5-1	INGR17061	Late blight resistant, widely adapted meiotic tetraploid potato hybrid developed by unilateral sexual polyploidization (USP) scheme.
2.	Crd-6	INGR17062	Late blight resistant, tetraploid & male fertile interspecific potato somatic hybrids produced by protoplast fusion between the dihaploid <i>Solanum tuberosum</i> 'C-13' and the wild potato species <i>S. cardiophyllum</i> .
3.	MS/6-1947	INGR17063.	Drought tolerant advanced potato hybrid possessing high tuber yield and good keeping quality.
4.	MS/8-1565	INGR17064	Purple skin coloured specialty advanced potato hybrid having high tuber yield and very good keeping quality.
5.	MP/6-39	INGR17065	Processing advanced hybrid with excellent keeping quality and high tuber yield.

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. Five genetic stocks were registered with NBPGRI, New Delhi (Table 4)

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 and selection: In all, 2, 84, 826 true potato seeds were obtained from 167 crosses attempted by Jalandhar, Modipuram and Patna center. A total of 92,549 seedlings were raised in field from sowing of 2, 01,779 true potato seeds of 167 crosses. At harvest, 11,071 promising clones were selected. In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 11,481 clones were evaluated at 60/75/90 days. At harvest 2,674 promising clones were selected. In all, 105 advanced stage hybrids were evaluated in 12

replicated yield trials at 60/75/90 DAP at Jalandhar, Modipuram and Patna, and 50 promising hybrids were selected.

Promising advanced stage hybrids identified: Based on consistent good performance over the years, six hybrids namely J/10-91 (J/97-243 x Kufri Khyati), J/10-148 (PS/M75 x J/93-139), MS/12-2116 (Kufri Surya x CP2340), MCIP/12-185 (CP4047 x K Pukhraj), PS/11-47 (K. Arun x CP 3192) and PS/11-86 (PS8/97-1 x PRT-19) were identified (Tables 1, 2, 3, 4 & Fig. 1).



Fig. 1. Promising advanced stage hybrids

Table 1. Promising advanced hybrid identified at Jalandhar

Genotypes	Total tuber yield(t/ha)							
	2015-16		2016-2017		2017-2018		Average	
	60 days	75 days	60 days	75 days	60 days	75 days	60 days	75 days
J/10-91	27.4	33.0	23.4	32.9	13.7	30.1	21.4	32.0
J/10-148	28.4	37.5	27.4	38.5	20.7	36.5	25.5	37.5
K. Pukhraj	24.2	30.5	23.3	30.5	13.9	23.6	20.5	28.2
K. Khyati	24.1	30.4	22.9	30.7	14.3	24.1	20.4	28.4
CD (0.05)	1.96	2.22	2.01	2.07	0.9	1.7		

Table 2. Promising advanced hybrid identified at Modipuram

Genotypes	Total tuber yield (t/ha)							
	2015-2016		2016-2017		2017-2018		Average	
	75 days	90 days	75 days	90 days	75 days	90 days	75 days	90 days
MS/12-2116	33.32	40.02	39.95	47.41	41.93	52.72	38.40	46.72
K Bahar	28.68	30.08	35.33	33.69	38.76	48.77	34.26	37.51
K Garima	35.65	44.10	36.15	52.30	46.09	57.55	39.30	51.32
K. Pukhraj	35.60	41.27	33.06	45.37	41.60	56.32	36.75	47.65
CD (0.05)	2.68	2.79	1.90	1.63	2.15	2.79		

Table 3. Promising advanced hybrid identified at Modipuram

Genotypes	Total tuber yield (t/ha)							
	2015-2016		2016-2017		2017-2018		Average	
	75 days	90 days	75 days	90 days	75 days	90 days	75 days	90 days
MCIP/12-185	33.71	49.94	34.18	49.46	41.71	48.80	36.53	49.40
K Bahar	34.15	43.86	33.32	36.32	37.92	45.40	35.13	41.86
K Garima	46.38	57.60	41.14	50.29	44.19	53.19	43.90	53.69
K. Pukhraj	41.78	51.20	41.11	50.29	43.79	47.65	42.23	49.71
CD (0.05)	2.70	2.16	2.70	2.16	2.19	1.84		

Table 4. Promising advanced hybrid identified at Patna

Genotypes	yield (t/ha)							
	2015-2016		2016-2017		2017-2018		Average	
	75 days	90 days	75 days	90 days	75 days	90 days	75 days	90 days
PS/11-47	25.48	32.98	37.45	27.39	36.28	28.62	36.87	
PS/11-86	24.98	30.15	37.22	29.34	37.03	28.16	37.13	
K. Lalit	26.15	24.56	29.08	23.38	32.34	24.70	30.71	
K. Lalima	11.03	20.12	24.53	21.87	27.91	17.67	26.22	
CD (0.05)	2.11	2.07	2.05	4.36	4.07			

Advanced hybrids introduced in AICRP: MS/11-664 (K. Kanchan x K. Khyati): MS/11-664 (43 t/ha) produced 20, 10 and 19% high total tuber yield than K. Lalima (36 t/ha), K. Lalit (39 t/ha) and K. Sindhuri (36 t/ha) respectively at 90 days (Fig.2).

Recommendation of new potato varieties: New improved potato varieties namely Kufri Ganga,

Kufri Neelkanth and Kufri Lima were recommended for release in 35th group meeting of ACIRP (Potato) held during 16-18 September, 2017 at BCKV, Kalyani, West Bengal (Fig.3).

Optimizing agro-technology for variety Kufri Mohan: Two years investigation for optimizing crop geometry of K. Mohan suggested that this



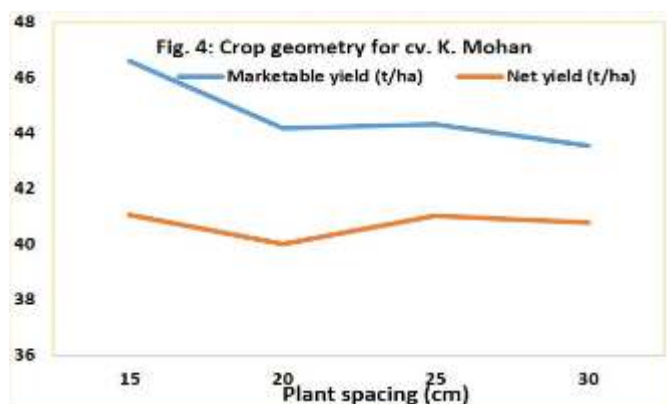
Fig.2 MS/11-664- Leaf, flowers, tubers and sprout



Fig.3 Tubers of new potato varieties

variety may be planted at 60 cm row spacing, while keeping plant spacing at 20 cm based upon net marketable yield ranging between 40-41 t/ha at different plant distances (Fig. 4).

Optimizing agro-technology for Kufri Ganga: In 90 days crop duration economic optimum dose of nitrogen (261 kg N/ha), phosphorous (80 kg



P_2O_5 /ha) and potassium (132 kg K_2O /ha) was computed based upon marketable tuber yield (41-44 t/ha). Crop geometry of 60 X 20 cm was found better for higher marketable (41.7 t/ha) and net marketable yield (37.5 t/ha).

Optimizing agro-technology for variety Kufri Neelkanth: The variety responded up to 240 kg nitrogen (37.1 & 40.5 t/ha), 40 kg phosphorous (37.0 & 39.5 t/ha) and 50 kg potassium (32.4 & 35.3 t/ha)

per hectare for marketable and total tuber yield, respectively at 90 days crop duration.

Evaluation of advanced stage hybrids for late blight resistance at Modipuram: Results on screening for late blight on fifty seven advanced stage hybrids along with 18 varieties in field (88, 93, 101, & 109 days) and lab condition revealed that all the hybrids possessed less AUDPC than highly susceptible variety Kufri Bahar (1140).

Research activity 2: Breeding for processing varieties

Hybridization and selection: In total, 1, 29, 879 TPS of 66 crosses were produced at Kufri/Modipuram. A total of 89,492 TPS of 37 crosses from were sown in nursery bed and 927 clones were selected from 21,825 seedlings transplanted at Modipuram. A total of 591 clones of F_1C_1 , 92 clones in F_1C_2 and 60 clones in F_1C_3 generation were evaluated and 169, 41 and 18 clones were retained respectively based on tuber characters and chip colour. In F_1C_4 generation 8 genotypes were selected out of 11 hybrids tested.

Identification of advanced hybrid for AICRP: Hybrids MP/9-45 (K Himsona x CP 1371) and MP/9-73 (MP/97-921xHT/97-727) were identified for introduction to AICRP (Potato) (Table 5,6).

Table 5 Identification of processing advanced Hybrids MP/9-45 and MP/9-73 at 90 days

Genotypes	Processing tuber yield (t/ha)					Total tuber yield (t/ha)				
	2017-18	2016-17	2015-16	2014-15	Mean	2017-18	2016-17	2015-16	2014-15	Mean
MP/9-45	42.5	26.1	29.7	21.4	29.9	47.3	30.6	38.0	26.9	35.7
MP/9-73	35.2	26.4	28.1	21.2	27.7	42.4	30.7	35.4	27.8	34.1
K. Chip-1	32.8	25.1	24.2	16.0	24.5	39.6	31.5	34.2	26.5	33.0
K. Chip-3	38.0	25.7	25.0	21.7	27.6	43.5	30.6	35.9	29.6	34.9
K. Chip-4	37.0	26.0	27.1	20.1	27.6	42.2	31.6	34.8	27.3	34.0
ATL	37.8	23.2	29.3	20.8	27.8	40.1	26.9	33.6	27.1	31.9
C.D. 5%	2.5	1.8	2.8	1.93		1.9	1.6	3.02	1.74	

Table 6. Quality attributes of advanced Hybrids MP/9-45 and MP/9-73 at 90 days

Genotype	Tuber dry matter (%)	Chip Colour	Reducing Sugar	Sucrose
	Mean of four years 2014-15 to 2017-18			2016-17 & 2017-18
MP/9-45	21.4	3.3	97.1	154.7
MP/9-73	22.5	3.5	119.4	179.1
K. Chip-1	21.2	2.9	98.9	180.3
K. Chip-3	20.8	3.6	130.4	228.2
K. Chip-4	21.5	4.4	138.9	214.9
ATL	20.4	3.5	93.3	152.5

RS/Sucrose= reducing sugar/ Sucrose (mg)/ 100g Fresh weight

Advanced stage hybrid introduced into AICRP: MP/10-172 (K Chip-1 × CP 3771) for chipping was introduced in AICRP based on performance during 2014-15-2016-17 at Modipuram. MP/10-172 produced 5% higher mean processing (26 t/ha) and

19 % higher total (35 t/ha) tuber yields than Atlantic (24 and 29 t/ha) and K Chipsona-3 (24 and 32 t/ha). The hybrids possess 20% dry matter and acceptable chip colour score (2.6) (Fig. 5).



Fig. 5. Leaf, flower, sprouts and tubers of MP/10-172

Tuber yield and processing quality of genotypes at Jalandhar: Among the 13 processing genotypes evaluated for yield and processing quality at 90 days, all genotypes recorded yield at par or better than control cultivars. Maximum total tuber yield was recorded in MP/11-221 followed by MP/11-34 and MP/10-172. Maximum fry grade yield was recorded in MP/11-34 followed by MP/09-73 and

MP/10-172. Chip grade yield was maximum in MP/11-221 followed by MP/11-37. All genotypes recorded >19 % dry matter at harvest. Bio-yield point (at which the probe punctures through the skin) of all advanced hybrids was higher than control cultivars (Fig. 6.).

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

Hybridization and selection: In all, 168,085 true potato seeds were obtained from the 74 crosses.

A total of 14,850 seedlings of 25 crosses were screened under controlled conditions against complex races of *P. infestans* and a total of 1370 resistant seedlings were obtained. At harvest, 187 clones were obtained from the resistant seedlings. In initial clonal stages (F_1C_1 to F_1C_4), 568 clones were evaluated and 166 clones were selected under natural field conditions at Kufri. At Ooty, 166 from 500 clones while at Shillong 202 from 500 clones were selected. In F_1C_5 stage, SM/11-120 yielded

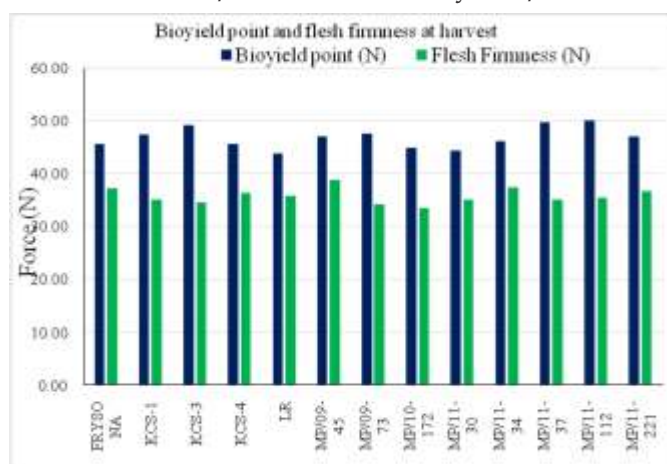


Fig. 6. Bio-yield point of advanced hybrids

significantly higher to all the controls and also showed immune reaction to late blight disease. In F_1C_6 stage, four hybrids were selected from six evaluated and SM/10-103, SM/10-118 and SM/10-178 yielded significantly better than the best control K. Girdhari. At Ootacamund, OS/08-8 recorded maximum yield than Kufri Girdhari.

Evaluation of medium maturing late blight resistant hybrids: In F_1C_7 stage, nine hybrids along with controls K. Jyoti (both sprayed and unsprayed), K. Himalini and K. Girdhari were evaluated and SM/10-139, SM/09-163 and SM/09-10 yielded significantly higher than the best check K. Himalini. All these hybrids were almost immune to late blight.

Multiplication and screening of advanced hybrids: The hybrid SM/00-42 performed exceptionally better than the control varieties and was found resistant to late blight, PVM, PVS, PVA, PLRV and ToALCNDV. This hybrid also possessed very high dry matter.

Identification of photo-insensitive/day-neutral advanced stage hybrids: Twenty two (22) advanced stage hybrids along with controls were evaluated at Modipuram. Based on consistent performance of the hybrids SM/03-23 and HR/09-04 was identified for introduction in AICRP (P) multi-location trials (Fig. 7).



Fig.7. Promising advanced stage hybrids

Screening of advanced stage hybrids for late blight at Modipuram: Twenty five advanced stage hybrids along with nine varieties were evaluated for late blight resistance. All hybrids showed less AUDPC in comparison to highly susceptible control variety K. Bahar. Minimum AUDPC was recorded in hybrid VMT/5-1 (21) and SM/00-42 (41).

Biochemical parameters of advanced stage hybrids at Modipuram: A total of 22 advanced stage hybrids were analysed for biochemical parameters viz., chip colour (visual), specific gravity, dry matter content, reducing sugars and sucrose content. SM/00-42 (3) and VMT 12-7 (3.2) were found suitable for chips and possessed high dry matter and low reducing sugars.

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 (Ry_{adg} , Ry_{sto}) and potato cyst nematodes ($H1$, HC_QRL and $Gro1-4$) resistance using molecular assisted selection. A total of 23,395 hybrid TPS were extracted from 15 successful crosses.

Characterization of core set for resistance genes: A total of 217 tuberosum and 77 andigena genotypes were screened for presence of resistance genes or linked molecular markers. Results revealed that 18 genotypes were positive for $R1$ gene, 15 possessed $R2$, 22 possessed $R3a$ and 30 possessed $R3b$ gene imparting resistance against late blight. PVY resistance genes, $Rysto$ was present in 51, Ry_{adg} in 17, $STM003$ in 40, $RX1$ in 28, $RX106$ in 20, PCN resistance genes, $TG689$ in 29, HC in 13, $Gro-VI-XO2$ in 28, $RX2-106$ in 10, $GPA2-1$ in 25 and $GPA2-2$ in 29 genotypes.

Characterization of advanced hybrids for multiple resistance: Twelve genotypes including three check varieties were screened for late blight, major potato viruses and potato cyst nematode. All the hybrids showed resistant reaction to late blight. Late blight resistant gene R1 (AS) was present in only two hybrids (SM/08-11, SM/00-120), R2 gene was present in three hybrids (VMT-5-1, SM/00-42, LBY-18), while R3 gene was observed in six hybrids (Fig. 8). RYadg gene for PVY resistance was present in only one hybrid i.e. LBY 18, while STM003 was found in K. Himalini only. For PCN resistance, Gro VI-XO2 was present in five hybrids; SPUD 1636 was found only in check variety K. Jyoti; HC gene present in six hybrids; TG 432 was found in four hybrids and one check variety K. Jyoti.

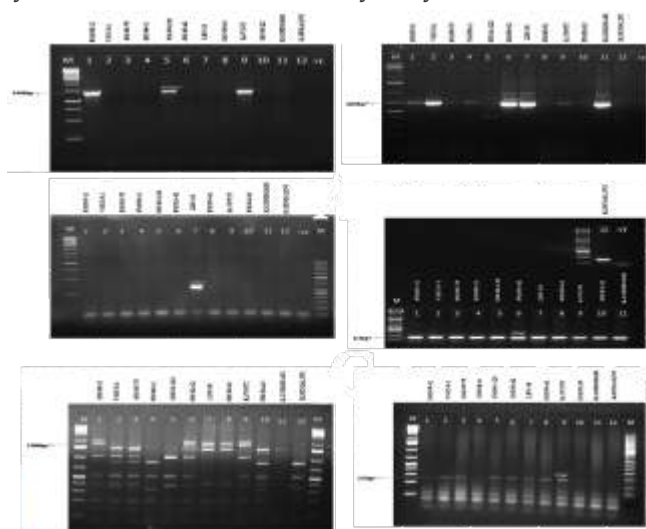


Fig 8: Agarose gel electrophoretic pattern using different R genes A) R1-Late blight B) R2- Late blight, C) *Ry_{adg}*-PVY, D) STM003-PVY, E) TG 432-PCN, F) HC-PCN.

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

Breeding for heat tolerance

Hybridization and selection: A total of 1, 10, 451 TPS were obtained from 74 successful crosses at Kufri /Modipuram involving parents having earliness and heat tolerance. In all 9, 923 seedlings

were recovered from 1, 49,353 TPS of 51 crosses and at harvest 403 selections were made. A total of 85 selections were also made from 564 single tubers derived from 12 crosses screened under heated glass house. In all 391 clones of F_1C_1 , F_1C_2 & F_1C_3 were multiplied and evaluated at Modipuram in winter crop and 88 clones were retained. Among 11 advance stage hybrids, eight hybrids namely, HT/10-1554, HT/13-109 (18 t/ha), HT/12-43, HT/12-751 (17 t/ha), HT/12-830, HT/12-834 (16 t/ha), HT/13-68 and HT/12-116 (14 t/ha) were found to be promising at 75 days early crop as compared to Kufri Lima (18 t/ha) and Kufri Surya (14 t/ha).

Evaluation of advance stage trial at Bhubaneswar, Ladol and Pune: At Bhubaneswar, among 6 hybrids evaluated at 90 days, HT/12-834 and HT/12-116 produced 22 t/ha tuber yield as compared K Surya (25 t/ha). At Ladol, among 7 hybrids evaluated at 90 days, significantly higher total tuber yield was obtained in HT/12-830 (39 t/ha), HT/12-751 (38 t/ha), HT/12-43 (35 t/ha) and HT/12-725 (33 t/ha) as compared to K Surya (30 t/ha). At Pune, among 6 hybrids evaluated under Kharif season at 90 days, significantly higher total tuber yield was obtained in HT/12-725, HT/12-751 (16 t/ha), HT/12-830 (15 t/ha) and HT/12-43 (14 t/ha) as compared to best control K Badshah (13 t/ha).

Identification of promising advanced stage hybrid: Based on consistence performance at Modipuram, hybrid HT/10-1554 (K. Jawahar x YY-6) has been identified for entry into AICRP. It produced 14% higher marketable and total tuber yields respectively over the best control K. Surya (Table 7). It produces white cream ovoid tubers with shallow eyes and yellow flesh. It showed tolerance to mite and hopper burn as compared to Kufri Surya. It possess 19% dry matter, medium dormancy and very good keeping quality. At Ladol, it produced 15% and 16% higher marketable and total tuber yields respectively over the best control K. Surya.

Table 7. Performance heat tolerant advanced stage hybrid HT/10-1554 at Modipuram

Genotypes	Marketable/ha				Mean	Total tuber yield/ha				Mean
	2014	2015	2016	2017		2014	2015	2016	2017	
HT/10-1554	10.5	13.8	14.3	16.4	13.7	11.4	14.2	16.4	17.9	15.0
K.Lauvkar	6.9	11.0	7.1	12.0	9.2	7.8	12.7	9.2	13.3	10.8
K.Surya	7.4	14.4	13.7	14.7	12.5	8.3	15.6	14.4	15.9	13.5
C.D. 5%	1.4	2.0	2.2	2.7		1.3	2.2	2.3	9.5	

Advanced hybrid Introduced into AICRP: Based on three years consistence performance during early planting season at Modipuram, hybrid HT/11-3 (K. Khyati x K. Surya) has been introduced into AICRP. HT/11-3 produced 18% and 24% higher marketable and total tuber yields respectively over the best

control K. Surya. It produces white cream, ovoid tubers with shallow eyes and light yellow flesh (**Fig.9**). The hybrid has 17% dry matter, long dormancy period and very good keeping quality under country store conditions.



Fig 9. Leaf, Sprout and tubers of HT/11-3

Screening against leafhopper burn and mite damage at Modipuram: Amongst the 20 screened, Kufri Bahar had the highest mite damage (15% at 65 days and 63% at 75 days). HT/10-1554 and HT/12-664 had minimum mite-burn (2%) at 65 days and moderate (13% and 8%, respectively) at 75 days. The lowest mite burn at 75 DAP was recorded in Kufri Lima (8%).

Analysis of key stages of potato development being affected by high temperature: In order to

dissect the effect of high temperature on tuberization in different growth stages were analysed when exposed to high temperature (26 °C) *vis-a-vis* normal temperature (18 °C). High temperature was found to affect the tuberization as well as bulking stages of potato development. However, high temperature did not exhibit any significant effect on stolonization process (**Fig 10**). Effect of high temperature on the tuberization and tuber bulking proteins of the (leaf, tubers and stolons) is in progress.



Fig. 10 Tuberization (a) and stolonization (b) in response to high temperature at 80 DAP in Kufri Pukhraj

Breeding for drought tolerance

Hybridization and selection: In all 4320 seedlings were recovered from 18,500 true potato seeds of 10 crosses and at harvest 199 selections were made. In all 216 clones of F_1C_1 , F_1C_2 , F_1C_3 & F_1C_4 were multiplied and evaluated at Modipuram in winter crop and 23 clones were retained at harvest. A total of 15 hybrids were evaluated under water stress and well-watered conditions. Based on all traits, seven hybrids namely WS/09-609, WS/11-344, WS/11-367, WS/12-9-12, WS/12-9-110, WS/12-16-6 and WS/12-16-10 were selected.

Identification of promising hybrid for entry into AICRP: Based on superiority in traits associated with drought tolerance viz. high net photosynthesis, compact phenotype, high stress tolerant index, WS/07-113 has been identified for entry into AICRP. WS/07-113 recorded maximum marketable tuber yield (23 t/ha) under mild water stress (66% watering), which was 38.7% higher over Kufri Bahar (17 t/ha) (**Fig.11**).

Compact phenotype under drought infuse yield superiority: Drought may affect potato growth and production. WS/07-113 was found to have compact



Fig. 11. Tubers of WS/07-113

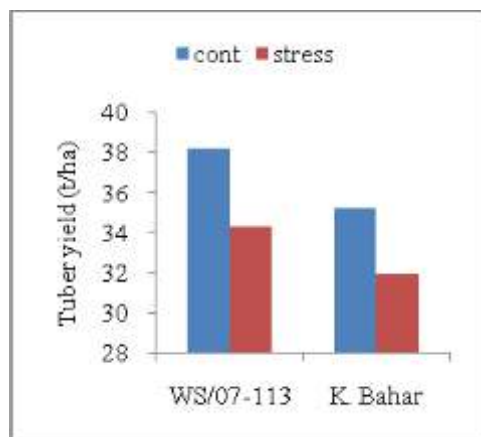


Fig 12a. Tuber yield in potato genotypes under drought

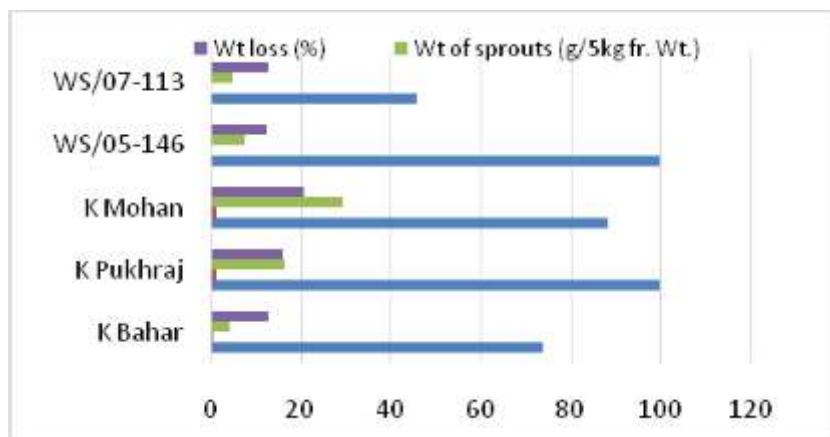


Fig 12b. Keeping quality traits after 90 days storage

Evaluation of advanced hybrids for higher yield & water use efficiency: The advanced water stress hybrids *viz.* WS/07-113 & WS/09-605 produced statistically at par yield with K. Bahar at low irrigation regimes. WS/07-113 & WS/09-605 produced good quality attractive tuber yields followed by WS/09-609 and found water use efficient.

Research activity 5: Development of nutritionally superior varieties

Hybridization and selection: A total of 21,600 TPS were generated from 19 crosses. In all, 18186 TPS of 20 crosses were used for seedling raising and 2059 seedlings were recovered and transplanted in the field. At harvest, 72 promising clones of 12 families were retained. From total of 359 clones of 15 families, 19 promising clones were selected from 6 families. 40 clones of 7 families were evaluated and 11 promising clones were retained. In F_1C_3 stage, 9 clones of cross Bareilly Red x CP3770 were evaluated and 6 promising clones namely MSP/15-26, MSP/15-44, MSP/15-51, MSP/15-56, MSP/15-60 and MSP/15-64 were retained (Fig. 13). The

maximum number of tubers/plant were recorded in MSP15-60 (47 tubers/plant) followed by MSP/15-64 (43), MSP/15-44 (36), MSP/15-51 (32), MSP/15-26 (20) and MSP/15-56 (17). Among the selected clones MSP/15-26 produced at par tuber yield with Kufri Bahar and red skin varieties and also possessed high carotenoids (14 $\mu\text{g/g}$ FW). MSP/15-44 possessed high carotenoids (11 $\mu\text{g/g}$ FW) and Zn (19 mg/kg) in flesh. MSP/15-51 possessed high values of anthocyanin in peel (125 $\mu\text{g/g}$ FW) and anthocyanin (16.70 $\mu\text{g/g}$ FW), ascorbic acid (138 mg/100g FW), Zn (18 mg/kg) and Fe (47 mg/kg) in flesh. MSP/15-56 possessed high flavouring compounds (2.06 $\mu\text{g/g}$ FW) and produced acceptable chip colour score of 2.5 with multi-coloured chips. MSP/15-60 possessed high values of amylose (34%) and Fe (56 mg/kg) in flesh. MSP/15-64 possessed high values of anthocyanin in flesh (6.62 $\mu\text{g/g}$ FW), starch (77% NIRS), carotenoids (15 $\mu\text{g/g}$ FW), flavouring compound (2.78 $\mu\text{g/g}$ FW) and Zn (19 mg/kg) in flesh (Figs. 14-15).

Nutritional profiling of clones: Forty clones of F_1C_1 stage (MS/16 series) were analyzed for anthocyanin

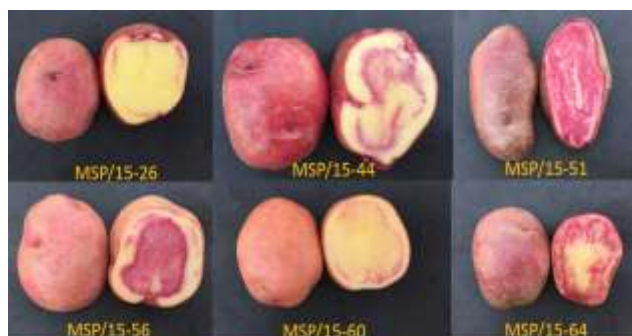


Fig.13. Tubers of nutrient rich clones from Bareilly Red x CP3770

content in tuber peel and flesh, carotenoids and ascorbic acid content. Anthocyanin in peel ($\mu\text{g/g}$ fresh weight) varied from 2.56 to 46.6 while the content in tuber flesh ranged from 1.77 to 9.10 $\mu\text{g/g}$ fresh weight. Total carotenoid was highest in MSP/16-272 (9.17 $\mu\text{g/g}$ fr. wt.) while MSP/16-362 depicted ascorbic acid content of 98 mg/100g fr. wt. In F_1C_2 stage (MS/15 series), nine clones of crosses Bareilly Red x CP 3770 selected from 19 clones, represented the highest anthocyanin and ascorbic acid content (Fig. 16) in tuber flesh of MSP/15-51 (23.57 $\mu\text{g/g}$ fr. wt. and 99 mg/100g fr. wt. respectively). The second highest ascorbic acid content was of MSP/15-56. Total carotenoid content



Fig. 14 Promising clones at F_1C_2 stage with desirable attributes, nutritional superiority & coloured chips

was high in MSP/15- 26 (12.92 $\mu\text{g}/100\text{g}$ fr. wt.). Based on two year nutritional profiling of nine clones (MS/15) developed from cross Barielly Red x CP 3770, clones MSP 15-51 had the highest anthocyanin and ascorbic acid content with medium iron and zinc content. The carotenoid content was at par in MSP/15-64 (highest content) and MSP/15-26 (Table 8)

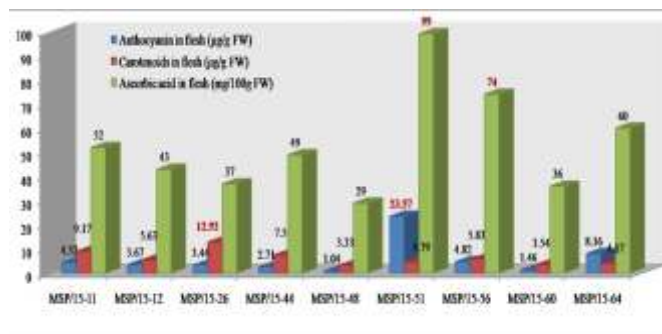


Fig. 16. Nutritional profiling in F_1C_2 stage (MS/15 series)

Table 8. Nutritional profiling of MSP/15 series (mean of 2015-16 and 2016-17)

Genotypes	Anthocyanin flesh ($\mu\text{g/g}$ FW)	Carotenoids flesh ($\mu\text{g/g}$ FW)	Ascorbic acid flesh (mg/100g FW)	Fe (mg/kg) flesh	Zn (mg/kg) flesh
MSP/15-11	6.22	5.96	31.45	30.74	17.83
MSP/15-12	5.43	10.54	24.53	45.15	17.35
MSP/15-26	6.10	14.30	29.40	35.00	16.29
MSP/15-44	3.56	10.51	31.04	42.00	19.06
MSP/15-48	1.90	8.76	16.61	39.26	14.50
MSP/15-51	16.70	8.35	137.84	46.82	18.20
MSP/15-56	4.73	5.51	64.40	33.00	15.67
MSP/15-60	2.31	7.66	22.62	56.00	14.50
MSP/15-64	6.62	15.50	77.27	39.32	18.94
Barielly Red	8.72	14.50	106.00	65.44	10.26
CP 3770	4.04	15.00	22.21	64.50	49.17

Identification of SSR alleles linked to tuber flesh colour: Sixty four progenies (Bareilly Red × CP3770) for tuber flesh colour (**Fig. 17**) characterized by 60 SSR markers. A highly polymorphic and diagnostic SSR marker (STM2005) was identified in the parents for tuber flesh colour and accordingly it showed segregating profiles in the progenies (**Fig. 18**). The STM2005 marker amplified distinct 150, 181, 201 and 229 bp alleles in Bareilly Red, and 150 and 181 bp alleles in CP3770, whereas variable patterns of these four alleles were observed in the progenies. The SSR alleles 201 and 229 bp were specific to the parent Bareilly Red and likely to be associated with purple flesh colour, whereas these alleles were absent in another parent CP3770.

Research activity 6: Breeding for enhanced micronutrient content in potato

In order to develop new potato cultivars with, improved quality, improved nutritional (Zn and Fe content) and health characteristics, 49 clones of F_1C_1 and F_1C_2 stage were screened with respect to important mineral content. Zinc in peeled potato tubers varied from 8.79 mg/kg MSP/16-362 to 23.70 mg/kg in MSP/16-04 with an average value of 16.44 ($3.47 \pm SD$) mg/kg on dry weight basis. Iron content in peeled potato tubers varied from 17.87 mg/kg in MSP/16-307 to 44.57 in MSP/15-12 mg/kg with an average value of 30.93 ($6.07 \pm SD$) mg/kg on dry weight basis. Copper concentration in peeled potato tubers varied from 5.56 mg/kg in MSP/16-362 to 37.38 mg/kg in MSP/15-64 with an average value of 15.73 ($8.75 \pm SD$) mg/kg. Manganese concentration



Fig. 17. Tubers of MSP/15-51 and MSP/15-56

in peeled potato tubers varied from 9.96 MSP/16-171 in to 35.73 mg/kg in MSP/15-51 with an average value of 19.55 ($6.73 \pm SD$) mg/kg. Calcium concentration varied from 182.0 in MSP/16-04 to 565.0 mg/kg in MSP/16-343. Magnesium concentration was higher than calcium concentration and varied from 796 mg/kg in MSP/16-307 to 1530 in MSP/16-257 mg/kg. On an average basis mineral concentration was in the order of $Mg > Ca > Fe > Mn > Zn > Cu$ in peeled and whole potato tubers. Out of 49 clones MSP/16-04, MSP/16-29, MSP/16-51 and MSP/16-272 (**Fig. 19**) had above average concentration of both Zn and Fe. Among the parental lines CP1702 contained high values of Zn (17 mg/kg), Fe (39 mg/kg), Cu (45 mg/kg), Mn (26 mg/kg) and Mg (1397 mg/kg).

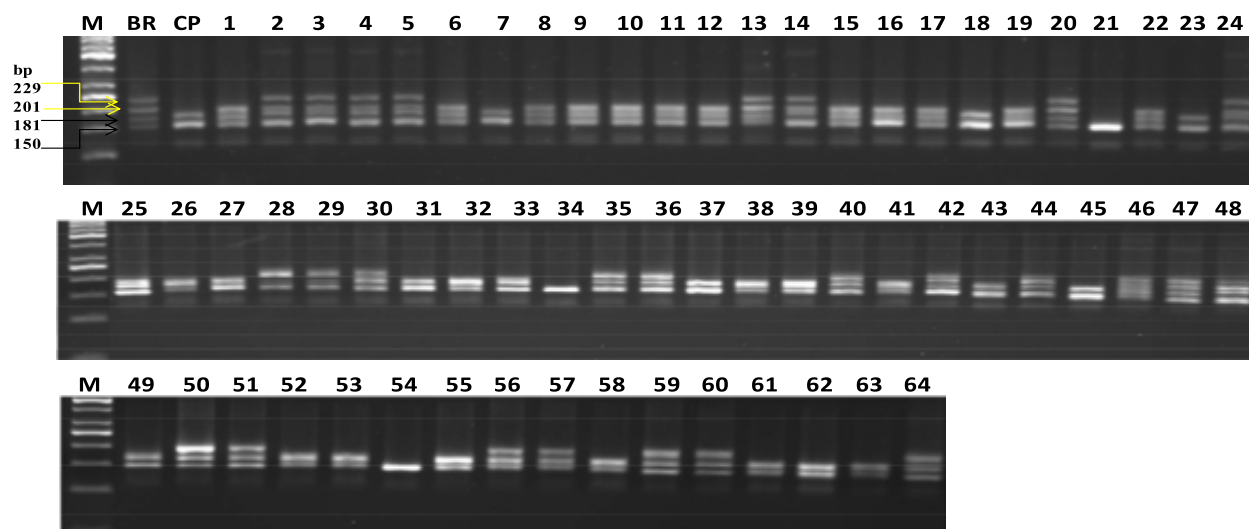


Fig.18. SSR marker (STM2005) profile of 64 progenies and parent (Bareilly Red and CP3770) on 3% high-resolution agarose gel; SN 1-64 denotes 64 samples MSP/15-1 to -64; M = 50 bp DNA ladder; Parents: BR = Bareilly Red and CP = CP3770



Fig. 19. Tubers of promising genotypes MSP/15-51, MSP/16-272 and MSP/16-362

Research activity 7: Development of nutrient and water use efficient cultivars

Hybridization and selection: A total of 88563 seeds of 72 crosses were obtained. A total of 71,390 seedlings obtained from 1,56,659 seeds of 36 crosses were transplanted and 28,954 selections were made. 13335 F_1C_1 clones were evaluated and based on tuber characters 2003 clones were selected. In F_1C_2 stage, 756 clones were evaluated and 272 clones were selected. The yield range of the selected clones was 560 to 700 g/plant as compared to 540 g/plant of Kufri Gaurav. In F_1C_3 stage, 277 clones were evaluated and 54 clones selected. In four preliminary yield trials, 12 hybrids namely were selected out of 49 hybrids evaluated at 90 days. All these hybrids gave significantly higher yield than controls. In three confirmatory yield trials, 4 hybrids namely N/12-12, N/12-25, N/12-38 and N12-46 were selected out of 14 hybrids evaluated at 90 days.

Research activity 8: Diploid potato breeding

Potato is propagated through tubers to maintain the

purity of cultivars due to high heterozygosity and polyploid genome. The true potato seeds (TPS) i.e. botanical seed is never used in propagation of varieties which otherwise is easy to maintain, easy to transport, easy to store, amenable to genetic manipulations and is free from diseases and pests inoculums. Homogenous F_1 hybrid TPS is possible through development of diploid inbred lines in potato. In order to accomplish this, twenty-two (22) accessions of 12 different wild species were planted in *Kharif* 2017 at Shimla for confirmation of their ploidy through FACS and further use in diploid breeding. Thirteen accessions were found to be true diploid while rest 9 were found to be tetraploids (**Fig. 20**). The identified diploids were hybridized as females with self-compatible gene (*sli*) carrying line (M6). In order to speed up the work, diploid populations in the form of TPS and in-vitro diploid accessions were imported for use in diploid breeding work from USDA.

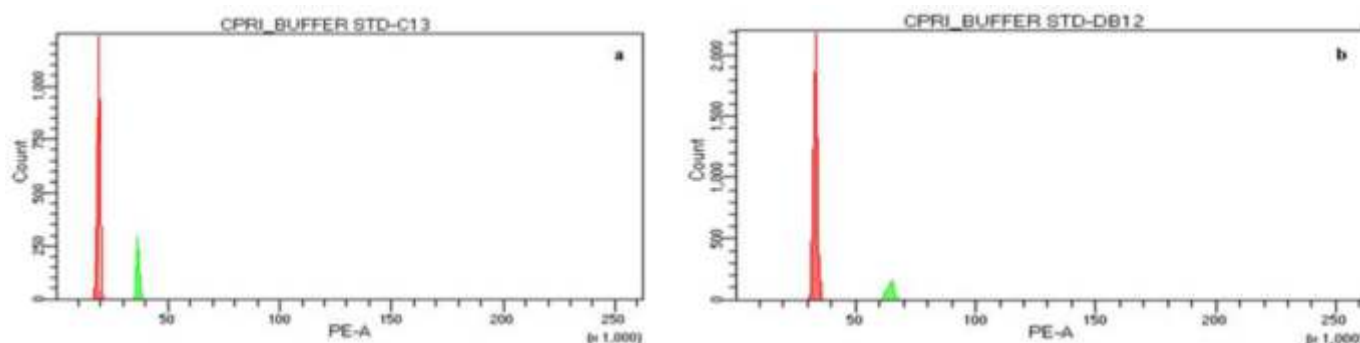


Fig. 20. Ploidy analysis of potato samples through FACS a) Diploid b) Tetraploid

Programme: Genetic enhancement of potato through molecular and genomic tools

Whole genome sequencing of androgenic dihaploid potato clone 'C-13': The androgenic dihaploid clone 'C-13' is a parent used in protoplast fusion and was developed at the institute. Whole genome sequencing of C-13 was completed by Illumina Nextseq 500 platform using Paired End sequencing. The high quality 344.79 million clean reads were mapped to the reference potato genome. On average recovery of 80.68% reference assembly only with short reads data indicates higher quality of the assembly with 60X coverage, Phred score > Q30, average GC content 44%, and identified 42,064 protein coding genes. Mapping matrix is given in **Table 1** and C-13 is depicted in **Fig. 1**.

Development of advanced progenies of somatic hybrids and SSR alleles for breeding: Advanced to hybrid clones (F_1C_4) of somatic hybrid (C-13 + *S. pinnatisectum*) were selected. SSR alleles- linked to late blight resistant somatic hybrid parent P8 (103 and 144 bp) and their progenies (103 and 144 bp) of cross P8 × Kufri Jyoti (132 and 144 bp)- were identified. SSR allele of 103 bp of P8 was transmitted in the progenies and was identified for the genetic fidelity/breeding. Eight promising advanced hybrids (Kufri Garima × Bulk pollen: MSH/14-7; Kufri Gaurav × P2: MSH/14-129 and -131 for yield

enhancement; P8 × Kufri Jyoti: MSH/14-112, -113, -115, -122 and -123 for late blight resistance and dry matter) were identified as elite clones. Study concludes successful exploitation of somatic hybrids in potato molecular breeding (**Fig. 2**).



Fig 1. *Solanum tuberosum* dihaploid C-13

Table 1. Genome mapping matrix of C-13

Details	Count	Reads (%)
Mapped reads	313,810,684	91.01
Not mapped reads	30,983,332	8.99
Reads in pairs	230,706,332	66.91
Broken paired reads	83,104,352	24.10
Total reads	344,794,016	100

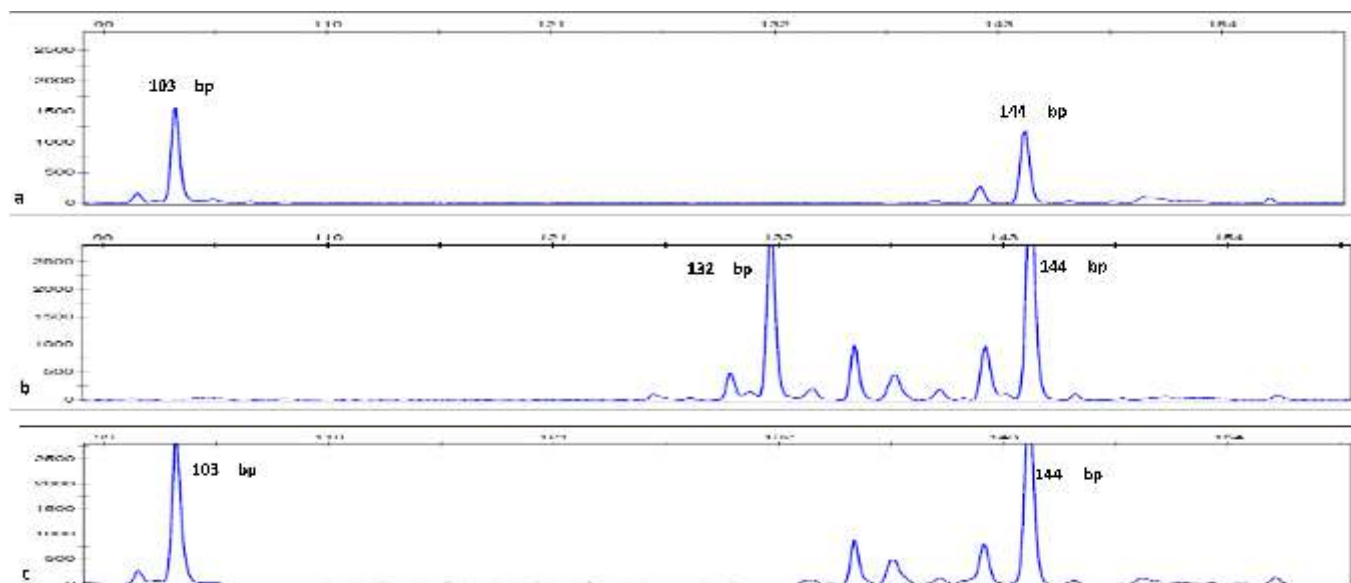


Fig. 2. SSR Profile of somatic hybrid progenies and parents using STM0003 marker. a. Parent P8, b. Parent Kufri Jyoti, c. Progenies MSH-14/112, /113, /114, /115, /116, /122, and /123. Similar profiles were observed in all progenies.

Genetic improvement of somatic hybrids:

Conventional breeding method was applied to improve the somatic hybrids (*S. pinnatisectum*/ *S. cardiophyllum* derived) for desirable tuber traits through breeding with potato varieties (Fig. 3-4). Total 9451 TPS of 30 crosses were obtained during this year for further advancement through clonal selection. In various field experiments: i) *Seedling stage*: 20 clones of 7 crosses were selected; ii) *Evaluation of F_1C_1 segregating population*: 3 clones MSH/17-16 (Kufri Garima x Card 10), MSH/17-25 (Kufri Garima x P10) and MSH/17-27 (Kufri Jyoti x Card 16) were retained; iii) *Replicated yield trials*: the advanced hybrids MSH/14-07 (45.14 t/ha) and MSH/14-131 (43.37 t/ha) produced significantly high tuber yield than Kufri Bahar (39.68 t/ha) at 90 days; iv) *Evaluation of elite clones of cross P8 x Kufri Jyoti under early crop*: MSH/14-113 (165 g/plant, 20% mite burn) and MSH/14-123 (138 g/plant, 20% mite burn) produced at par

tuber yield and tolerance to mite burn at 75 days with heat tolerant variety Kufri Surya (195 g/plant, 22.5% mite burn) under early planting conditions; v) *Evaluation of elite clones of cross P8 x Kufri Jyoti under main crop*: MSH/14-113 (631 g/plant) and MSH/14-123 (523 g/plant) produced at par tuber yield at 90 days with Kufri Bahar (621 g/plant) under main planting conditions. However, clones namely MSH/14-112, MSH/14-113, and MSH/14-122 produced significantly high tuber dry matter (20.75-22.10%) than Kufri Bahar (19.78%); and vi) *Evaluation of progenies of somatic hybrids for late blight resistance*: All the advanced hybrids possessed less AUDPC than the susceptible variety Kufri Bahar. However MSH/14-113, MSH/14-115 MSH/14-122 MSH/14-123 showed tolerance to late blight under field and laboratory (detached leaf method). Specifically MSH/14-113 and MSH/14-122 showed high level of late blight resistance.



Fig.3. Elite genetic stock form cross P8 x Kufri Jyoti performed well under early/main crop and possesses high tuber dry matter, late blight resistance and tolerance to mite burn



Fig. 4 Tubers of somatic hybrids, parents and most popular variety of region Kufri Bahar

Sequence variation analysis of genes involved in nitrogen use efficiency (NUE) in potato: Nitrogen being the most important nutrients for plant growth, and its excessive application leads to degrading soil health, limited cultivable land and high cost of

fertilizers make N-use efficient as an inevitable approach for sustainable potato production. Sequence variation in candidate genes involved in nitrogen (N) metabolism was analyzed in two contrasting potato varieties Kufri Gaurav (N

efficient) and Kufri Jyoti (N inefficient). N metabolism genes-specific primers (nitrate transporter-NRT, ammonium transporter-AMT, nitrate reductase-NR, nitrite reductase-NIR and asparagine synthetase-AS) were analyzed. Following sequence analysis, non-redundant sequences with uninterrupted open reading frames of 12 'N-homologous genes' were identified to the known N metabolic pathways (Fig. 5-6).

Development of CAPS marker of nitrate reductase (NR) gene for NUE: Sequence variation of nitrate reductase (NR) gene involved in N metabolism in potato was analysed to develop molecular marker

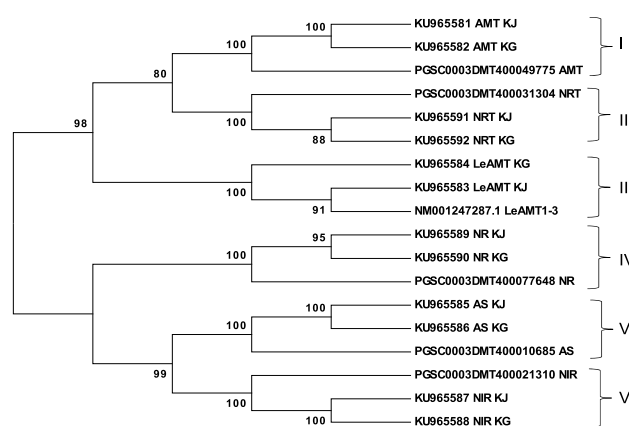


Fig. 5 A cluster analysis the nucleotide sequences of 12 N-homologues and known N metabolism genes.

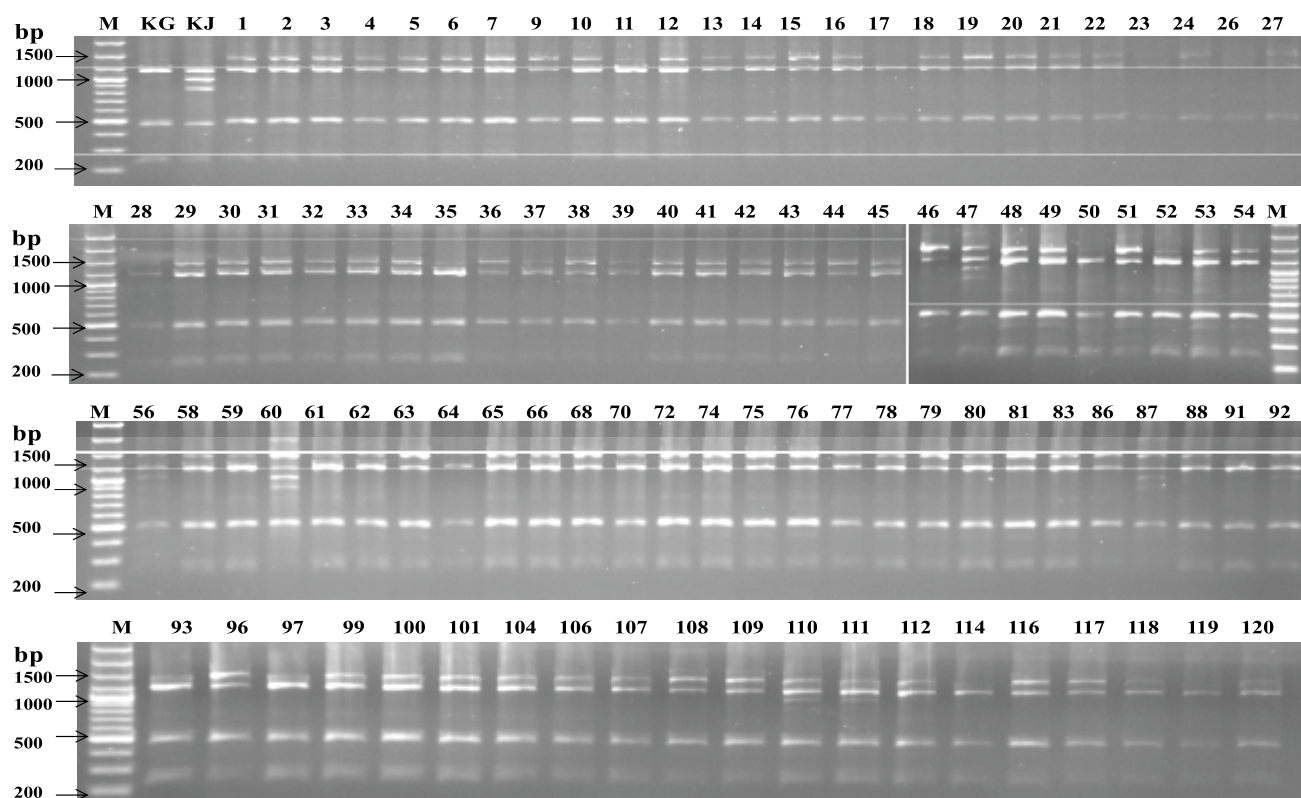


Fig. 6. Development of CAPS marker for the NR gene and validation in a mapping population of 123 individuals developed by crossing between Kufri Jyoti (KJ) and Kufri Gaurav (KG). Gel SN 1-120 shows amplification of the CAPS marker (restricted PCR products: 500, 900, 1000 and 1200 bp) by *DraI* enzyme in the mapping population. Missing individual nos. has no amplification.

for breeding. Two diverse potato varieties Kufri Jyoti (N inefficient) and Kufri gaurav (N efficient) were used to PCR amplify, cloning and sequence analysis. A cleaved amplified polymorphic sequence (CAPS) marker was developed for MAS in potato. The CAPS marker was validated in a tetraploid mapping population of 123 individuals and 48 potato varieties for its polymorphism. Thus, the development of new CAPS marker would be useful for MAS with better NUE in potato.

Investigating NUE variables and genes in potato grown with variable N supplies under aeroponics

Potato varieties Kufri Jyoti and Kufri Gaurav were grown in aeroponics with nutrients solution supplying low N (0.75 mM NO_3^-) and high N (7.5 mM NO_3^-) treatments. All other macro and micro nutrients remain same expert one or two. Several stock solutions were prepared using various salts: KNO_3 (1M), KH_2PO_4 (0.5 M), K_2SO_4 (0.5

KJ 7.5 NKG 7.5 NKJ 0.75 NKG 0.75 NM), $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ (1 M), $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (0.5 M), $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (1 M), $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ (0.125 M), $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (0.125 M), $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (0.005 M), $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ (0.005 M), Fe-EDTA (0.0125 M) and H_3BO_3 (0.125 M). Plant were grown till full crop duration (90 days) and data were recorded for phenotypes, root system architecture (root traits), plant biomass (fresh weight/dry weight), NPK content, chlorophyll content, yield, dry matter, NUE variables (Agronomic N use efficiency, N uptake efficiency, N utilization efficiency, harvest index, N harvest index) etc to investigate NUE in these varieties (Fig. 7-8).



Fig. 7. A phenotypic overview of potato varieties (Kufri Jyoti and Kufri Gaurav) grown with low N (0.75N) and high N (7.5N) supplies under aeroponics.

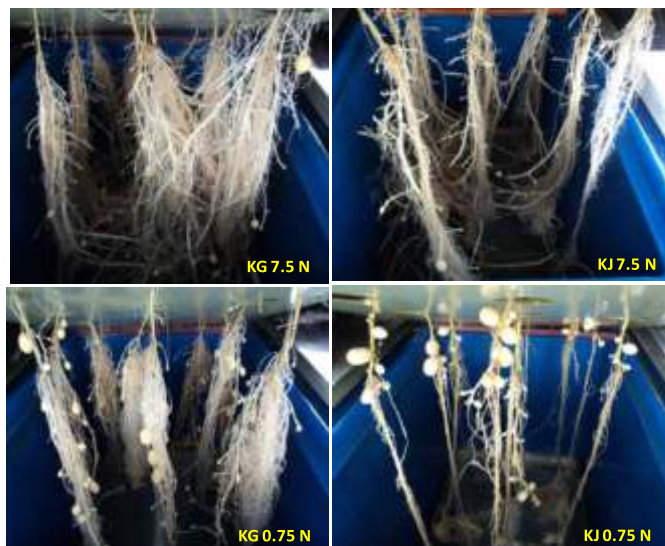


Fig. 8. Root system architecture of potato varieties (Kufri Jyoti and Kufri Gaurav) grown with low (0.75N) and high N (7.5N) under aeroponics.

Development of SSR markers for identification of Indian potato varieties: Allelic variation in potato varieties was analyzed and a dataset of SSR (simple sequence repeat) markers was developed for the varietal identification. Total of 155 SSR alleles of 12 markers were scored in 48 varieties with alleles per locus varied from 4 (STM1053) to 35 (STIKA), and polymorphic information content (PIC) ranged between 0.53 (STM1053) to 0.92 (STIKA). Allelic profiling of potato varieties showed distinctness and polymorphism of the SSR markers system (Fig. 9).

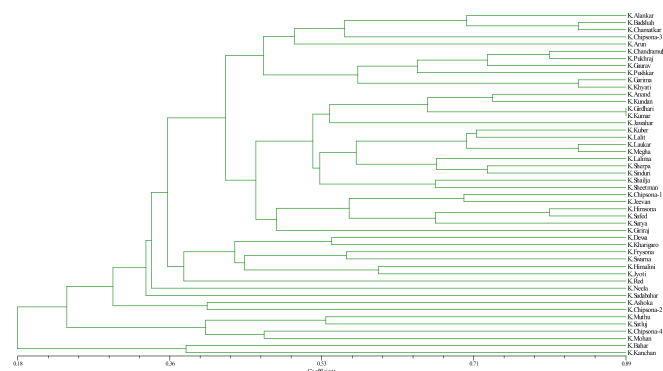


Fig. 9. Clustering of 48 Indian potato varieties based on the Jaccard's coefficient by UPGMA method using a two-markers-set (STIKA and STU6SNRN).

Field evaluation of NUE mapping population under low N: A total of 121 progenies (F_1C_3) of the NUE mapping population (Kufri Jyoti $\times$ Kufri Gaurav) were evaluated in replicated field trial under low nitrogen (50 kg N ha^{-1}) at Modipuram to study NUE. Variability in SPAD reading and tuber yield is depicted in Fig 10.

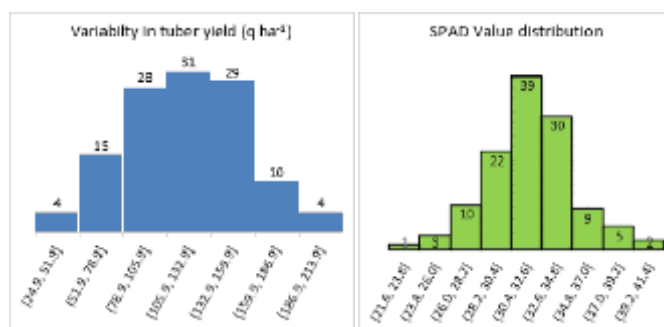


Fig 10. Distribution of SPAD values (75 days) and variability in tuber yield (90 days) under low N in the NUE mapping population.

Development of modified and rapid protocol for ploidy estimation potato: Understanding the ploidy level and 2C DNA content in the potato clones has prime importance. We have developed and tested the protocol for determining the ploidy

level and 2C DNA content of potato by testing various nuclei isolation buffers with modifications to the available methodologies. Our results clearly showed that modified HPI buffer is the most suitable buffer followed by modified Galbraith's buffer for FACS analysis of potato leaf samples (Fig. 11).

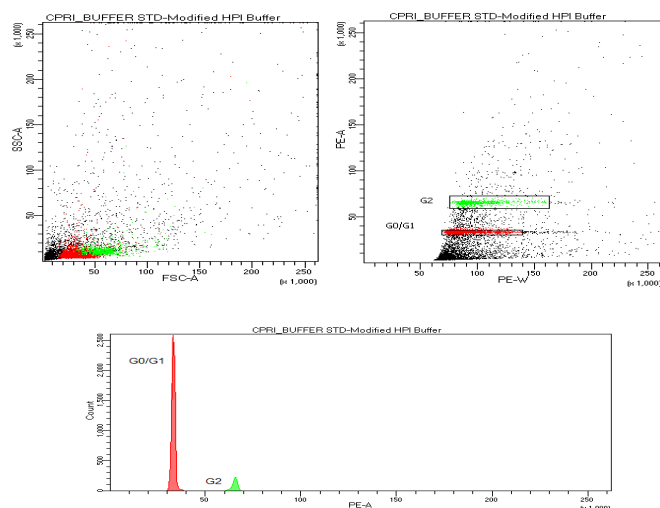


Fig. 11. A. Dot plot showing the FSC-A Vs SSC-A for KG tested with the modified HPI buffer. B. G0/G1 and G2 population plotted on the dot plot of PE-W Vs PE-A. C. Histograms showing the G0/G1 and G2 peak.

Identification of SNP level differences in the late blight responsive SWEET promoter: SWEET transporters plays important role in plant pathogen interaction, reproductive development, senescence, abiotic stress response, and ion transport. Expression of these genes was analyzed under late blight conditions in potato and out of 37 SWEET genes in potato 6 genes namely StSWEET10, 14, 18, 29, 31 and 32 were found to be responsive to the late blight. The promoter elements of these genes were cloned and sequenced from the LB resistant cultivar,

K. Girdhari and LB Susceptible cultivar, K. Bahar. Sequence level variation was observed in these promoters' elements and their functional validation is underway.

Expression analysis of Rubisco activase (RCA) isoforms under the heat stress conditions in potato: Photosynthetic potential of plants is highly affected at high temperatures (heat stress). Endogenous levels of Rubisco Activase (RCA) could serve as an important determinant of photosynthetic response under heat-stress conditions. We identified the four isoforms of RCA and generated the expression profiles under heat stress in K. Badshah. Our results shows that all the isoforms of RCA are down regulated under heat stress conditions indicating their thermo-sensitivity. In order to maintain the photosynthetic potential of the potato crop under heat stress conditions, thermo-stable RCA is prime requirements.

Cloning and characterization of potato annexin gene (StAnn1) for exploring its potential in providing heat stress tolerance: Annexins are calcium dependent, membrane-associated proteins involved in wide range of cellular and developmental processes. Being a signaling molecule it is hypothesized that annexins might play important role in tuberization under heat stress condition. Keeping this in view the expression profiling of annexin gene family were performed in potato under heat stress conditions using contrasting genotypes and study revealed strong up-regulation of StAnn1 gene. By considering its importance the StAnn1 was cloned from the heat tolerant potato cultivar, K. Surya for exploiting its potential for providing heat stress tolerance in other susceptible potato cultivars (Fig. 12).

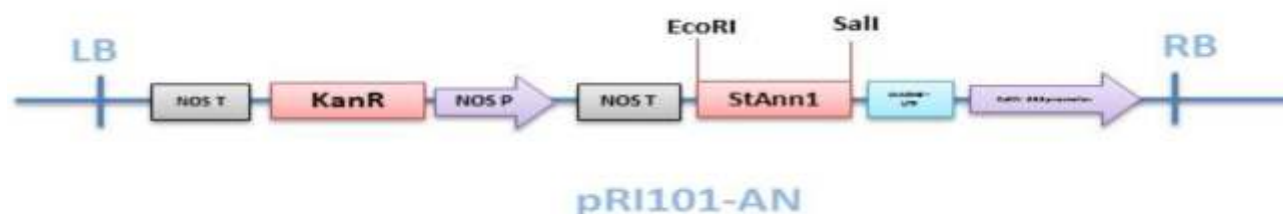


Fig. 12. Gene construct for potato annexin gene in pRI101 binary vector

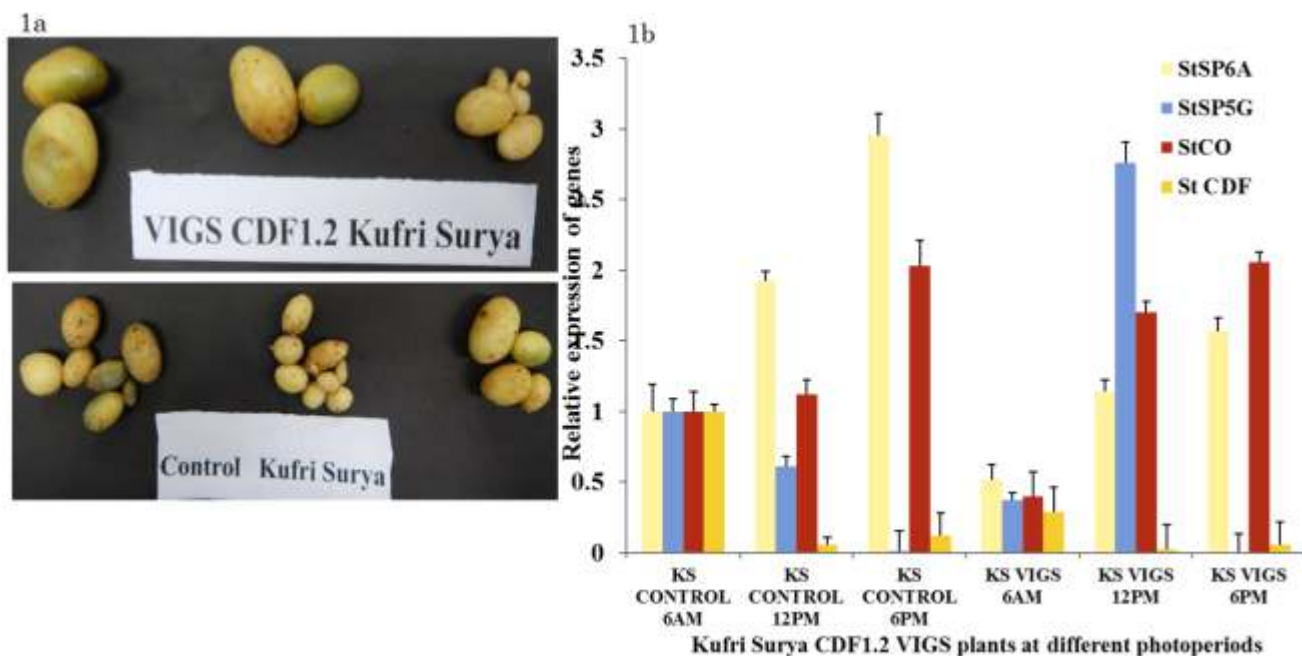


Fig 13. a) Response of tuberisation process in VIGS of CDF1.2 allele in Kufri Surya b) relative quantification of CDF1.2, SP6A, CO and SP5G in VIGS and control plants.

Functional screening of heat tolerant genes in Kufri surya in response to tuberisation using transient VIGS technology: Understanding of molecular mechanisms by which temperature effects tuberisation is crucial for development of thermo tolerant potato cultivars. In the present study, based on in our earlier microarray expression profile of KS selected 5 genes, developed VIGS construct and assessed their role in tuberisation using transient agro inoculation VIGS technology. The sprouted tubers were used for Agroinoculation with 5 gene construct in different combination, like 2 genes (StSSH2 + StWTF), 3 (StUGT+StBHP+StSP6A) genes and all five genes (StUGT+StBHP+StSP6 A +

StSSH2+ StWTF) in one combination. At 17days after heat stress (47 day old plants), VIGS plants showed early senescence and which yield less number and size of the tuber in VIGS plants compared to enough tuberisation in control plants compared to healthy green normal phenotype of control plants. Relative quantification of all five genes revealed reduced expression (< 1.0 fold) compared to enough transcript accumulation in control plants. This comprehensive functional assay provided useful information on potato tuberisation and provides a framework for further investigations into heat stress in potato (Fig. 13a, b & 14).

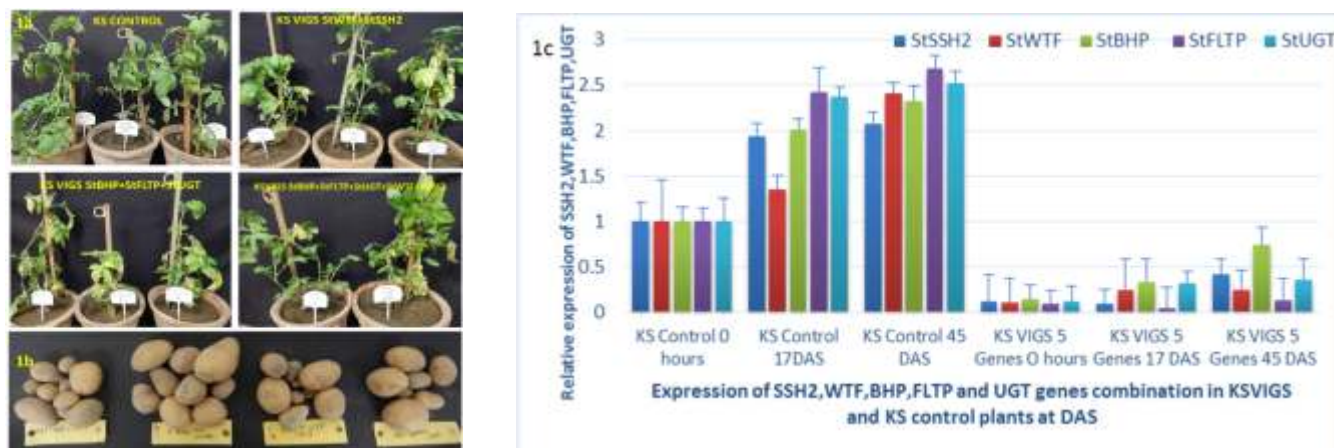


Fig. 14. Phenotype of Kufri Surya VIGS plants and KS control plants at elevated night temperature conditions and their tuberisation response: 1a) VIGS plants showing early senescence and 1b) less and delayed tuberisation in compared to control KS 1c) Relative expression of Heat tolerant genes in KS VIGS and KS control plants

F-Box mediated auxin signalling maintains defence against *Phytophthora infestans* in *Solanum demissum*: RNA seq of *S. demissum* revealed a strong induction of auxin signalling F-box proteins and its interacting defence proteins for inducing resistance mechanism. Most of the highly up regulated genes in the pathway belongs to auxin signalling genes and these genes were validated using real time PCR. Most of the RNA seq profile genes like St AUX IAA2 (3.2 to 8.9 fold), StGH3 gene (9.8 to 13.71 fold), SKI3 (1.1 to 1.3 fold), Cyclin F-BOX

(5.02 to 9 fold) and Ubiquitin mediated F-box proteins (1.17 to 3.29 Fold), these F-Box mediated auxin signalling genes were hypothesised as activating downstream signalling process involved in various cellular activities including RNA processing, which induce defence mechanism. Therefore, validated the downstream signalling genes like Aminotransferase (3.6 fold expression), Anthocyanin synthase (7 fold), Cytochrome 450 (15 fold), Pectin esterase (14.2 fold) gene expression (Fig. 15).

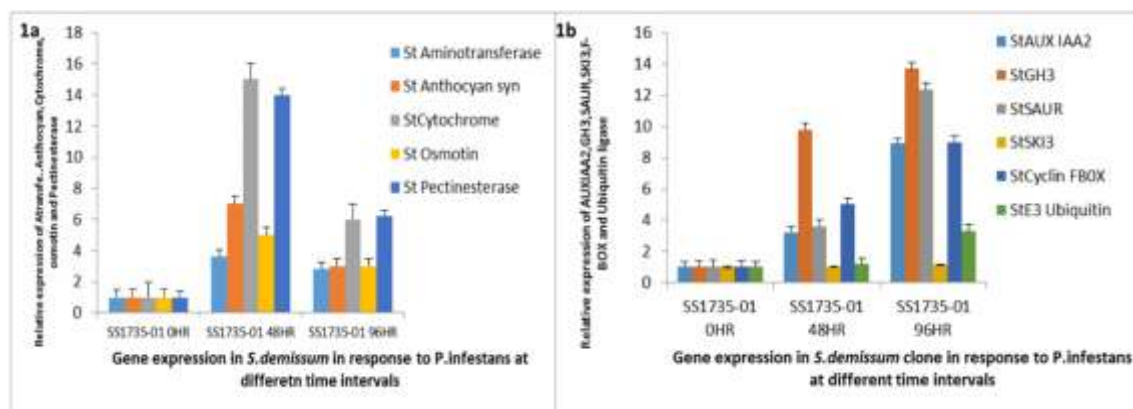


Fig. 15. Relative expression of a) F-Box mediated auxin signalling genes and b) downstream regulated genes in response to late blight resistance in *S. demissum* clone SS1735-01.

Genotyping-by-sequencing analysis in potato: Genetically diverse potato core collection of 287 accessions was characterized through Genotype-by-Sequencing (GBS) for genome wide SNP detection. The DNA samples were normalized and used for the digestion using *Pst*I. The final libraries were paired end sequenced on Illumina NextSeq 500. The high quality reads were filtered, assembled and polymorphic SNPs were mined using TASSEL pipeline. The GBS analysis generated 371.76 million reads which resulted in a genome wide set of 4522550 Single Nucleotide Polymorphisms (SNPs)

segregating across the entire collection and several thousand SNPs segregating within every accession ranging from 1492 in CP 1873 and CP 2110 to 55321 in CP 3799.

Metagenomics: In soil meta-genomics activity under potato based cropping systems, nine samples are in pipeline for 16S rRNA sequencing for bacterial diversity analysis. If contrasting differences are found, then same samples will be given for the whole meta-genome analysis. Root and inter-row soil samples have been collected from relevant treatments for further analysis.

Division of Crop Production

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

Real time N management by fine tuning top dressing using leaf SPAD value: Nitrogen being most mobile nutrient in soil, its application should be aimed to synchronise the uptake pattern of crop as far as possible. Failing to do so its wandering in the environment decreases the efficiency of resources, increases carbon and nitrogen footprint of crop management practices. For cultivating potato in low organic matter and low clay soils real time N management becomes more imperative. In these experiments leaf chlorophyll content as reflected in the SPAD value has been effectively used to identify the stage when crop is witnessing N stress and decide the optimum time for its top dressing. Experiments were conducted at Modipuram, with three cultivars namely Kufri Khyati, Kufri Garima and Kufri Bahar and at Gwalior with two cultivars Kufri Chipsona-1 and Kufri Chipsona-3. At Modipuram experiment was planted on 29-10-2017 in soil having pH 6.47, organic carbon 0.28%, available N 165 kg/ha, available P-111 kg/ha, available K-236 kg/ha. All three cultivars showed highest yield in the reference plot where 125% of recommended N was applied in two splits. However, in the treatment where recommended N was applied in three splits showed at par yield of reference plot. In the treatments where 10 or 20% N was applied at 90% of SPAD value of reference plot after applying $1/3^{\text{rd}}$ N as basal, $1/3^{\text{rd}}$ at earthing up

yields were at par with those plots where three splits of recommended N were applied without compromising on yield (Fig. 1). At Gwalior the cultivar Kufri Chipsona-1 had highest tuber yield in plots with 125% of recommended N which was comparable to the yield obtained in plots receiving

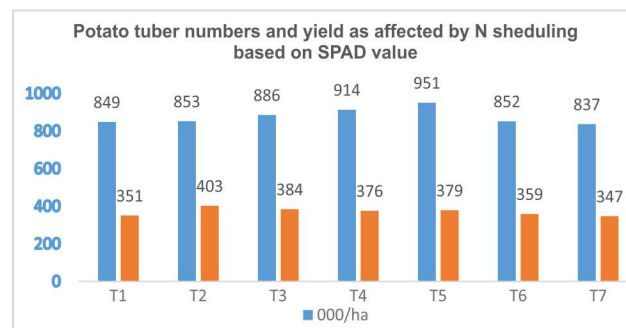


Fig. 1. Potato tuber numbers and yield as affected by N scheduling based on SPAD value. T₁: 50% basal and 50% at earthing up of recommended N; T₂: 62.5% basal and 62.5% at earthing up of recommended N; T₃: 33.33% basal, 33.33% at earthing up + 33.33% at 80% SPAD value of over fertilized plot (T₂); T₄: 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).

Table 1. Comparison of QUEFTS model based NPK recommendations with standard recommendations in different regions.

Treatment	Location		
	Jalandhar	Modipuram	Patna
Minus N	27.8	8.8	12.8
Minus P	29.7	30.2	32.2
Minus K	28.5	27.1	28.3
Minus NPK	25.6	9.4	13.3
FYM only	30.5	14.2	15.0
75% NPK as per standard recommendation	31.3	30.9	28.5
100% NPK as per standard recommendation	31.8	31.9	32.5
125% NPK as per standard recommendation	33.0	30.7	34.5
75% NPK as per QUEFTS model	32.0	34.9	29.2
100% NPK as per QUEFTS model	30.8	37.3	30.0
125% NPK as per QUEFTS model	31.3	40.2	35.4
C.D. (p=0.05)	3.43	7.7	5.9

10% of the recommended N applied based on 90% SPAD value of referenced over fertilized plot. However for cultivar Kufri Chipsona-3 highest tuber yield was recorded when 20% N was applied at 80% SPAD value of reference plot. Thus real time N management could save 10 to 20% N.

Experiments for validation and calibration of QUEFTS model: Experiments on validation and calibration of QUEFTS model were under taken at Modipuram, Gwalior, Jalandhar and Patna. Standard NPK recommendations for the respective region were compared with the NPK recommendations generated by QUEFTS model based on soil test values. At Modipuram, yield was obtained when 125% NPK was applied based on QUEFT model's recommendation which was at par with 125% NPK dose of the standard recommendations. At Jalandhar application of 75 per cent of the NPK dose as recommended by QUEFTS model for produced the yield equivalent to standard NPK (100%) recommendation. Increasing the level of N (in the form of neem coated urea), P and K application beyond 75 per cent of the recommended rate for the did not increase the yield significantly. At Gwalior highest tuber yield was recorded with the application of 100% NPK as per QUEFTS model recommendations which was equivalent to 125% of recommended NPK for the region Table 1.

Omission plot experiments: For optimising site specific fertilizer nutrient doses experiments were conducted at Jalandhar, Modipuram, Patna and

Shimla using varying levels of NPK for different varieties. In omission plot experiment at Jalandhar nitrogen resulted in highest yield reductions for cultivar Kufri Jyoti in a green manured field (low in minralisable N (90 mg/kg) and medium in available P (19.3 mg/kg) and K (145 mg/kg). Omission on nitrogen reduced the yield significantly in all the treatments. Omission of P or K did not reduce the yield significantly. At Modipuram (Kufri Garima) and Patna (Kufri Pukhraj) omission of N resulted in higher yield reductions compared to Shimla (Kufri Girdhari), Jalandhar (Kufri Jyoti). Omission of P did not have any significant effect on yield at all the locations Table 2. In order to create awareness amongst farmers regarding need based fertiliser use experiment was conducted at farmer's field at Shimla (having medium levels of available NPK). Lowest yield (25.85 t/ha) was obtained without NPK (FYM alone) application compared to 31.78 t/ha with 100% NPK. Omission of N resulted in larger yield reductions (14.7%) than omission of K (8.7%). At CPRI farm at Shimla in was found only yield limiting nutrient for Kufri Girdhari (Fig. 2).

In another experiment at Jalandhar conducted on a field (having low levels of available NPK) without any application of manures omission of NPK either individually or in combination resulted in significant yield reductions in Kufri Pukhraj (Fig. 3). The order of yield delimiting nutrients was N>P>K. Highest yield (34.4 t/ha) was obtained when 150% of the recommended NPK dose was applied which was at par with 100% NPK.

Optimization of phosphorus dose in potato: Invariably P is applied at the higher rate than its uptake because of its lower use efficiency. Regular



Fig. 2. Omission plot experiment in Kufri Girdhari at farmer's field at Shimla

Table 2. Effect of NPK omissions on tuber yield (t/ha) at different locations.

Treatments	Jalandhar	Shimla	Modipuram	Patna
	Kufri Jyoti	Kufri Girdhari	Kufri Garima	Kufri Pukhraj
N ₀	27.8	24.0	8.8	12.8
P ₀	29.7	30.4	30.2	32.2
K ₀	29.2	30.9	27.1	28.3
N ₀ P ₀	26.9	26.0	9.2	12.6
P ₀ K ₀	29.9	26.5	28.2	27.4
N ₀ K ₀	27.3	31.3	11.8	11.3
N ₀ P ₀ K ₀	25.2	24.4	9.4	13.3
100% NPK	31.1	30.3	31.9	32.5
C.D. (0.05)	2.5	3.6	8.7	4.5

applications of P over the years results in its build up in soil, resulting in adverse effect on dynamics of other nutrients particularly secondary and micro nutrients. Therefore, experiments were undertaken in soils having high available P content in soils with the objective to utilise soil P at Gwalior, Modipuram, Patna and Ooty (Fig. 4). At Gwalior 20% of the recommended dose produced the tuber number and yield equivalent to 100% recommended dose. At Modipuram reduced doses of P had no significant effect on yield level of cultivar Kufri Bahar in soil having available P 111kg/ha Table 2. No response to applied P in terms of yield was obtained in Kufri Khyati at CPRS Patna in a green manured field although variations in tuber number were observed.

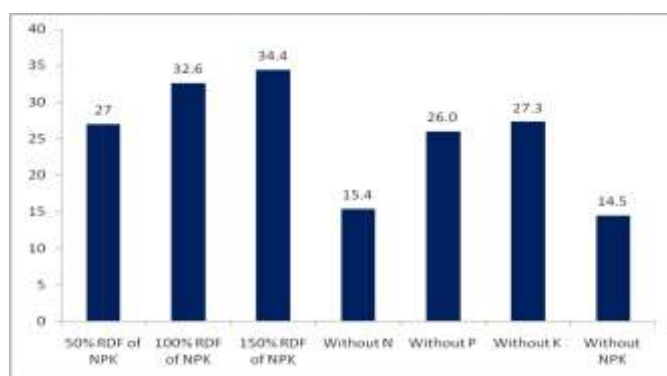


Fig. 3. Effect of varying levels of NPK on fresh tuber yield (t/ha) of Kufri Pukhraj at Jalandhar

In the acid soils of Ooty the experiment was conducted with four cultivars viz., Kufri Girdhari, Kufri Jyoti, Kufri Swarna and Kufri Himalini for evaluating the response of different levels of

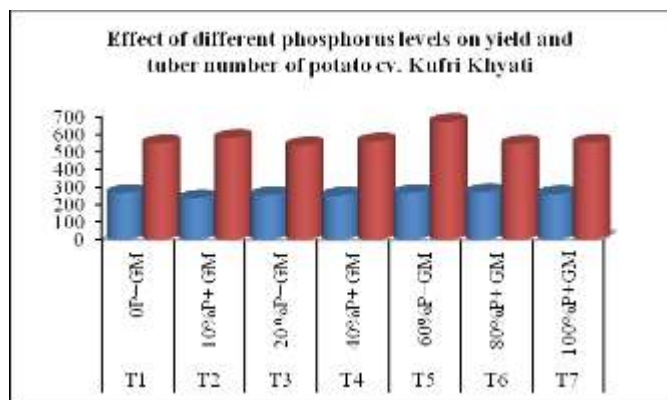


Fig. 4. Effect of different phosphorus levels on yield and tuber number of potato cv. Kufri Khyati. GM= green manure, P= phosphorus, T1-0 P+ Green Manure(GM); T2-10% P of RD(recommended dose) + GM; T3-20 % P of RD + GM; T4- 40 % P of RD + GM; T5- 60 % P of RD + GM; T6-80 % P of RD + GM and T7-100 % P of RD + GM

phosphorous (Fig. 5). Application of 135 kg P_2O_5 /ha produced highest yield of 41.44 t/ha in Kufri Girdhari (41.44 t/ha) and 37.15 t/ha in Kufri Himalini whereas in Kufri Jyoti (15.28 t/ha) highest yield was obtained with 90 kg P_2O_5 /ha and in Kufri Swarna with 180 kg P_2O_5 /ha (21.50 t/ha).

Optimizing fertilizer requirement for potato cultivars Kufri Girdhari and Kufri Himalini: A field experiment was conducted at Shillong for optimizing fertilizer doses for new varieties Kufri Girdhari and Kufri Himalini. Both the cultivars performed better and gave significantly better yield when 75% N, 125% P and 100% K of recommended level was applied.

Studies on interaction effects of P and S: Phosphorus and sulphur both being anionic nutrients are likely to interact and compete each other in soil as well as in uptake by plant. This chemistry may even affect the uptake of these nutrients affecting crop yield. To see the interaction effect, an experiment with four levels each of P and S were tried with potato variety Kufri in soil having pH 7.55, organic carbon 0.38%, available N 167 kg/ha and available P 39 kg/ha. Though, the interaction effect on yield was not significant, response of S was better at higher level of P (Fig. 6).

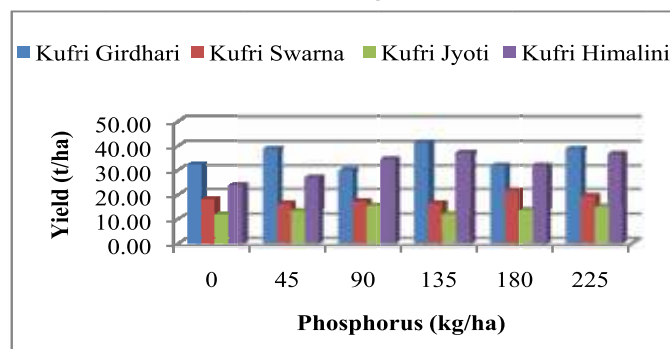


Fig 5. Effect of different levels of phosphorus on different varieties of potato and yield.

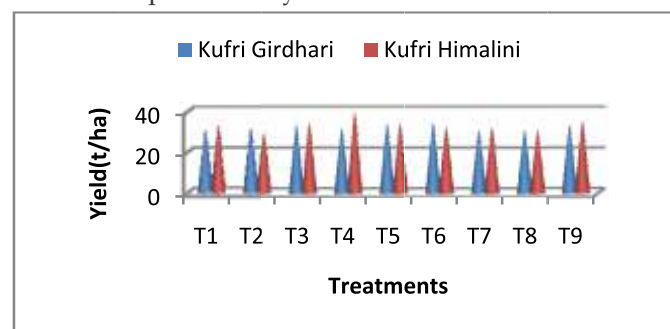


Fig 6. Optimizing fertilizer requirement for potato cultivars Kufri Girdhari and Kufri Himalini:

Experiments for increasing Zn and Fe content in tubers: Experiments were conducted to increase the Zn and Fe content in tubers grown in field using cultivar Kufri Jyoti and Kufri Pukhraj at CPRS Jalandhar using chelated and sulphate sources (Fig. 7 and 8). Application of 5.0-10 kg Zn /ha as zinc sulphate and 1.0 and 2.0 kg Zn /ha as Zn-EDTA increased the Zn content significantly in peeled (tuber flesh) and whole tubers. Application of 10.0 kg Fe /ha as ferrous sulphate and 1.0 kg Fe as Fe-EDTA increased the Fe content significantly in the whole potato tuber (unpeeled). However, Fe did not increase significantly in tuber flesh (peeled tubers). Chelated sources of both the nutrients were effective at 5-10 times lower rate compared to sulfate forms of the respective element were equally effective in improving zinc and Fe content in tubers.

A field experiment was conducted at Ooty to study the effect of foliar application of boron and molybdenum in the cultivars *viz.*, Kufri Jyoti, Kufri Himalini, Kufri Girdhari, Kufri Swarna. Application of boron @ 1-1.5 g/L and ammonium molybdate @ 0.5g/L recorded highest yield over control in different varieties (Fig. 8).

To develop variety specific water and nutrient management schedule under limited water availability: Field experiments were conducted at Modipuram, with six potato cultivars with three

moisture regimes *viz.* irrigation applied at 2.5, 2.0 and 1.5 IW:CPE under furrow irrigation, and four fertility levels *i.e.* 120, 150, 180 and 210 kg N/ha. The potato tuber yields were in the order of Kufri Khyati > Kufri Anand > Kufri Pukhraj > Kufri Garima > Kufri Sadabahar > Kufri Bahar. Irrigation applied at 2.5 IW : CPE ratio produced significantly higher total yield (41.6 t ha^{-1}), and was statistically at par with irrigation given at 2.0 IW:CPE ratio. All potato varieties produced significantly lower yield when irrigation was applied at critical stages of crop *i.e.* at 1.5 IW : CPE ratio.

To work out N requirement of newly released potato variety through drip fertigation: Field experiment was conducted Modipuram, with drip-fertigation treatments, 1/3 of each NPK level (25, 50, 75 and 100% of recommended NPK), was applied as basal dose. The remaining 2/3 doses were applied through drip-fertigation twice in a week in 2, 4, 6 and 8 splits starting after crop emergence (21 DAP), respectively as per the treatments. One pre-emergence irrigation was applied to all the plots for quick and uniform emergence in the field. Kufri Mohan produced higher yield (38.5 t ha^{-1}) with 100% NPK drip-fertigation which was at par with 75% NPK fertigation (37.0 t ha^{-1}).

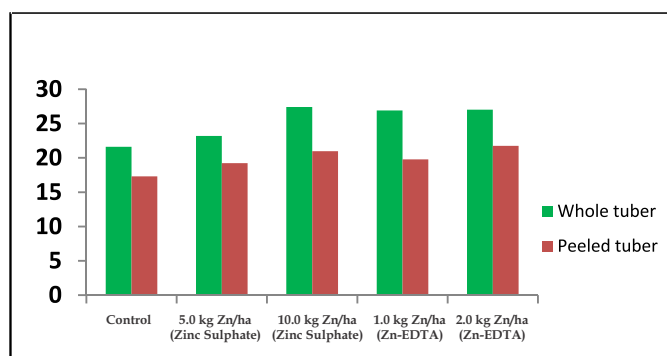


Fig. 7. Effect of zinc sources on Zn concentration in tubers

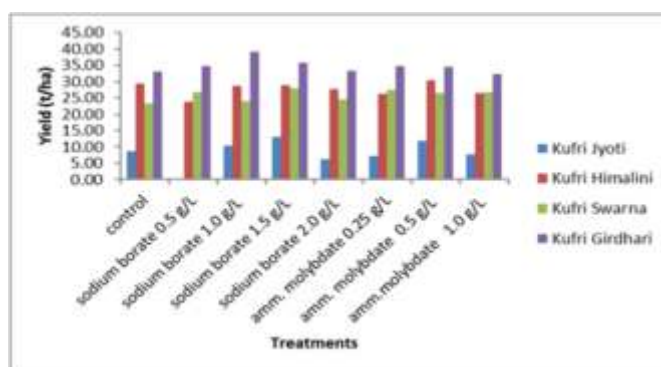


Fig. 8. Effect of foliar application of boron and molybdenum on potato cultivars

Programme: Resource optimization in potato based cropping system

Yield gap analysis for potato crop in different agro-ecological regions comparison of institute recommendations and farmer's practices:

Experiments on yield gap were conducted for the second year at Modipuram and Patna. At Modipuram, newly released varieties Kufri Mohan (42.2 t/ha) and Kufri Khyati (38.8) were better in terms of marketable tuber yields as compared to Kufri Pukhraj (36.1) and Kufri Bahar (29.5) when raised under with soil test based nutrition and earthing. Variety Kufri Bahar with Agra farmer's practice and earthing recorded yield of 28.9 t/ha, while cv. Kufri Pukhraj had yield of 36.4 t/ha with Kannauj practices and earthing. Earthing up improved marketable tuber yields slightly (3-5%) in this season (Fig. 1).

At Patna, recommended POP under 60x20 spacing and soil test based crop nutrition produced yield (40.7 t/ha) equivalent to tuber yield (42.1 t/ha) produced with the application of 215:210:115 N, P₂O₅, K kg/ha) produced with the application of fertilizer. Tuber yield at Muzaffarpur (17.6-21.6 t/ha) was almost 50% of the institutes recommendations. Yield obtained by progressive

farmers' practices (37.0 t/ha) was comparable yield to that obtained by following institute's recommend package of practices (37.9 t/ha). From these finding, it may be concluded that there is more scope of better productivity in this region with adoption of institute production technology (Table 1).

Indian good agricultural practices (GAP) for production of potato crop

Developing Indian GAP: Good agricultural practices are required for organized marketing of potato crop. Document for production and handling of potato crop is in final phase to make aware farmers about environment friendly and non-polluting technologies. At Modipuram, effect of N levels (140 and 210 kg/ha) on tuber shape was studied on ten common potato cultivars grown under inorganic and organic system. Random samples analyzed for quantification of shape (potato shape index-PSI) from replicated trial revealed that varietal variability exists in their response to production systems for tuber shape. Computed PSI values when referred to a confirmed scale for different shapes viz. round (100 to 160), oval (161 to 240), long (241 to 340) and very long (>340), tuber shape of K. Mohan, K. Chipsona-1 and K. Ganga remained unaffected (Fig. 2).

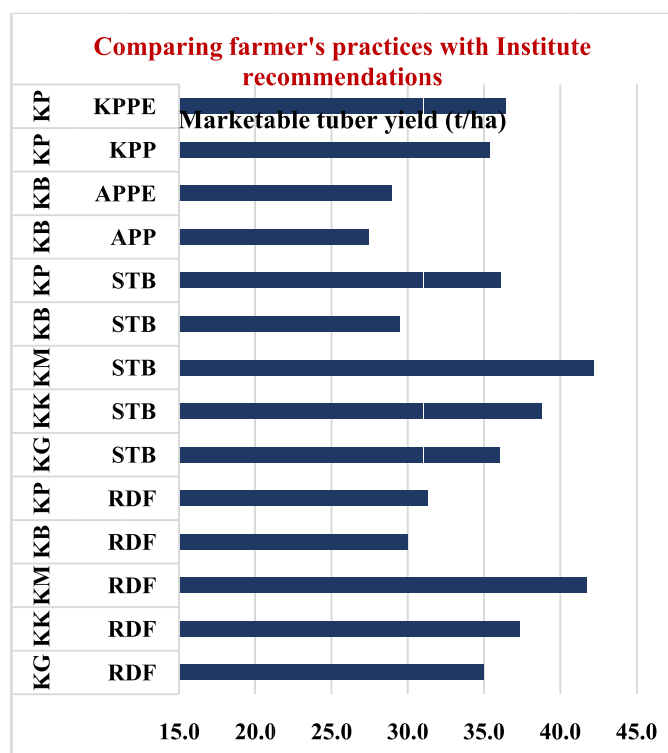


Fig.1. Comparing institute recommendations and farmer's practices at Modipuram

Table 1. Potato yield as affected by different practices

District specific Farmers' practice	Fertilizer (N:P:K Kg/ha)	Spacing (cm)	Yield (t/ha)
Recommended PoP	RDF	60x20	37.9
Recommended PoP	STB	60x20	40.7
Patna farmer spacing	RDF	50x30	34.1
Patna	215:210:115	60x20	42.1
Patna	215:210:115	50x30	33.9
Muzaffarpur	150:170:100	40x10	21.6
Muzaffarpur	150:170:100	60x20	18.9
Muzaffarpur	RDF	40x10	17.6
Practice of reportedly high yield taker farmer			37.0
Mean			31.5

A tendency from round to oval-ness was observed under organic system in four cvs. namely K. Pukhraj, K. Khyati, K. Anand and K. Chipsona-3. On the other hand, K. Bahar and K. Sinduri had a tendency from oval to roundness under organic cultivation. The pattern of tuber shape in K. Garima was found inconsistent under organic as large size

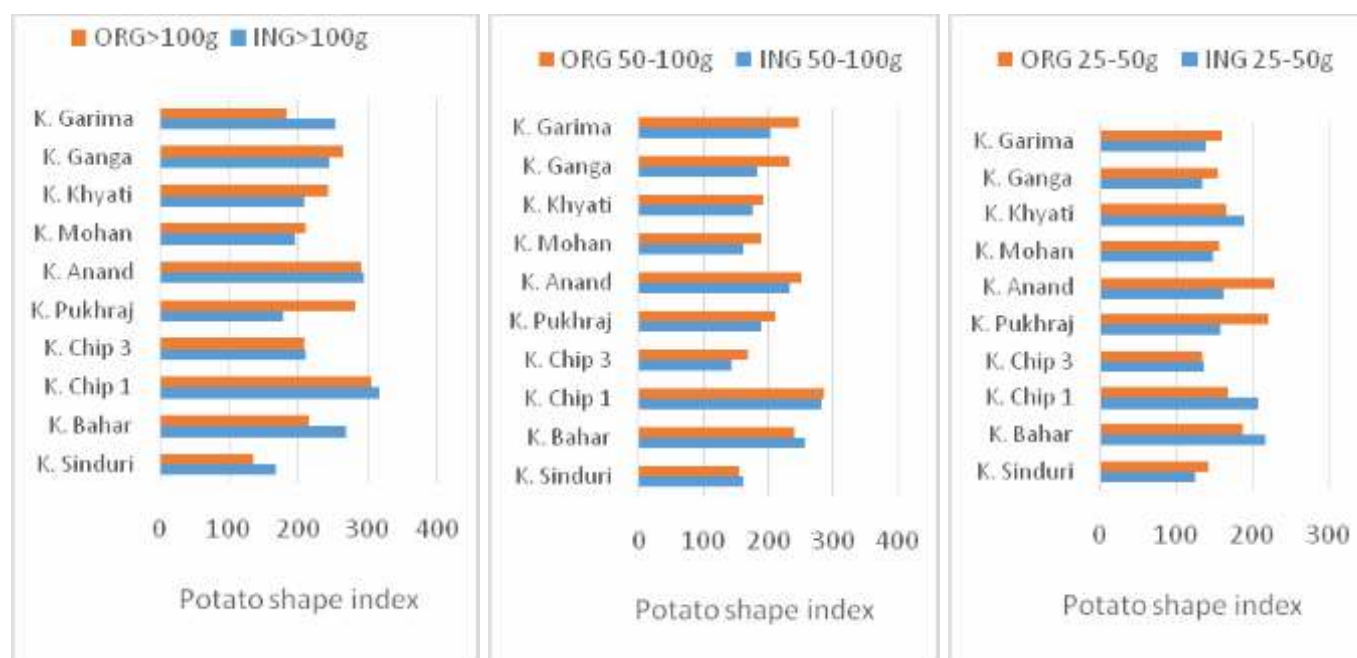


Fig. 2. Varietal behavior with respect to shape in three broad tuber categories grown under inorganic and organic cultivation practices in winter crop.

tubers preferred roundness, medium size towards oval-ness and small one with no significant variations. In another study on boron application for controlling tuber cracking, two sources borexdecadehydrate (10.5% B) and disodium octaboratetetrahydrate (20% B) were not found effective in controlling tuber cracking particularly in cv. K. Chipsona-3 in light soils at Modipuram. In heavy textured soil, significant tuber cracking was not observed.

Optimizing date of planting for potato cultivars in Nilgiris: A field experiment was conducted during summer season to find out the suitable date of planting from 04.05.2017 to 01.06.2017 at an interval of seven days for maximum yield of four cultivars viz., K. Girdhari, K. Himalini, K. Jyoti and K. Swarna. Planting on 11.05.2017 recorded highest tuber yield (29.57 t/ha) followed by 04.05.2017 (26.69 t/ha). K. Girdhari (31.3 t/ha), K. Swarna (38.4 t/ha) and K. Jyoti (17.13 t/ha) planted on 11.05.2017 recorded maximum yield whereas, K. Himalini (35.77 t/ha) on 04.05.2017 (Fig.3).

Organic potato production technology development

Varietal performance in organic farming: At Modipuram, ten varieties were evaluated in organic farming system. In this third year of Organic based system variety K. Mohan (30.5 t/ha) and K. Anand

(24.0 t/ha) performed better than others with the yield maintenance of 64.1 and 66.4%, respectively compared to inorganic nutrition. Amongst processing varieties K. Chipsona-1 (21.7 t/ha) and K. Chipsona-3 (20.6 t/ha) attained 73.1 and 63.1% yield of inorganic nutrition (Fig. 4).

Organoleptic evaluation of inorganic vs. organic potato tubers: In organoleptic evaluation by a panel at Modipuram organically cultivated potatoes of K. Anand, K. Chipsona-3, K. Garima, K. Mohan, K. Pukhraj and K. Ganga scored better whereas inorganically grown potatoes of cvs. K. Chipsona-1, K. Khyati, and K. Sindhuri tasted better (Fig.5).

Disease incidence: Disease incidence was 0.5- 5.0 % in organic treatment, whereas, it was more in

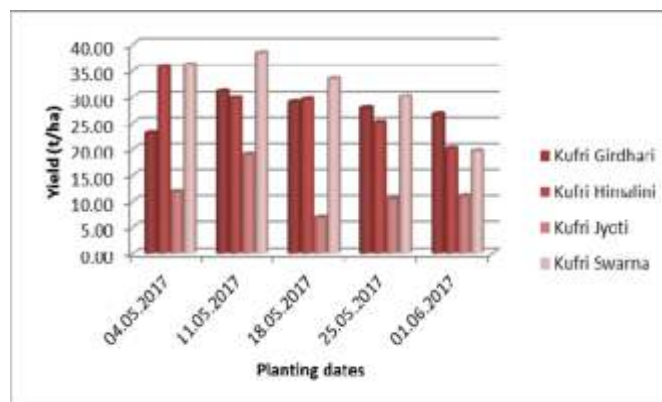


Fig.3. Performance of potato cultivars in Nilgiris in different planting dates

inorganic nutrition (2.0-7.5%). In another experiment, late blight management was done through organic based chemicals/ restricted used chemicals. Among six treatments, copper oxychloride @ 0.2% (45%) and copper hydroxide @ 0.2 % (47%) showed lower disease severity as against control (85%).

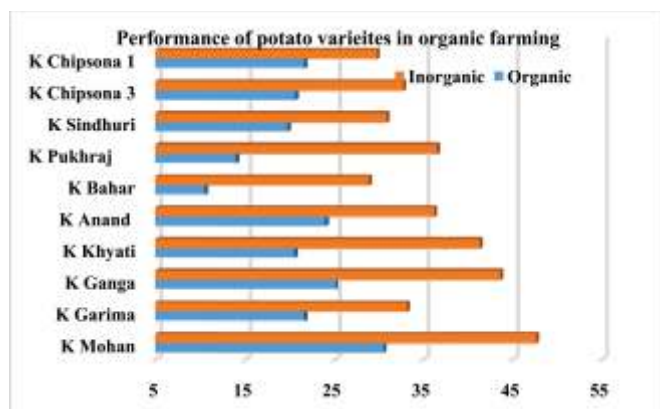


Fig. 4. Marketable tuber yield (t/ha) in organic farming system

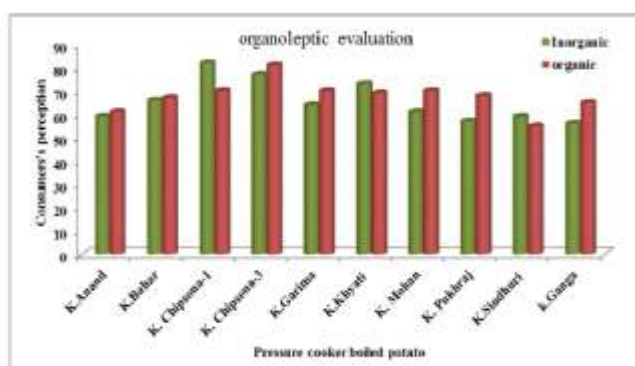


Fig.5. Overall acceptance of organic vs inorganic treatments of boiled potatoes

Better crop sequence and nutrient management option for eastern plains: At Patna, four crop sequences having 300% cropping intensity were tried in combination of five nutrient management practices. Highest system productivity was recorded in potato- cowpea- maize system with 100% recommended fertilizers levels. Application of organic or green manures was found effective in enhancing soil health as compared to inorganic nutrition.

Developing organic based potato cropping systems in eastern region: A fixed plot field trial was started during 2015 at Patna for developing remunerative and stable potato-based sequences under organic management with 300% cropping intensity. The results of two consecutive year's work showed that potato-onion-maize was most remunerative with application of 100% recommended nitrogen through vermi-compost.

Development of potato based cropping systems for different agro-ecologies

Developing potato based cropping systems for west central plains: At Gwalior effect of cropping sequence on productivity was studied. Highest maize equivalent yield (15 t/ha) was recorded in maize + cowpea- potato system, while, lowest maize equivalent yield (10.4 t/ha) was recorded in cowpea- potato sequence. Highest maize equivalent (13.1 t/ha) was recorded with 100% RDF NPK followed by 50% RDF NPK + 50% through FYM. Planting of potato after maize+ cowpea inter-crop with 100% RDF NPK was found best cropping sequence for the region (Fig.6).

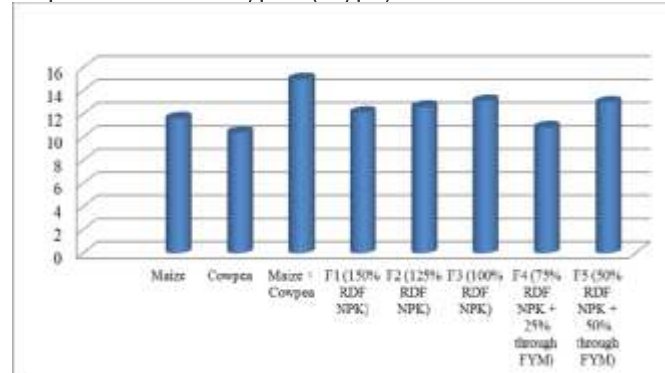


Fig. 6. Maize equivalent yield (t/ha) of different cropping systems

Cropping system and nutrient management practices for Meghalaya region: Potato-cabbage (CS3) produced highest potato equivalent yield (28.7 t/ha) followed by potato-radish (CS4) sequence (27.6 t/ha). Application of 50% RDF + 25% recommended dose of nitrogen (RDN)-FYM+ Azospirillum + PSB in potato crop and 50% RDF to subsequent crops resulted in highest potato equivalent yield (28.1 t/ha) followed by 50% RDF + 50% RDN-FYM to potato and 75% RDF to subsequent crop (27.8 t/ha) as depicted in Fig.7 and 8.

Evaluating potato based cropping system in Nilgiris: Amongst three potato based crop sequences, highest potato equivalent yield was obtained from potato-garlic system (52.6 t/ha), which was statistically at par with potato-carrot (48.1 t/ha) sequence. The lowest Rf value of PCN multiplication was recorded with potato-garlic (0.86) system as compared to potato-potato (1.72) sequence.

Long term plant nutrition studies in potato based cropping systems

Productivity: In tenth crop cycle, inorganic nutrition produced total tuber yield (24.0- 34.9 t/ha) comparable to 100% inorganic nutrition + secondary nutrients or crop residue (24.9- 31.4 t/ha) in all three cropping systems where absolute control (6.2- 9.9 t/ha) had significantly lower yields (Fig. 21). Wheat (33.3%), potato (30.0%), onion (20.4%) and maize (27.3%) yield was higher in 100% organic nutrition in comparison to inorganic treatment. Productivity of rice, groundnut and green gram was at par in organic and inorganic nutrition. Mean system productivity was highest in maize-potato-onion (61.0 t/ha) followed by groundnut- potato- green gram (51.2 t/ha). Lowest

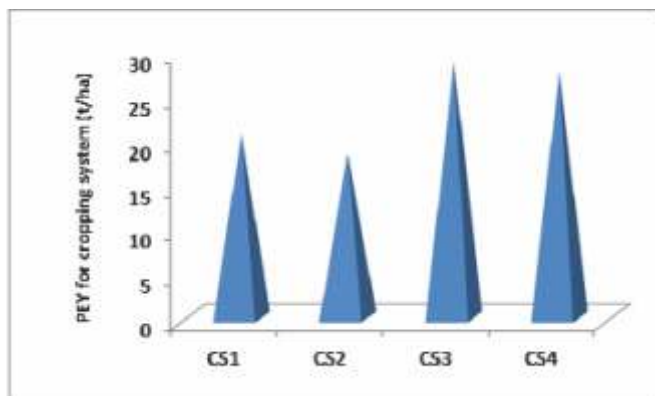


Fig.7. Potato equivalent yield for different cropping systems



Fig. 8. View of cropping system experiment at CPRS Shillong

system productivity was recorded in rice-potato-wheat (42.5t/ha) (Fig. 9).

Soil Health: Organic carbon (%) and available phosphorous exhibited significant variations amongst different treatments after tenth year of the trial (Fig. 10 and 11). Incorporation of crop residue and organic manures with or without chemical fertilizers improved the organic carbon content and availability of phosphorous in soil. In rice- potato-wheat system highest organic carbon content (0.97%) was in 100% organic+ crop residue treatment whereas in 100% inorganic nutrition it was 0.48% only. Available P was in 100% organic+ crop residue treatment (226.7 kg/ha). Inorganic nutrition (100%) and control recorded 101.3 and 53.7 kg/ha available P, respectively. The results suggest that P application should be optimised in different potato based cropping systems and integration of organic and sources would help in reducing the cultivation cost.

Disease Incidence: Pathogens are affected by different sources of nutrients applied during crop cultivation and sequences followed. Among all three cropping systems viz., potato-wheat-paddy (C1), potato-onion-maize (C2) and potato-green gram-groundnut (C3) foliar diseases like *Phoma* and leaf spot complexes were more in absolute control followed by 100 % organic nutrition and 100% organic+ crop residue. Incidence of black scurf of potato ranged from 5.20 to 6.33% when 100% NPK was applied as either as through organics or inorganics compared to 20.67% in

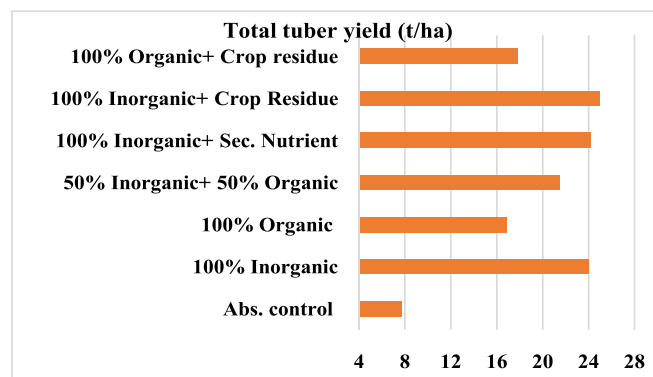


Fig. 9. Total tuber yield in rice- potato- wheat system

absolute control treatment. Incidence of powdery mildew of wheat was more in treatment consisting inorganic sources than the organic sources. Similar trend was also observed during 2016-17. In paddy, disease incidence of sheath blight and *bakane*

disease was highest (78.33%) when 100% NPK and secondary nutrients were applied inorganically and incidence of *bakane* disease of rice was highest in 50% NPK inorganic + 50% organic (27.50%). Highest incidence of banded sheath blight of maize was recorded in 100% NPK organics + crop residue (36.67%) followed 50% NPK inorganic+50% organic. In potato-maize-onion cropping system, incidence of *Alteraria* leaf spot of onion was recorded and the incidence was less under organic nutrition (Fig. 12-13).

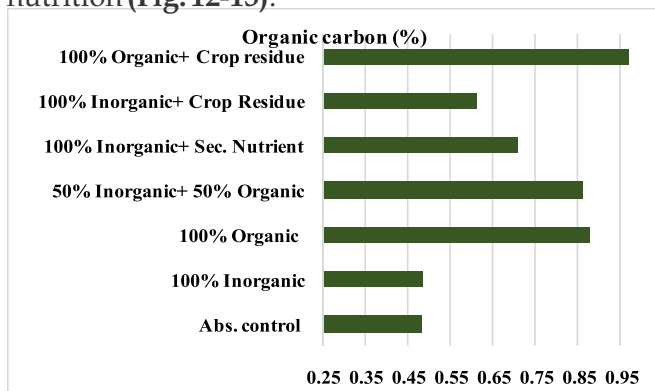


Fig. 10. Status of organic carbon in rice-potato-wheat system

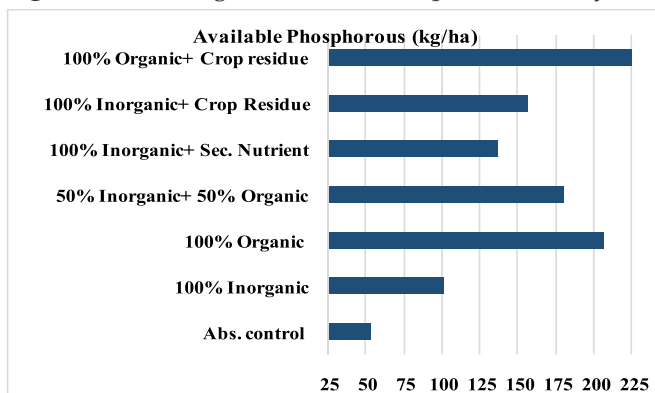


Fig. 11. Status of available phosphorous in rice-potato-wheat system

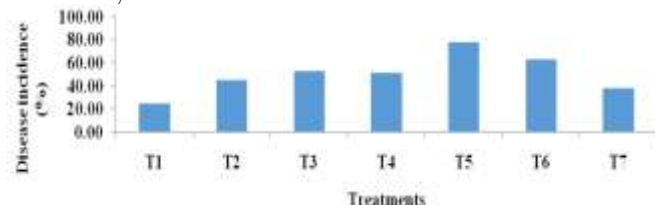


Fig. 12. Incidence of sheath blight of rice in potato-wheat-paddy cropping system.

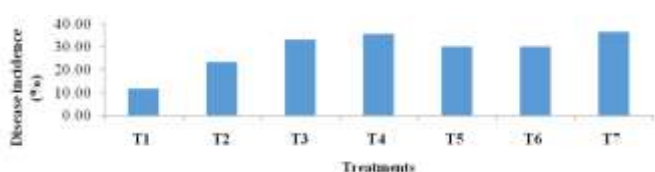


Fig.13 Incidence of banded sheath blight of maize in potato-maize-onion cropping system.

Pest Incidence: Population of thrips on groundnut, % stem borer damage in maize and % leaf folder and stem borer damage in rice did not show any significant differences among various treatments. However, the maximum incidence of blister beetle was recorded on ground nut in 100% NPK + secondary nutrients followed by 100% NPK + crop residue. Similarly, maximum incidence of leafhoppers in groundnut was recorded in 100% organic + crop residue (Fig. 14).

Low incidence of whitefly and thrips was observed on green gram and onion crops, respectively. Sporadic incidence of pod borer was also recorded in green gram crop. Whitefly incidence in 50% organic +50% inorganic had maximum incidence in C1 (100% organic+crop residue) and C2(100% organic) system, while it was maximum in 100% NPK inorganic in C3 system. Cutworm damage in tubers was maximum in C3 (100% NPK+ secondary nutrients) followed by C2 and C1 as depicted in Fig. 15.

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

Optimizing N requirement for different potato cultivars suitable for *kharif* season: Field experiment was conducted for optimizing nitrogen

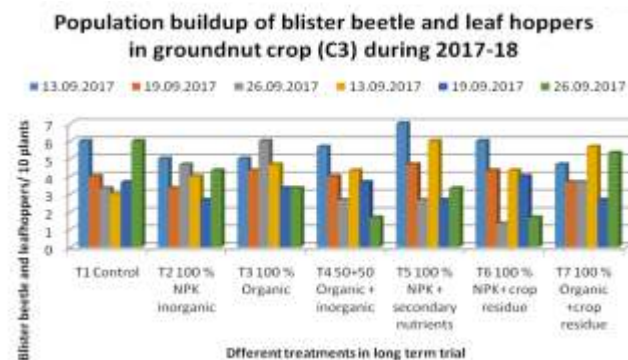


Fig. 14. Population build-up of blister beetle and leaf hoppers in groundnut

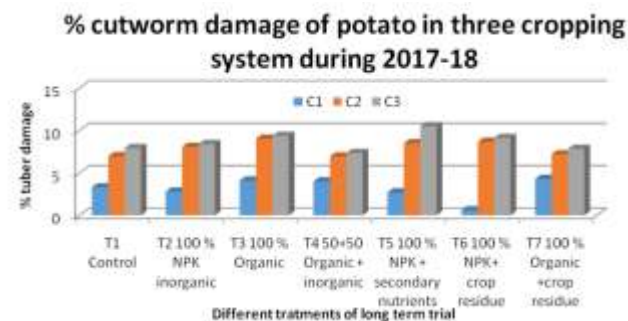


Fig. 15. Cutworm damage of potato in three cropping system

dose for three cultivars viz., Kufri Jyoti, Kufri Himalini and Kufri Surya in Hassan with five levels of N (0, 50, 100, 150 and 200 kg/ha) in split plot design. Significantly higher yield (10.23 t/ha) was recorded with 100 kg N/ha and found to be at par with 50 kg N/ha. Kufri Jyoti (7.24 t/ha) recorded highest yield at 50 kg N/ha of N while Kufri Himalini (12.80 t/ha) and Kufri Surya (11.84 t/ha) recorded maximum yield at 100 kg N/ha (Fig. 16).

Optimizing P requirement for different potato cultivars suitable for *kharif* season: Field experiment was conducted during 2017-18 for optimizing phosphorus dose for three commercial cultivars viz., K. Jyoti, K. Himalini and Kufri Surya in Hassan with five levels of P (0, 40, 80, 120 and 160 kg/ha) in split plot design. No response was observed. All levels of P except 40 kg/ha found on par with each other. In the interaction, Kufri Jyoti (6.81 t/ha) recorded highest yield at 40 kg/ha of P, Kufri Surya (13.26 t/ha) at 80 kg/ha P, whereas, Kufri Himalini at 0 kg P/ha (Fig. 17).

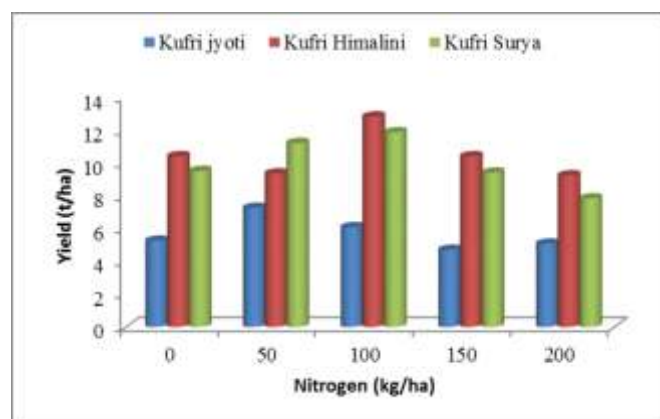


Fig. 16. Response of three potato varieties to different nitrogen levels at Hassan

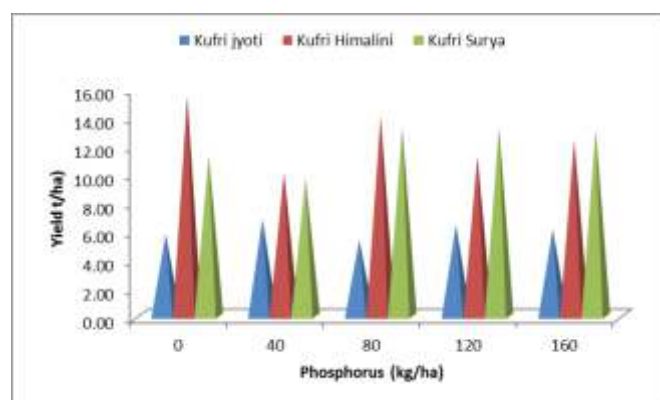


Fig. 17. Response of three potato varieties to different phosphorus levels at Hassan

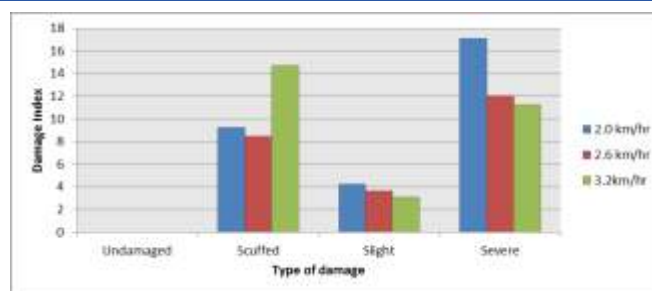


Fig. 18. Damage Index at tractor's three different speeds of operation in K. Pukhraj

Optimizing K requirement for different potato cultivars suitable for *kharif* season: A field experiment was conducted for optimizing potassium doses for three cultivars viz., Kufri Jyoti, Kufri Himalini and Kufri Surya in Hassan. Among the treatments, control recorded significantly higher yield as compared to plots applied with different doses of potassium. Whereas in the interaction effect studies, Kufri Jyoti recorded maximum yield (9.37 t/ha) at 50 kg K/ha, Kufri Surya (13.07 t/ha) at 150 kg K/ha whereas, Kufri Himalini at 0 kg K/ha.

Mechanical technologies for potato cultivation

Assessment of potato damage during mechanical operations and its remedial measures: Severe type of damage index was minimum (11.2) with a tractor operated potato elevator digger at forward speed of 3.2 km/hr whereas the scuffed and slight damage indices (8.47 and 3.07, respectively) were minimum at forward speed of 2.6 km/hr & 3.2 km/h, respectively (Fig. 18). Lowest total damage index was 24.1 at the forward speed of 2.6 km/h compared to 30.5 observed at forward speed of 2.0 km/h. Bruising percentage with potato elevator digger was measured 8.7% and 2.6% for slight and severe type of bruising, respectively. A test was performed to simulate the mechanical damage caused by all tumbling and dropping during harvesting and handling operations. Tubers of Kufri Pukhraj varieties were dropped from various heights (30, 60, 90 and 120 cm) onto a hard surface in order to perform damage to tubers. External damages (30%) were maximum with drop height of 120 cm and similar was the case for severe bruising (20%). In order to reduce the damages in potatoes during harvest with a tractor operated potato elevator digger, a rubber mould (dye) for 6 pieces for providing rubber lining (4 mm thick) on all the rods in chain conveyor of tractor operated two row

potato elevator digger was designed and got fabricated.

Development, improvement and evaluation of potato combine harvester: Two row tractor operated potato combine harvester's (prototype-I) design was improved for better tuber separation and reducing bruising injury. It consists of six major unit *viz.* main frame, digging system, elevator conveyor, side delivery/ discharge conveyor, power transmission and transport system. During the field operation two tractors are required, one to operate the machine and other one to carry the trolley to receive dug material. Transport system of prototype consisting of two pneumatic wheels (size 19 x 6.25) was further improved by providing one more wheel for bearing the weight adequately of prototype-I and for its proper transportation and operation in field. Prototype II comprised six major systems *viz.* main frame, digging cum horizontal conveying system, cage wheel type vertical conveying system, trash separator and tuber inspection system, bunker hopper and power transmission system. Improvements in design of bunker hopper were done and its potato holding capacity was increased from 5 to 800-900 kg. A folding type bag holding system having provision

for holding two bags at a time has also been provided at the end of delivery chute for collection of tubers directly in bags. Field trial and testing was carried out in the actual field conditions (Fig. 19).

Minituber size separation mechanism: Minitubers need to be graded before planting/marketing for uniform germination. An electric operated machine for grading of small tubers was fabricated. In this unit tubers from hopper are conveyed through electromagnetic generated vibrations. Separation is performed on the basis of size. A special mechanism has been developed for separation of different size tubers. Grade variation from < 1.0 gm to > 5.0 gm can easily be changed as per requirement.

Design of a low cost net house: For multiplying early generation seed material a low cost net house was designed and fabricated at Jalandhar (Fig. 20). Net consists of columns made of GI pipes (square or round) and the roof web is made of flexible wire. Net house includes curvilinear side and central supports fixed over the columns. Net covering can be easily removed for keeping at safe place in off season. Similarly, structure can also be dismantled for shifting to different location to avoid soil borne diseases. Cost of this net house is about 60% of the traditional net houses.



Fig. 19. Tractor operated potato combine harvester (Prototype I and II)

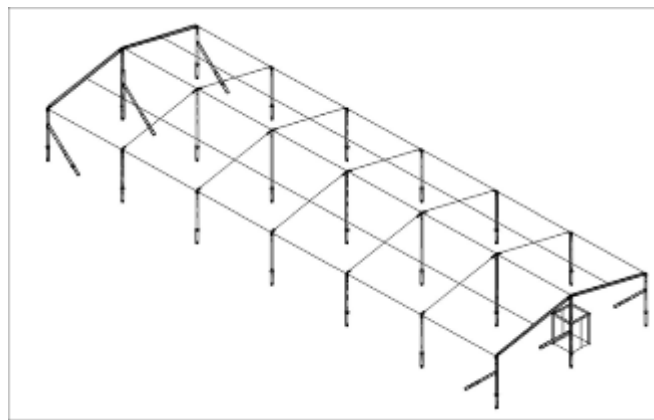


Fig. 20. Low cost net house with wire netted roof for seed multiplication

Programme: Climate change impact and adaptation strategies for potato crop

Project: Impact assessment and development of adaptation strategies for potatoes using modelling and GIS tools: Anthropogenic emission of greenhouse gases (GHGs) in the last two centuries have resulted into a rapid global change. As a consequence of which sharp rise in temperature levels in the Earth's atmosphere has been observed. Globally averaged concentrations of CO₂ reached 403.3 ppm in 2016, up from 400.00 ppm in 2015 because of a combination of human activities and a strong El Niño event. Concentrations of CO₂ are now 145% of pre-industrial (before 1750) levels. Atmospheric methane (CH₄) and nitrous oxide (N₂O) reached a new high of about 1853 ppb and 328.9 ppb respectively in 2016 and is now 257% and 122% of the pre-industrial level. Climate change could exert

acute effects in food supply; therefore, one of the main challenges for modern agriculture is to develop strategies to cope with potential negative impacts of future climate change to ensure food security by 2050 and beyond. Potato is the most important non-grain crop in the world and is often the main source of income and food security in developing countries. Therefore, understanding the potential impacts of climate change on potato production is crucial for future global food security. Potato, a temperate region crop being grown in sub-tropical regions of India is vulnerable to climate change not only in terms of total production but also susceptible to major diseases and pests in the region. Hence, miscellaneous efforts should be chalk out for mitigating the climate change impact in a sustainable approach. The investigation under

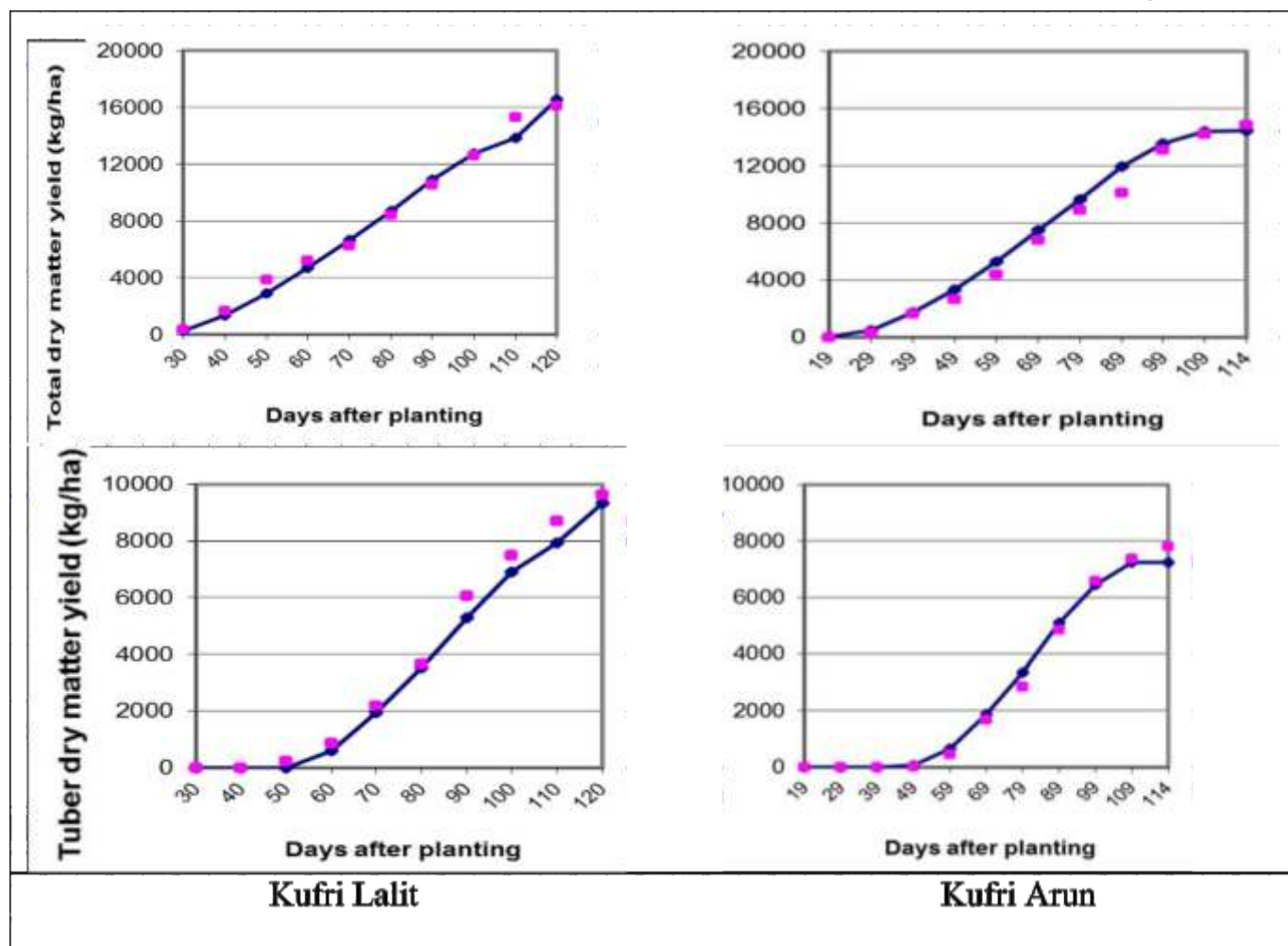


Fig 1. Validation results of simulated and measured dry matter yields

the present programme are planned to study the impact of climate change on potato productivity and disease and pest dynamics and to develop improved management strategies to combat the threats of climate change for sustainable potato production in India.

Calibration of WOFOST crop growth model for potato cultivars Kufri Lalit and Kufri Arun:

WOFOST is one of the most widely used model for studying the crop growth and estimating the potential productivity of the annual crops. It is among the top three models in the world which are being used extensively for the climate change impact studies. During this year, the model was calibrated for Kufri Lalit and Kufri Arun cultivars using time course data on potato crop growth parameters generated at ICAR-CPRS, Patna during 2011-12 and 2012-13 (Kufri Arun) and 2013-14 and 2014-15 (Kufri Lalit). A close match between simulated and the observed values was found for total dry matter as well as tuber dry matter yield (Fig. 1). The results shows that the model can be satisfactorily used to study the crop growth of Kufri Lalit and Kufri Arun.

Carbon footprint of potato production: On an average agricultural greenhouse gas (GHG) emissions account 10-12 percent of all manmade GHG emissions and reducing agriculture's carbon footprint is central to limiting climate change and to help to ensure food security. To minimize the negative impact of agricultural production system on the environment, there is an increased interest to quantify the amount of CO₂ emission per unit of products. Studies on carbon footprint estimation for the potato production are almost nonexistent in hilly states like Himachal Pradesh. The aim of this study was to estimate the carbon footprint and energy consumption for potato production in one of the major potato growing region of the state to identify different energy efficient management practice. The analysis of GHG emissions in two production systems with (production system-I) and without the use of fuel operated machinery (production system-II) in representative farms of Shimla area suggested that major drivers of the GHG emissions are fertilizer production, FYM and soil-related field emissions from applied N, all together accounted for on average 48.93% of the total emissions across both production systems in

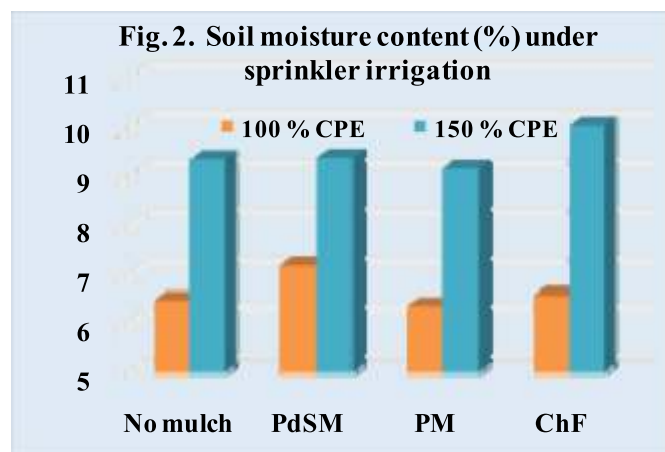
the present study. Energy use according to the kinds of fertilizers (FYM and chemical fertilizers) revealed that nitrogen alone accounted for 26.27% share of total energy and was responsible for 38.48 % of GHG emissions including emissions from soil, followed by FYM (6.79%), phosphorus (6.17%) and potassium (2.43%) across the production systems. Considering average yield of 18.30 t/ha the GHG emission in production system-II was 34.89 kg CE /t (127.94 kg CO₂) and the corresponding emission figure in production system-I was 34.27 kg CE /t (125.7 kg CO₂) of fresh potatoes. Renewable input seed also accounted for significant (33.13%) share of emission total emission. Fertilizers, particularly nitrogen, and seed were found to be significant emitters of greenhouse gas emissions.

Effect of water levels and mulching on potato under drip irrigation: At Modipuram, drip irrigation applied at 125 % CPE (cumulative pan evaporation) produced significantly higher total yield (30.2 t/ha) compared to irrigations scheduled at 75% CPE (27.4 t/ha). However, the effect of irrigation levels on large and small size tuber yields was non-significant. Paddy straw mulch @ 5 t/ha (PdSM) produced significantly higher total yield (30.6 t/ha) followed by polythene mulch (PM) and spray of chemical formulations ChF-1 and ChF-2 than without mulching.

Effect of water levels and mulching on potato under sprinkler irrigation: In another experiment at Modipuram, the effect of water levels was significant on total yield and tuber numbers under sprinkler irrigation. Irrigations scheduled at 150% CPE produced significantly higher total tuber yield (35.0 t/ha) compared to irrigations at 100% CPE (28.8 t/ha). Similar trend was noticed in case of total tubers as well as large and medium size tuber yields. Paddy straw mulch @ 5 t/ha (PdSM) produced higher yield (32.5 t/ha) over no mulch, but was statistically at par with the produce of crop sprayed with chemical formulations ChF-1 and ChF-2 followed by polythene mulch (PM). However, the effect of mulching was non-significant on tuber numbers and grade wise tuber yields.

Soil moisture content and soil temperature as influenced by water levels and mulch under micro-irrigation: The soil moisture content was higher (7.18%) when paddy straw mulch (PdSM)

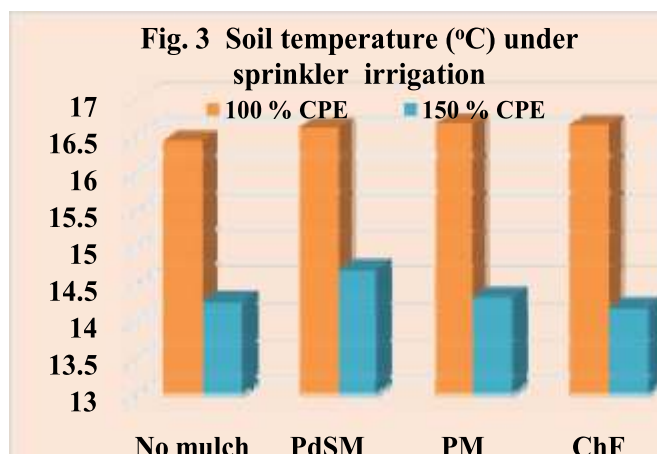
was applied to potato fields than other approaches *viz.* polythene mulch and chemical formulations (6.35-7.18%) were tried under water stress conditions (100% CPE water level), whereas the control plot recorded 6.47% soil moisture (Fig. 2). In case of soil temperature the polythene mulch moderated the parameter by 1.8% over control at



Evaluation of drip and sprinkler irrigation methods with or without mulch: At Gwalior, potato *cv.* Kufri Jyoti was planted in paired row system on raised beds under drip and sprinkler irrigation methods. The sprinkler irrigation produced significantly higher total yield (26.3 t/ha) and tuber numbers (512,000/ha) over drip irrigation (20.5 t and 491,000/ha), respectively. The tuber numbers were maximum at 125% CPE water level (561,000/ha) over 75% CPE (464,000/ha) under sprinkler irrigation method. However, reverse trend was observed under drip irrigation. Paddy straw mulch with sprinkler irrigation produced significantly highest tuber yield (28.8 t/ha) followed by polythene mulch (26.4 t/ha) and no mulch (23.6 t/ha). The reverse trend was noticed in case of drip irrigation, however, polythene mulch produced highest yield and tuber numbers (23 t and 569,000/ha), respectively at 75% CPE water level. It was also found to be at par with the yield (23 t/ha) and tuber numbers (516,000/ha) produced without mulch at 125% CPE. The paddy straw mulch under sprinkler irrigation at 75 and 125% CPE gave higher tuber numbers (532 and 598 thousands/ha), respectively than other treatments, however, the differences were not significant.

Identification of climate resilient potato cultivars in relation to rising CO₂ level and temperature: Rising atmospheric CO₂ concentration coupled with

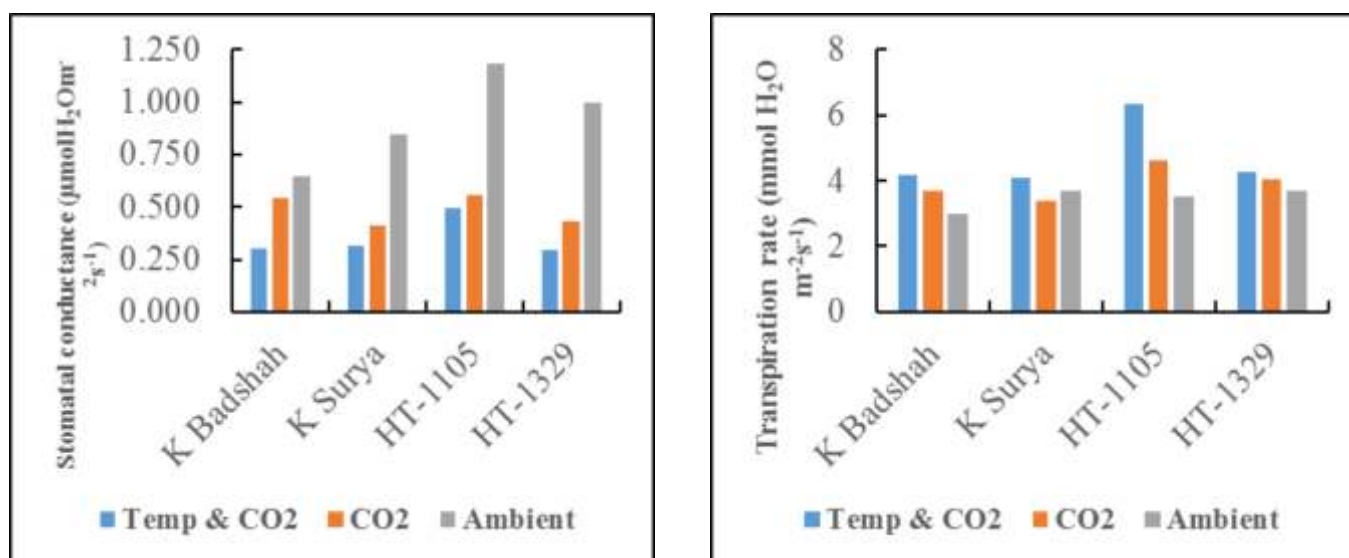
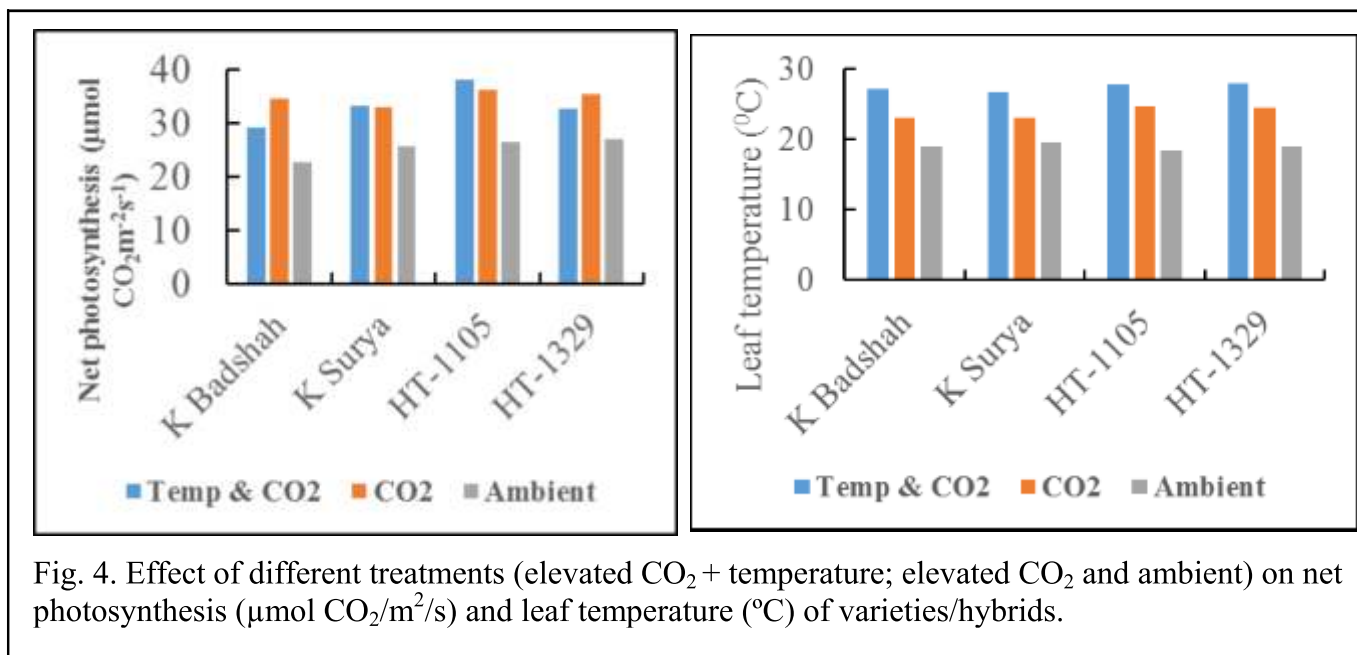
100% CPE water level, which had 2.2°C higher mean temperature when sufficient irrigations were scheduled at 150% CPE (Fig. 3). However, the lowest crop canopy temperature (23.4 °C) was recorded with chemical spray over control (24.1°C) and other mulch treatments (23.4 - 24.8 °C) at low water level.



temperature increase is one of the important global threats for crops including potato under the era of climate change. Adaptation strategies by exploring tolerant varieties may be the possible alternative to tackle this issue. To identify the climate resilient potato cultivars/hybrids in relation to rising CO₂ level and temperature, two hybrids *viz.* HT/7-1105 and HT/7-1329 with commercial check varieties Kufri Surya (heat tolerant) and Kufri Badshah were chosen for the present investigation in open top chambers (OTCs) at ICAR-CPRS, Jalandhar. The plants were raised at two temperatures (ambient and +3 °C) and two CO₂ levels (ambient and 600 ppm). Plant height of varieties/hybrids have slight increase under elevated CO₂ (with or without temperature) except for Kufri Surya. Leaf area index (LAI) of each varieties/hybrids increased linearly with crop age under all the conditions and attained its peak at 70 DAP and then declined. The LAI of varieties/hybrids was higher under elevated CO₂ (with or without temperature) except for Kufri Badshah where LAI under elevated CO₂ coupled with higher temperature decreased. Photosynthesis (PS) rate was higher (34.4 μmol CO₂/m²/s) under elevated CO₂ than control. Exposure to high temperature (around 3 °C) and CO₂ during growing season reduced PS rate (33.2 μmol CO₂/m²/s). Nevertheless, it sustained higher than control (25.4 μmol CO₂/m²/s) (Fig. 4).

Exposure to high temp and CO₂ further reduced stomatal conductance (Fig. 5) and increased the leaf temperature (Fig. 4) which resulted into higher transpiration rate (4.72 mmol H₂O/m²/s). It appears that availability of CO₂ as raw material for the photosynthesis became limiting due to higher transpiration rate. Advance stage heat tolerant hybrids HT/07-1105 and HT/07-1329 appears to had higher PS rate under all the treatments. Tuber yield of Kufri Surya, Kufri Badshah, HT/7-1105 and HT/7-1329 increased by 50.2, 15.3, 37.0 and

10.5%, respectively under elevated CO₂. Further, tuber yield under elevated CO₂ combined with temperature increased in Kufri Surya, HT/7-1105 and HT/7-1329 only by 8.2, 14.3 and 3.5%, whereas, it declined drastically by 29.3 % in Kufri Badshah (Fig. 6) as compared to control. Results indicate an appreciable level of resilience in crucial physiological traits (Photosynthesis, stomatal traits, transpiration etc) in studied genotypes, particularly in heat tolerant material, at enhanced temperature regime under elevated CO₂ level.



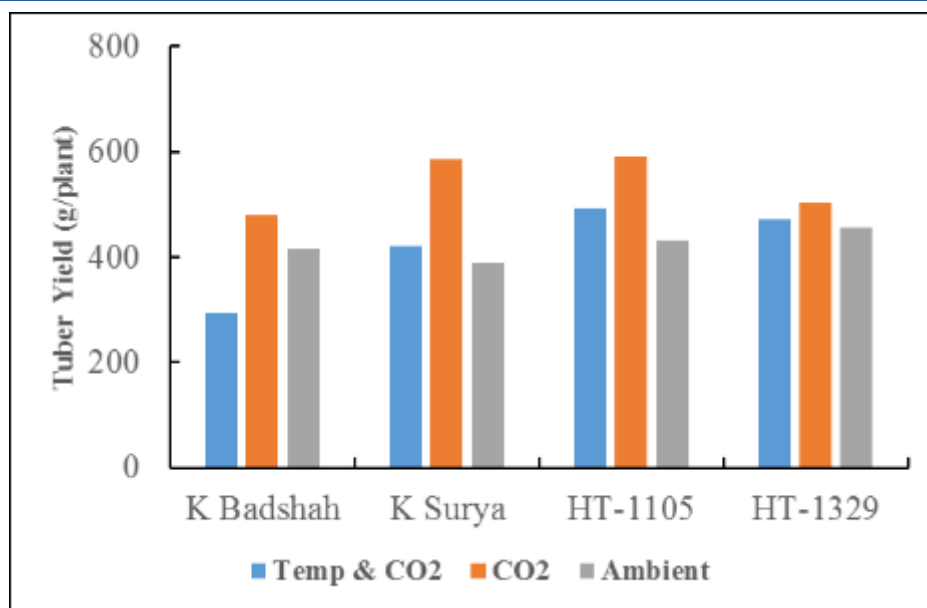


Fig. 6. Effect of different treatments (elevated CO₂ + temperature; elevated CO₂ and ambient) on tuber yield (g/plant) of varieties/hybrids.

Potential impact of climate change on potato late blight outbreak in Punjab using Indo-Blightcast model: Punjab is known as seed bowl of potato in the country. The occurrence of late blight in this state is frequent and significantly affects the potato productivity once every three-four years. As climate is warming globally, it is going to affect the incidence of late blight, hence potential impact of climate change on late blight appearance in Punjab was analysed using Indo-Blightcast. The model was run using districts level data on minimum and maximum temperature (°C) of Indian Meteorological Department's normals for baseline (year 2000) and future climate scenarios of RCP 6.5 (years 2030 and 2050) for 13 districts. The model predicted that late blight favourable period is likely to reduce in Amritsar, Ferozepur, Moga, Mukatsar, Patiala and Sangrur districts while it is likely to increase in Faridkot, Fategarh, Ludhiana and Mansa districts in the future climate (2030 and 2050).

Appearance of late blight and insect-pests in climate analogues: Climate analogues are important to study the appearance of late blight and subsequent effect on its incidence in future climate change scenarios. Late blight may appear either at same time or at different times in similar climate analogues. It was observed that at Kannauj (27.055 °N, 79.918 °E) late blight appeared on 6 Feb, 2018

while its analogous Bijnor (29.313 °N, 78.377 °E) it appeared on 19-21 December, 2017. The difference in late blight appearance in these two locations was less during 2014-15 and 2016-17. Similarly, at Patna (25.617 °N, 85.167 °E), which is analogous of Agra (26.753 °N, 78.773 °E), late blight appeared during first week of January (2-7 January, 2018) while at Agra, it appeared during second week of January (12-15 January, 2018). However, at Agra (26.753 °N, 78.773 °E) and its analogous Etah (27.739 °N, 78.729 °E), late blight appeared at same times i.e. second week of January. Late blight did not appear at Jalandhar (31.326 °N, 75.579 °E) and its analogues Baghpat (29.274 °N, 77.191 °E). Similarly, observations were recorded on incidence of insect pests on potato crop. The data generated will be used to correlate the weather parameters with late blight appearance using models.

Periodic generation of data on arrival and build-up of aphid and whitefly population on potato: The arrival and build up of *Myzus persicae* (Sulzer) on potato crop was monitored by leaf count method and yellow sticky traps at Jalandhar. *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. 7). The aphid reached the critical limit of 20 aphids per 100 leaves by 1st week of December. The

population growth continued till it was more than 1200 aphids per 100 leaves by the end of February. After this, the population of *M. persicae* suddenly declined due to fungal epizootic and remained low thereafter. The production of alati form nymphs started towards the last week of December which

indicated that immigration of alates continues at least till the last week of December. The production of alate and alati form morphs sharply increased after the 1st week of February, probably preparing for emigration from the plains.

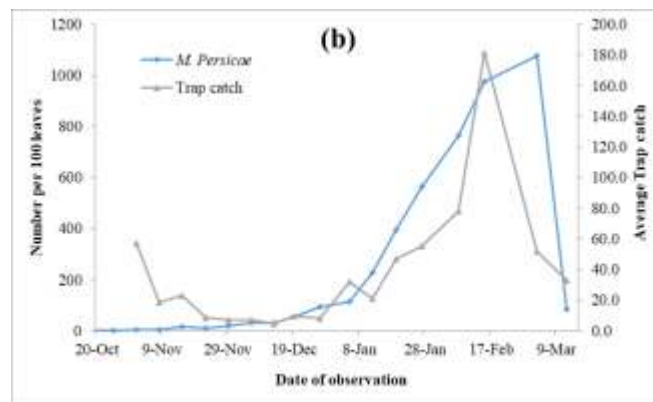
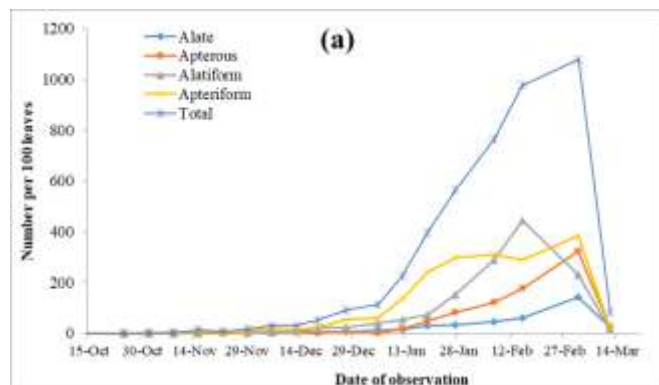


Fig. 7: Arrival and build up of *Myzus persicae* determined by leaf count and trap catch methods. (a) Population build up by leaf count method, (b) Comparison over time of leaf count and trap catch.

Similarly, arrival and build-up of *Myzus persicae*, *Aphis gossypii* and whitefly (*Bemisia tabaci*) were studied at Gwalior by planting the crop at four dates (30th October, 5th November, 10th November and 15th November, 2017) of aphids, whitefly

population on potato crop. The data is being generated on appearance and build-up of these potato pests to develop thermal constants of aphid development stages and to develop models for prediction of arrival of potato pests.

Division of Plant Protection

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

Disease Monitoring and Pathogens Profile

This was non blight year as there was no late blight epiphytotic across the country. However, late blight appeared on 29th June, 2017 on cv. Kufri Jyoti in Shimla hills and its overall severity ranged from 25-75% in Himachal Pradesh depending upon the cultivar raised and plant protection measures adopted. In western Uttar Pradesh the disease appeared in Bijnor on 19th December, 2017 on cv. Kufri Pukhraj with 5.0% disease severity and it did not spread further due to low temperature. Late blight survey was carried out in different districts of western UP (Meerut, Muzaffarnagar, Bijnor, Baghpat and Hathras). Highest disease severity was recorded at Muzaffarnagar (35%) and Meerut districts (15%). In most of the districts of Uttar Pradesh late blight appeared in the month of January except Hathras and Bijnor where it appeared in third week of December, while in Baghpat it did not appear. The incidence of other diseases like leaf spot complex and sclerotinia disease were also observed in western UP (Fig. 1). The conditions for outbreak of late blight were not favourable in West Bengal but *Alternaria* leaf spot incidence was very high. The potato root (var. Atlantic) and tuber (var. Kufri Frysona) samples were received from Gujarat. The primary and secondary roots had reddish brown lesions near soil line. The tubers had small, sunken and wrinkled lesions. When tubers peeled, white fungal growth forming a cavity was observed (Fig. 2). In both symptoms, the fungus – *Fusarium solani* was found associated.



Fig. 1: Initial symptoms of Sclerotinia rot and Sclerotinia rot affected field.

Comparative Genomics of Potato Pathogens

Characterization of *Phytophthora infestans*: It is essential to understand the pathogen variability to devise suitable management strategies. Since last two years, population of *P. infestans* is being monitored for sensitivity to cymoxanil,



Fig.2: Root rot and dry rot of potato due to *Fusarium solani*

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 was genotyped using two polymorphic SSR primers (Pi04 & Pi89). In most of the isolates two alleles (177/200bp and 181/169bp) were observed with primer Pi89 while two (176/195 bp) to three alleles (162/171/190bp) were observed with primer Pi04 (Fig. 3). A few isolates of *P. infestans* were also characterized using RG57 oligo probe. Results revealed a unique banding pattern for each isolate tested. No bands were found to be allelic. Tested isolates showed unique banding pattern and non-homozygous to US-8 type (Fig. 4). This indicates that Indian isolates are different from the global US isolate. This needs to be further investigated to confirm the population structure using DNA finger printing by SSR markers.

Comparative genome analysis of *Phytophthora infestans*: Earlier we generated ~50X coverage of whole genome of *P. infestans* and assembled 238 Mb

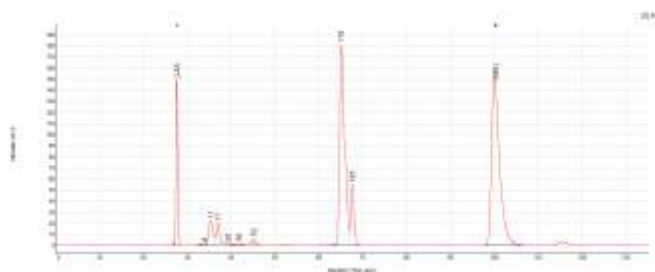


Fig. 3: Electropherogram of *P.infestans* isolate with Pi04 primer showing two alleles

using Ion Torrent (Next Generation Sequencing) technology and Illumina platform. Considering the huge contig number and repeat sequences, mate pair run was done using nano pore platform and generated enough reads to cover the whole genome and assembled to generate 220 Mb (**Table 1**). Now the data is ready for downstream analysis at gene as well as at genome level. The comparative genome analysis will help us to mine effectors responsible for pathogenicity as well as for future resistance breeding.

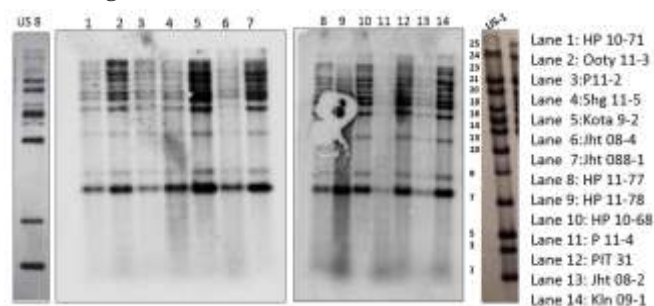


Fig.4: Genetic analyses of *Phytophthora infestans* isolates using RG57 probe

Table 1: Mate pair run and hybrid assembly of *P. infestans* genome details

WGS:	Phytophthora-DNA
Scaffolds Generated :	3508
Maximum Scaffold Length :	6926814
Minimum Scaffold Length :	48
Average Scaffold Length :	62898.3
Total Scaffold Length :	220647160
Total Number of Non-ATGC Characters :	204762172
Percentage of Non-ATGC Characters :	0.928007
Scaffolds >100 b :	3507
Scaffolds > 500 b :	3453
Scaffolds > 1 Kb :	3193
Scaffolds > 10 Kb :	783
Scaffolds > 1 Mb :	254
n50 value :	1645634
n90 value :	73783

Molecular Diagnostics and Detection of Potato Pathogens

Development and validation of one step RT-LAMP assay for Potato Virus X: One-step reverse transcription loop-mediated isothermal amplification (RT-LAMP) assay was developed for detection of *Potato virus X* (PVX) by reducing the steps and time involved (**Fig. 5a & b**). The developed one-step RT-LAMP assay was validated for its reproducibility or its robustness by running across more than hundred leaf samples which indicated the suitability of the assay for rapid screening of potato samples against PVX (**Fig. 5 c & d**). Further, the assay was expanded for detection of PVX in dormant potato tubers where the assay was able to detect the target virus successfully (**Fig. 6a & b**).

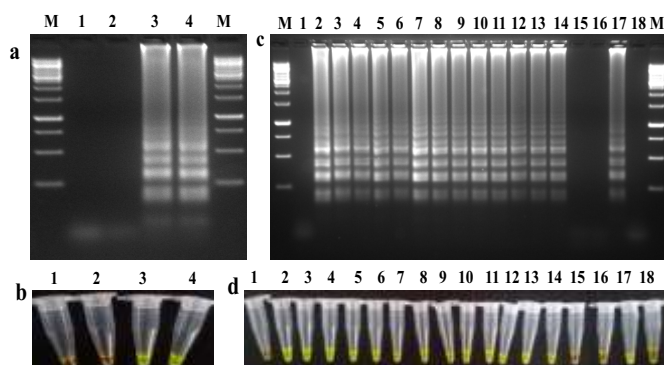


Fig. 5: One step RT-LAMP assay (a) with its visual detection by SYBER gold nucleic acid fluorescent dye (b) where tube 1 and 2 are no template and healthy controls whereas, tube 3 and 4 are positive samples of PVX. Validation of optimized one step RT-LAMP assay (c) where, lane M 1kb ladder, lane 1 and 18 are no template and healthy controls whereas, lanes 2-17 are test samples. Visual detection of the same (d)

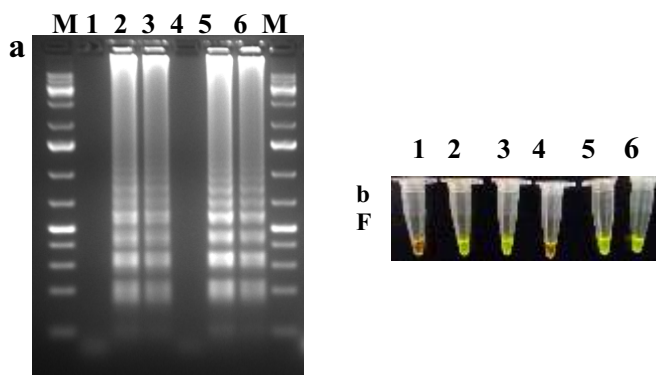


Fig. 6: Detection of PVX in dormant potato tubers by one and two step RT-LAMP assay where lane M 1 kb ladder, lane 1 no template control and lane 4 healthy control, lane 2 and 3 are one step RT-LAMP assay and lane 5 and 6 are two step RT-LAMP assay (a). Visual detection of the same using SYBER gold nucleic acid fluorescent dye in tubes (b)

Squash print reverse transcription loop-mediated isothermal amplification (SP-RT-LAMP) assay for detection of PLRV: Squash print reverse transcription loop-mediated isothermal amplification assay was developed for detection of *Potato leafroll virus* (PLRV) in single aphid. Healthy aphids were given an acquisition feeding on pure culture of PLRV and used for isolation of RNA by squash print method (Fig. 7). The RT-LAMP assay was carried out with the help of PLRV specific LAMP primers and amplification was carried out at 65°C for 60 min followed by 80°C for 10 min. The product was run on 2% agarose gel where it showed a typical ladder-like pattern in the virus acquired aphids indicating that the assay was able to detect PLRV from individual aphid. The same was visualized directly by adding fluorescent dye in LAMP product where a change in the colour from dark orange to fluorescent yellowish green was observed in virus acquired aphid samples. These results were confirmed by RT-PCR detection where an amplicon of expected size of 492 bp was observed. The assay was optimized with respect to its isothermal amplification temperature and its incubation period. The technique was examined for its relative selectivity with other potato viruses transmitted by aphids where it did not show any cross-reactivity with the tested viruses indicating its specificity. The assay was found equally sensitive with the existing RT-PCR assay. It was also found robust and highly reproducible as it could detect PLRV from known and unknown single aphid samples (Fig. 8). The assay was also successful in detection of PLRV in potato plants and tubers (Fig. 9).

Loop-mediated isothermal amplification technique for detection of *P. infestans*: Developed loop-mediated isothermal amplification (LAMP) assay targeting internal transcribed spacer (ITS) region of *Phytophthora infestans* for its visual detection. The ITS regions of ribosomal DNA are commonly used in diagnostics due to their relatively high copy

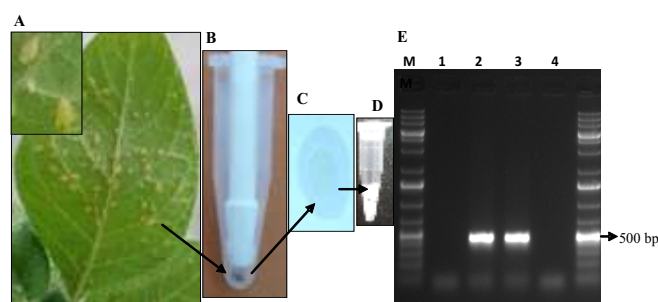


Fig. 7: Schematic representation of Squash Print method for isolation of nucleic acid from PLRV acquired and healthy aphid. (A) Healthy culture of aphids (B) Crushing of aphid in a tube containing NAR buffer (C) Printing of crushed extract of aphid on NCM (D) PCR tube containing nucleic acid in supernatant (E) Gel electrophoresis of RT-PCR amplified product of PLRV from aphid where, lane 1-no template control, lanes 2 & 3 are the templates obtained by Squash Print and kit methods respectively and lane 4- healthy (aphid) control.

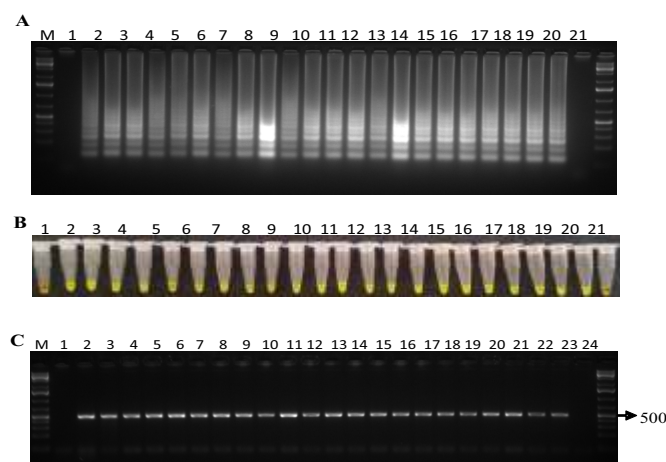


Fig. 8: Reproducibility of the optimized SP-RT-LAMP assay for detection of PLRV from known (acquired) single aphids. (A) SP-RT-LAMP amplified product where, lane 1- no template control, lane 2 to 22 are known samples, lane 23 & 24 are positive and healthy controls respectively. (B) Visualization of SP-RT-LAMP amplified product using SYBER Gold nucleic acid stain. (C) Similarly, agarose gel electrophoresis of RT-PCR amplified product of the same samples used for SP-RT-LAMP.

number and species specificity. LAMP is based on loop-amplification of a specific site of the genome by Bst polymerase with DNA-strand displacement activity. Warm-start Bst polymerase has been reported as a better alternative to Bst polymerase due to its precise activation at particular temperature to avoid random amplification. Present study focused upon ITS 1 region due to its

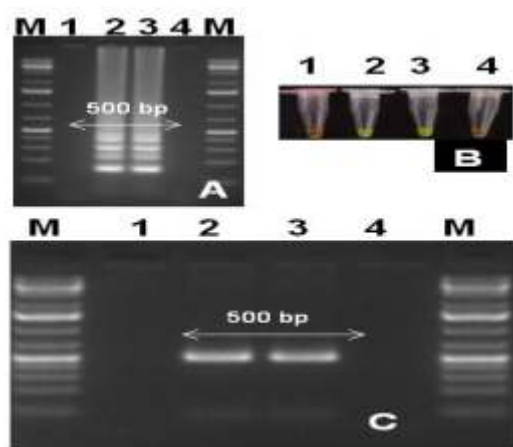


Fig. 9: Detection of PLRV in potato leaf and tubers by RT-LAMP and RT-PCR based amplification. (A) Agarose gel electrophoresis of LAMP amplified product where, lane M- 100 bp DNA ladder, lane 1 is no template control, lane 2 & 3 are leaf and tuber samples and lane 4 is healthy control. (B) Visualization of LAMP amplified product using SYBER Gold nucleic acid stain. (C) Similarly, agarose gel electrophoresis of RT-PCR amplified product of the same samples used for LAMP and the lanes are same as that of A.

higher specificity among commonly found *Phytophthora* species. The method used two sets of primers: two outer primers (F3 and B3), two inner primers (FIP and BIP) to accelerate the reaction (**Fig.10a&b**). The targeted region was PCR amplified and the product was sequenced to make assay more specific and reliable. The F3 and B3 primers spanning 233 nt region was cloned in pCR4 TOPO vector and works well as positive control (**Fig. 10c**). The ITS1 LAMP assay efficiently amplified the target region in 60 min at 65°C (**Fig.10d**). The assay was also optimized to decrease runtime for quick detection within 28 minutes of incubation at 65°C and it worked well. The assay also detected *P. infestans* from infected potato leaf tissues. The limit of detection (LOD) of ITS1 specific LAMP assay for *P. infestans* was 1pg/μl DNA (**Fig. 10e**). The described method employs SYBR Green dye, a nucleic acid stain found to be suitable for LAMP detection by fluorescence (**Fig. 10f**). The obtained results have shown ITS1-LAMP assay as a sensitive, less time consuming and specific alternative for PCR-based detection methods of *P. infestans*.

Development of simplified nucleic acid release protocol: Sensitivity, storage and stability analysis:

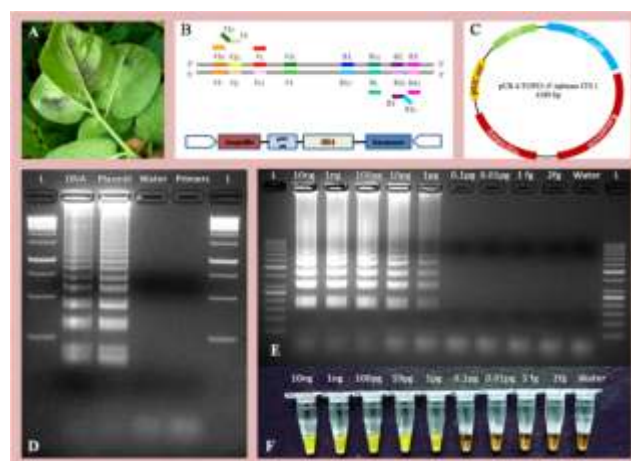


Fig. 10: A. Potato leaf infected with *P. infestans*, B. Target sequence for ITS1-LAMP primers: forward outer primer (F3), backward inner primer (B3), forward inner primer (FIP), backward inner primer (BIP), C. Cloned vector map of pCR4 TOPO:: *P. infestans* ITS1 as positive control, D. ITS1-LAMP amplification with *P. infestans* DNA and cloned plasmid. Products visualized with 2% agarose gel electrophoresis, E. Limit of detection assay: serial dilutions of the ITS1 target inserted into a plasmid, 10 fold dilution of plasmid from 10ng to 2fg and water (no template) control and F. Tubes following the ITS 1-LAMP reaction with SYBR Green fluorescent dye visualized under visible light.

The assay developed (last year) for isolation of nucleic acid (RNA/ DNA) was examined for its sensitivity, storage and stability. The assay was found equally sensitive in comparison to kit-based isolated RNA where both methods gave good amplification up to 10^5 dilutions (**Fig. 11**) without affecting the sensitivity and indicating that the RNA isolated using NAR buffer is as good as kit-based isolated RNA. The results (**Fig. 12**) revealed that the kit-based isolation is better, but considering the significance of NAR buffer with respect to its

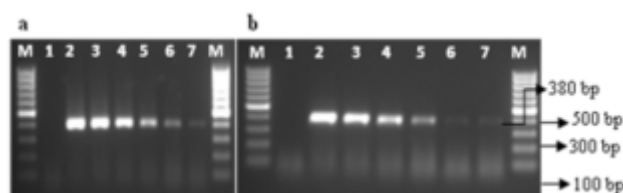


Fig. 11: Comparison of relative sensitivity of RNA isolated using NAR buffer to that of commercial kit. **a** RNA isolated using NAR buffer where, lane 1- no template control and lanes 2-7 are dilutions of the template (10^0 to 10^5). **b** similarly, the RNA isolated using commercial kit where, lane 1- no template control and lanes 2-7 are dilutions of the template (10^0 to 10^5).

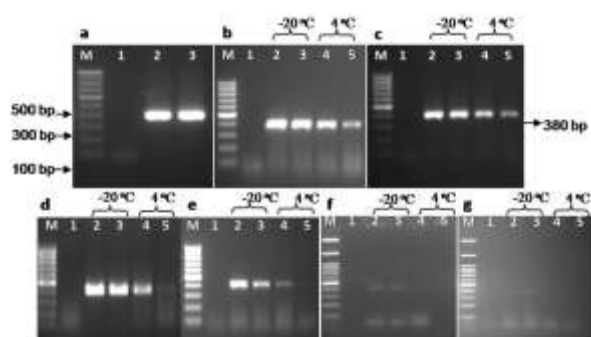


Fig. 12: Storage and stability analysis. **a** Stability of RNA on the day of isolation, lane 1- no template, lanes 2 & 3 - kit and buffer based isolated RNA, respectively. **b** Stability of RNA after 7 days of storage, lane 1- no template, lanes 2 & 3 -RNA isolated using kit and NAR buffer, respectively stored at -20°C and lanes 4 and 5 are same RNA at 4°C. **c** Similarly, the stability of RNA after 14 days, **d** 21 days, **e** 28 days, **f** 45 days and **g** 60 days of storage.

rapidity, simplicity and economy, the ability of buffer to keep the RNA stable for 28 days of storage at -20°C and 14 days of storage at 4°C is also a good finding for diagnostic purposes in laboratories having minimum facilities. However, the stability and concentration of total RNA isolated and stored at -20°C and 4°C was found to decrease significantly later on. It is advised to store the template at lower temperatures based on the facility available.

Production of polyclonal antibodies against potato virus Y: The pure culture of *Potato virus Y* (PVY) was mass multiplied in its pure form in 'Virus Pure Culture Facility', and purified the virus by conventional purification steps and checked for concentration by Transmission Electron microscopy. After checking for virus particle

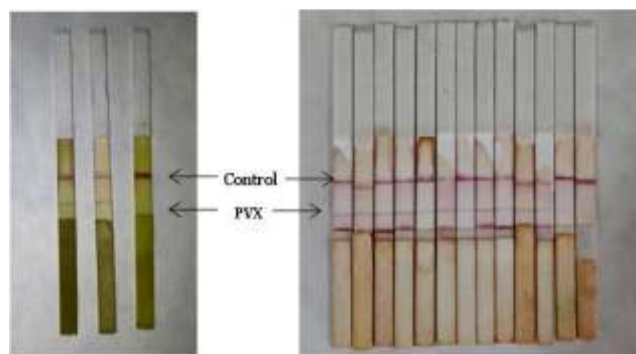


Fig. 13: Lateral flow immune assay detection of PVX using commercial

concentration, it was subjected for immunization in rabbits (outsourced) for production of polyclonal antibodies against PVY.

Dipstick kits for detection of potato virus X: Standardized dipstick kit for detection of PVX using commercial antibodies based on lateral flow immunoassay. The commercial antibodies were concentrated through 10K protein concentrated column and made up to required concentration. The kit was validated using 50 randomly collected field samples (**Fig. 13**). DAS-ELISA was performed for the same samples and the results were comparable to LIFA strip results.

Development of PCR based diagnostics for quarantined pathogens: A nested PCR protocol was standardized for detection of phytoplasma in potato. PCR with universal phytoplasma specific primer pair P1/P7 followed by nested PCR with another phytoplasma specific primer pair R16F2n/R16R2n were used to amplify the expected 1.2kb fragment of the 16SrRNA gene of phytoplasma (**Fig. 14**). DNA of peach yellows phytoplasma was used as positive control.

Multiplex RT-PCR system for rapid detection of potato viruses: A multiplex reverse transcriptase (RT)-PCR-based method was designed for the simultaneous detection of *Potato Virus A*, *X*, & *S*. The assay was targeted to amplify the specific region within the genome of respective viruses. The sequences were pre analyzed in sequence alignment tool with different accessions derived from NCBI of the respective viruses to remove chances of cross amplification. Thus, narrow down possibilities of getting false positive results during amplification. Each of the three pairs of

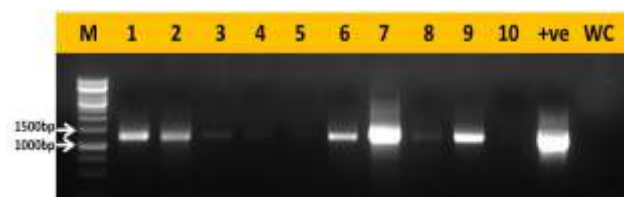


Fig. 14: PCR (p1/p7) product diluted (1:4) and used 2.5µl as template in nested PCR (R16F2n/ R16R2n) to amplify the expected 1.2kb fragment of 16SrRNA gene of phytoplasma. (Lane M= 1Kb maker; 1-4 and 6-10= phytoplasma symptomatic potato plants, lane 5= healthy tissue cultured K Jyoti plant, +ve= peach yellow phytoplasma, WC= water control)

oligonucleotide primers exclusively amplified the targeted regions of the specific pathogens (Fig. 15a). The targeted regions of respective viruses were further cloned in subcloning vector (pCR4-TOPO) to make them work as positive control. The cloned targeted fragment was confirmed with restriction digestion and Sanger sequencing (Fig. 15b). The sequencing results provided 98% nucleotide sequence similarity with NCBI sunbmitted accessions. The assay

was optimized to determine its limit of detection (LOD) and it was observed 25 pg, 12.5 pg and 50 pg for *Potato virus A*, *Potato virus X* and *Potato virus S*, respectively.

Sequence-specific molecular (Real time) based detection of potato pathogens: Bioinformatics approach allowed rapid selection of highly conserved and specific genomic fragments among the investigated viruses, while considering up to several hundred complete genomic sequences. The available sequences of PVA, PVM, PVX, PVS and PSTVd were aligned with ClustalW algorithm individually and specify candidate molecular regions within recombination junctions in case of viruses. While in PSTVd due to its small RNA structure the whole reported sequences of different viroids across the species were taken into

consideration. Using this workflow, the applied algorithm allowed selecting candidate molecular regions from different numbers of completed genome sequences, from as few as ten sequences for PVS to as many as 450 sequences for PSTVd. Selected molecular regions were used to generate (real-time) PCR primer sets for the detection of viruses from *S. tuberosum*. The designed primers were tested *in silico* for specific binding to the target virus strains, including all known genotypes and genetic variants. The *in silico* validation revealed that the individual primer sets were detected over 97% of all known genetic variants of the targeted virus and viroid species. The primer sets were aligned to their specific target reference sequences and relative primer orientation, amplicon size and overlap, and total mismatches for each primer were evaluated using the MFEprimer-3.0. Pairs targeting a specific virus with less than two mismatches in sense and antisense primers were defined as a hit and employed for sensitivity calculations. Unspecific binding of each primer to non-viral targets was investigated via the BLASTn algorithm, implemented within the National Center for Biotechnology Information website. Good quality RNA was extracted from positive of respective viruses and used as template for RT-PCR. The targeted regions were amplified with 2 sets for PVA and PVM, 3 sets for PVX and PSTVd and 4 sets for PVS and cloned in pCR 2.1-TOPO vector. The cloned regions were further sequenced and analysed. The results obtained from sequencing reveal that the candidate regions were amplified.

Epidemiology and Forecasting of Potato Pathogens

Role of weeds and other host crops in the epidemiology of potato viruses: Various *rabi* weeds, crops and ornamentals were sampled and tested for common potato viruses in Punjab. In total, 210 samples of 45 plant species were tested (3 to 7 samples per species) by DAS-ELISA and PCR method. Highest number of plant species tested positive for ToLCNDV-potato (25) followed by PVA (13), PVS (12), PLRV (11), and PVY (9 species each). *Sorghum helpense* tested positive for maximum number of viruses (5) followed by *Amaranthus spinosus*, *Am. viridis* and *Sorghum bicolor* (4 each), and *Boerhavia diffusa*, *Lantana camara*, *Phalaris minor*, *Solanum nigrum*, *Trianthema*

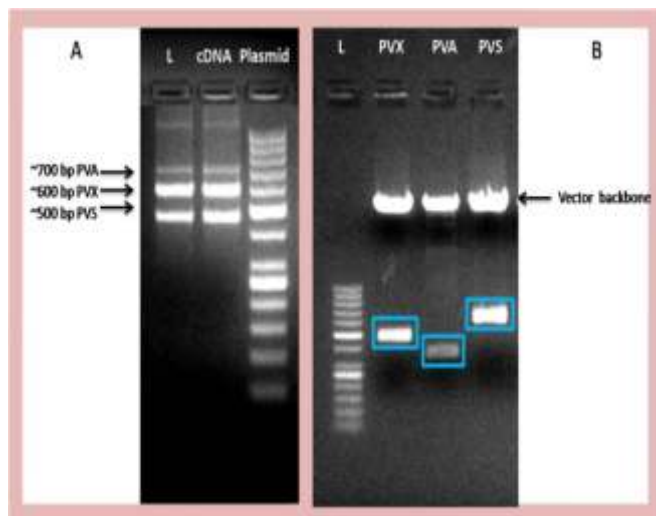


Fig. 15: (A) Gel electrophoresis of multiplex RT-PCR system for rapid detection of Potato virus A, X, & S in *Solanum tuberosum*, lane 1 (50 bp ladder), lane 2 (cDNA mix of targeted viruses) and lane 3 (cloned plasmids). (B) Restriction digestion of cloned fragment of PVX, PVA & PVS with *EcoRI* depicting 587 bp, 456 bp & 691 bp, respectively.

partulacastrum, *Solanum lycopersicum*, *Zea mays* and *Milletia pinnata* (3 each). Rest of the samples tested positive for lesser number of viruses. *Achyranthes aspera* (Chaff flower), *Conyza canadensis* (Canadian horseweed), *Malvastrum coromendaliunum* (Spine seeded false mallow), *Parthenium hysterophorus* (Congress grass), *Phyllanthus urinaria* (Chamber bitter), *Tridax procumbens* (Coat buttons), *Colocasia esculenta* (Taro), *Vigna unguiculata* (Cowpea), *Lagerstroemia indica* (Crepe-myrtle) and *Terminalia arjun* (Arjun tree) did not test positive for any of tested viruses.

Similar survey was repeated in the beginning of potato growing season (2017-18). In total, 135 samples of 29 plant species were tested (3 to 6 samples per species) for various potato viruses and virus strains (of PVY) by DAS-ELISA and PCR method. Highest number of plant species tested positive for PVS (21) followed by PLRV, ToLCNDV-(potato) and PVM (13 each), followed by PVY^C (8), PVY^N (6) and PVY^O (5). *Lantana camara*, *Brassica oleracea* var. *capitata*, *Capsicum annuum* and *Duranta* sp. tested positive for maximum number of viruses and virus strains (6 each), followed by *Boerhavia diffusa*, *Rumex* sp., *Solanum nigrum* and *Lagenaria siceraria* (5 each), followed by *Cannabis sativus*, *Raphanus raphanistrum* ssp. *sativus* and *Trigonella foenum-graecum* (4 each). *Chloris* sp. (Finger grass), *Curcuma longa* (Turmeric), *Chrysanthemum* sp. (*Chrysanthemum*), *Lagerstroemia indica* (Crepe myrtle) and *Pongamia pinnata* (Pongam tree) did not test positive for any of the viruses tested.

Temporal dynamics of Potato Apical Leaf Curl Virus Disease: The disease progress curve for PALCV disease in cv. Kufri Pukhraj resulted in a straight line with an initial rapid increase in the incidence of the disease, followed by a gradual increase (Fig. 16). The incidence of the disease during 2017-18 reached 59 %, starting with a potato seed infection of 5-8 %. The observed symptoms were curling and crinkling of apical leaves with small to large mosaic patches and bushy appearance of the plant later. The marked plants (144) were observed throughout the season for symptoms and the visual observations were confirmed at terminal sampling through RT-PCR. The samples testing negative were marked as healthy through all sampling dates and the infected

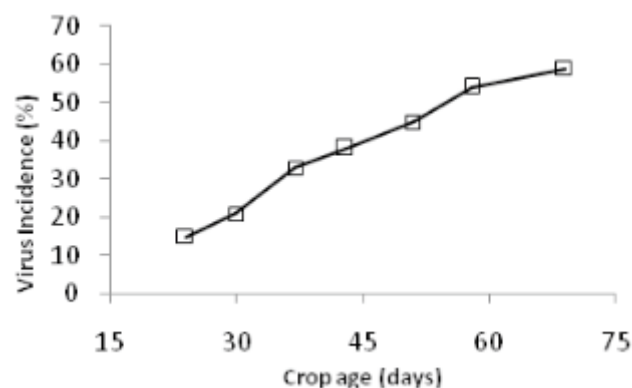


Fig. 16: Potato apical leaf curl disease progress curve in potato crop cv. K. Pukhraj at Jalandhar during 2017-18.

plants were appraised with symptoms only except at the last sampling when all observations were based on RT-PCR results. Disease incidence data were transformed as the number of plants displaying PALCV disease symptoms divided by the total number of plants observed. The disease progress curves were fitted to four growth models using linear regression analysis: monomolecular $\{\ln[1/(1-y)] = \ln[1/(1-y_0)] + r_m x\}$; logistic $\{\ln[y/(1-y)] = \ln[1/(1-y_0)] + r_L x\}$; Gompertz $\{-\ln[-\ln(y)] = -\ln[-\ln(y_0)] + r_G x\}$; and the exponential model $\{\ln(y) = \ln(y_0) + r_E x\}$; the symbols with their usual meanings. These models were used as predicted equations to compare the fitment of linearly transformed data. Statistical analysis was performed with R-software using the “lm” function. The parameters of the adjusted models indicated that the monomolecular growth model best described the disease progress of PALCV disease (Table 2). Thus, it is concluded that the PALCV disease in potato is a monocyclic or simple interest disease.

Table 2: Summary of linear regression statistics for four growth-curve models to describe the disease progress of PALCV disease in potato

S. No.	Model	R ²	Adj. R ²	F stat	Res. SE	P(>F)	AIC	BIC
1	Exponential	0.90	0.88	45.21	0.173	0.001	-1.03	-1.19
2	Monomolecular	0.99	0.98	521.10	0.028	<0.001	-26.19	-26.35
3	Logistic	0.95	0.97	95.19	0.028	<0.001	-0.03	-0.19
4	Gompertz	0.97	0.97	198.10	0.080	<0.001	-11.79	-11.95

Spatial dynamics of Potato Apical Leaf Curl Virus Disease The spatial pattern of PALCV disease incidence was quantified by fitting a binomial distribution and Ordinary runs analysis. Twelve

Table 3: Parameters of binomial distribution fitting to spatial dynamics of PALCV disease in potato. (NS= Not significant)

Date of sampling	χ square	d.f.	P	Deviation from binomial distribution
04-11-17	0.958	11	0.99	NS
10-11-17	0.062	11	1	NS
17-11-17	<0.001	11	1	NS
24-11-17	<0.001	11	1	NS
19-12-17	<0.001	11	1	NS

Table 4: Parameters of Runs analysis for spatial dynamics of PALCV disease in potato (n = 12)

Date of sampling	Observed Runs	Expected Runs	Mean virus incidence	Z statistic*	Pattern
04-11-17	3.58	4.11	1.83	-0.03	Random
10-11-17	4.75	5.05	2.58	1.48	Random
17-11-17	5.08	6.39	4.08	1.91	Random
24-11-17	5.73	6.54	4.33	2.75	Random
19-12-17	5.00	6.80	7.08	1.81	Random

blocks of 12 plants each (3 rows of 4 plants) were selected for the study and disease incidence was noted at 5 sampling dates. The disease incidence data were fitted to a binomial distribution and chi-square test was performed to check the agreement between observed values and the expected values (Table 3). The deviation from binomial distribution was non-significant on all the sampling dates. Similarly, for ordinary runs analyses, the blocks of 12 plants were treated as a continuous sequence and the Z statistic was calculated using standard methods (Table 4). It was found that disease

incidence exhibited random pattern of distribution at all sampling dates. The parameters of both the binomial distribution fitting and ordinary runs analysis indicate non-aggregated distribution of diseased plants, thus the plant to plant spread of the disease is negligible.

Development of PALCV disease: The weekly infection pressure of PALCV disease was evaluated by placing separate batches of potted bait plants (50 plants in each batch) in the field for a period of 5 days. After field exposure the plants were sprayed with insecticide (Imidacloprid 17.8 SL @ 0.03 %) to get rid of accompanying whiteflies and were maintained under net house for rest of the growth period. The disease incidence was recorded at 80 DAP. A control batch of 50 plants with no field exposure was also maintained under net house. The infection pressure was evaluated for four weeks after crop emergence. The corrected disease incidence data showed highest infection pressure for the first two weeks and gradual decrease thereafter (Fig. 17). This reduction in disease incidence was associated with decline in whitefly adult population over time (Fig. 18). The initial population was 7-8 whiteflies per plant in the last week of October which fell to 4-5 in the first week of November and to less than 1 per plant by the 3rd week of November. The flight activity showed similar trend however, the numbers recorded per trap were appreciable. Up to 55 whitefly adults were caught on YSTs on an average in the last week of October however, the trap catch showed a sudden drop by the 1st week of November. It was

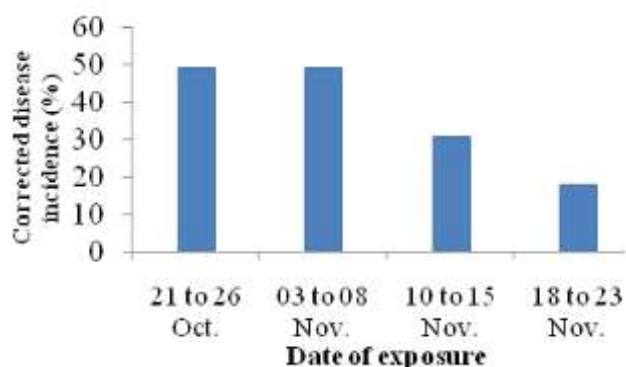


Fig. 17: Weekly variation in infection pressure of PALCV disease at Jalandhar, 2017-18

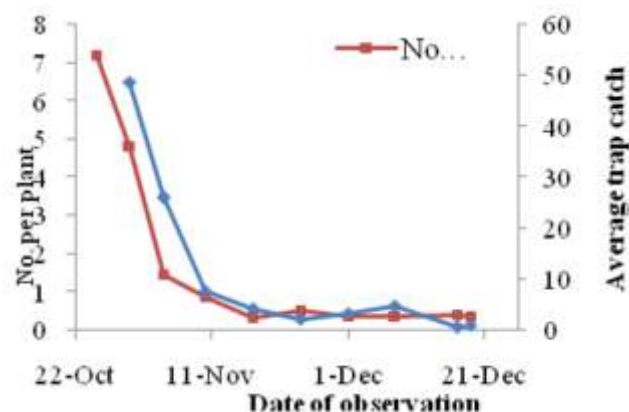


Fig. 18: Population fluctuation and flight activity of *Bemisia tabaci* sampled by (a) leaf count method and (b) YST catch respectively in potato at CPRS, Jalandhar (2017-18)

mainly due to general decline in whitefly population and also the significant fall in temperature which inhibits the flight activity of whitefly adults.

Validation of Indo-Blightcast and issue of agro-advisories: The model was validated across the agro-ecologies in India during *kharif* and *rabi* seasons of 2017-18 and it predicted late blight accurately at each location (**Table 5**). The results show that the disease did not appear at Kalyani and this may be due to prevalence of low temperature after prediction of late blight. The minimum temperature fell below 7.2 °C, which is not congenial for disease development. Accordingly

the advisories were issued to respective regions to protect the crop from late blight attack.

Host-pathogen Interaction

Transcriptome analysis of Kufri Bahar and Kufri Pukhraj plants un-inoculated and inoculated with ToLCNDV-[potato]: The unique differentially expressed genes (DEGs) identified through venn diagram analysis were further subjected to GO analysis using Blast2GO 4.0.2. to better understand their function. Default parameters were used for blast, mapping and annotation. The results were categorized with respect to Biological process, Molecular function and Cellular component at level 2. This method mapped all target gene candidates

Table 5: Performance of Indo-Blightcast late blight forecasting model during 2017-18.

Location	Prediction date of late blight	Actual date of late blight appearance
Shimla (HP)	27.06.2017	29.06.2017
Jalandhar (Punjab)	Blight appearance not likely	Did not appear
Modipuram (UP)	12.12.2017	19.12.2017 (Bijnor)
Pantnagar (Uttarakhand)	13.12.2017	29.12.2017
Kalyani (WB)	13.01.2018	Did not appear
Jalpaiguri (WB)	23.12.2017	27.12.2017
West Midnapur (WB)	Blight appearance not likely	Did not appear
Bankura (WB)	Blight appearance not likely	Did not appear
Hooghly (WB)	Blight appearance not likely	Did not appear
Burdwan (WB)	Blight appearance not likely	Did not appear
Patna	26.12.2017	10.01.2018
Faizabad	Blight appearance not likely	Did not appear
Kanpur	20.12.2017	22.12.2017
Jorhat	7.12.2017	19.12.2017

to GO terms in the database (<http://www.geneontology.org/>). The gene sequences were used as queries against the Kyoto Encyclopedia of Gene and Genome (KEGG) database, and this analysis identified metabolic and signal transduction pathways. Computational analysis allowed annotation of the DEGs into three categories i.e. cellular component, molecular function and biological process (**Fig. 19**). Under cellular component category, more number of DEGs was assigned to cell and cell part followed by membrane and membrane part in both Kufri Bahar and Kufri Pukhraj. In case of molecular function, the DEGs were assigned with binding and catalytic activity. Only in Kufri Pukhraj, 12 genes were assigned to nucleic acid binding transcription factor activity at 15 DAI. Under biological process,

the most represented category is metabolic process followed by cellular process. Some of the unique

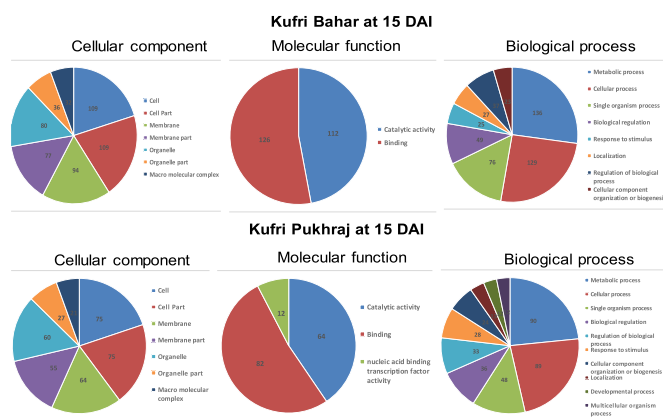


Fig. 19: Gene Ontology category distribution of novel transcripts and predicted genes in Kufri Bahar and Kufri Pukhraj at 15 DAI

genes belonging to “developmental process” and “multicellular organism process” were only found DEGs in Kufri Pukhraj at 15 DAI.

RT-qPCR validation of differentially expressed genes: RT-qPCR assay was performed for sixteen genes that were up-/ down-regulated in susceptible/ resistant cultivar after virus inoculation. Coding sequences (cds) of these selected genes were retrieved from PGSC site based on highest sequence homology. Primer Express 3.0 (Applied Biosystems, Foster City, CA, USA) was used with default parameters to generate primer pairs for selected transcripts. The same RNA samples used for RNA-seq were used for RT-qPCR. First strand cDNA synthesis was carried out with 1 µg of RNA using High capacity cDNA synthesis kit (Applied Biosystems, Foster City, CA, USA) following the instructions of the manufacturer. Assays were carried out in an ABI PRISM HT7900 (Applied Biosystems) with the following thermal cycles: 50°C for 2 min, 95°C for 10 min; 40 cycles of 95°C for 15s, and 60°C for 1 min. Each 15 µl reaction mixture contained 10µl of Power SYBR Green PCR Master mix, 1.0µl each of 5 µM forward and reverse primers, 1 µl of cDNA templates and 2 µl of nuclease free water. Expression levels were assessed based on the number of amplification cycles needed to reach a common fixed threshold (cycle threshold – C_t) in the exponential phase of PCR.

The relative expression of genes between inoculated and un-inoculated controls of resistant and susceptible cultivar was estimated using the $2^{-\Delta\Delta C_t}$ method and elongation factor 1- α gene (*ef1-a*) as reference. The RT-qPCR reactions were carried out in triplicates and average values were considered for relative quantification. Out of four LRR proteins (PGSC0003DMG400001252-Leucine-rich repeat protein, LRR252; PGSC0003DMG400006800-NBS-LRR protein, NB-LRR6800; PGSC0003 DMG 402007575-Leucine rich repeat, LRR-7575; PGSC0003DMG401008349-CC-NBS-LRR resistance protein, CNL-8349), LRR252 increased 1.58 fold in KBI at 15DAI and decreased at 20 DAI (0.50 fold). The same gene was down-regulated in KPI at both 15 and 20 DAI. Similar pattern of changes was observed in RT-qPCR also (Fig. 20). NB-LRR6800 and LRR-7575 were found differentially regulated only in RT-qPCR. CNL-8349 showed up-regulation (1.20 fold) in KBI at 15 DAI in both RNA-Seq data and RT-qPCR. Both RNA-Seq data and RT-qPCR assay indicated up-regulation of Cell division control 20 (PGSC0003 DMG401027032; CDC20) and down-regulation of Mads box protein (PGSC0003 DMG4 00018623; MDX-623) in KBI at 15 DAI. However, eukaryotic translation initiation factor (PGSC0003 DMG 400016697; EUTIR-6697, 28.35 fold) and cell division protein kinase 7 (PGSC0003DMG 400025069; CDPK7, 3.5 fold) was found up-

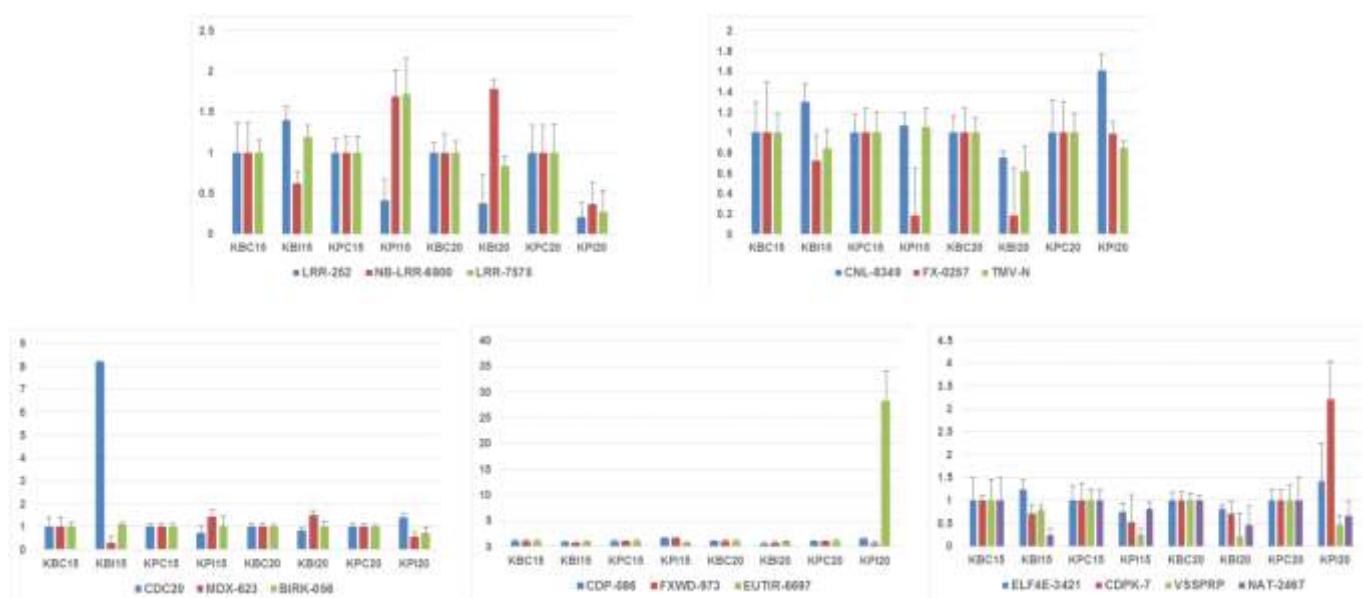


Fig. 20: RT-qPCR validation of differentially expressed genes

regulated in KPI at 20 DAI using RT-qPCR, whereas no such changes was noticed in RNA-Seq data.

Effect of virus (es) infection on late blight development: Effect of viruses infection (PVX, PVY^o, PVM, PVS), individually or in mixed infection, was studied on development of late blight using detached leaf method. Virus infected leaflets of Kufri Jyoti were challenge inoculated with *Phytophthora infestans* and incubated at 18±1°C in the humidity chamber. Results revealed that development of late blight is affected by virus infection and virus-infected plants had less development of *Phytophthora infestans* (except PVS) than were healthy ones. Plants infected with PVS enhanced late blight susceptibility (36.30%) while other viruses decreased it. Highest reduction in disease severity (71.48%) was recorded in PVX followed by PVM/PVY^o (65.93%) infected leaves. Amount of sporulation was also significantly higher on PVS infected leaves while it was significantly smaller on leaves infected with other viruses. In another set of experiment, nine advanced hybrids and three cultivars were first artificially inoculated with PVX, PVS, PVA, PVY^o, PVM and PALCV individually and thereafter challenge inoculated with *P. infestans*. In most of the cases, late blight severity decreased in virus infected plants except in hybrids SM/00-120 (PVX, PVA & PALCV), SM/09-161 (PVX & PVY^o), and SM/08-12 (PVX, PVA & PVY^o) which suggest that interaction depends on host genetic background too.

Management of Potato Pathogens

Chemical management: It is well known that *P. infestans* adapts to fungicides very quickly after its regular applications 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%), ametoctradin + dimethmorph (0.2%), azoxystrobin + tebuconozol (0.1%), mandipropamid (0.1%) and phenomidon + mancozeb (0.3%) resulted in 12.33, 14.67, 21.33, 22 and 23% disease severity respectively as against of 97% in control (Table 6). Similarly, fungicides were tested for developing spray schedules for managing late blight of potato. Among the treatments,

Table 6: Effect of new fungicides against *Phytophthora infestans*

Treatments	Terminal disease severity (%)	Disease control (%)
T1. Cymoxanil+ mancozeb - 0.3%	23.33	75.95
T2. Mandipropamid - 0.1%	22.00	77.32
T3. Dimethomorph - 0.2%	12.33	87.29
T4. Phenomidon+ mancozeb- 0.3%	23.00	76.29
T5. Ametoctradin+dimethomorph-0.2%	14.67	84.88
T6. Metalaxyl-M +chlorothalonil 0.1%	29.00	70.10
T7. Captan+hexaconazol-0.2%	31.67	67.35
T8. Azoxystrobin+tebuconozol- 0.1%	21.33	78.01
T9. Control	97.00	
CD (0.05)	3.24	

prophylactic spray with mancozeb (0.2%) followed by ametoctradin + dimethomorph (0.2%) at onset of the disease and one more spray with ametoctradin + dimethomorph after 7 days recorded lowest disease severity (29.00%) against control (97.67%). The next best treatment was prophylactic spray with mancozeb (0.2%) followed by azoxystrobin + tebuconozol- (0.1%) and one

Table 7: Experiment conducted at Ooty in kharif season revealed that prophylactic spray with mancozeb @ 0.2% followed by cymoxanil + mancozeb @ 0.3% at onset of the disease and alternate sprays at 6-12 days recorded lower AUDPC (118) as compared to control (317). The next best treatment was prophylactic spray of chlorothalonil @ 0.25% followed by ametoctradin + dimethomorph @ 0.3% and alternate sprays at 6-12 days (Fig. 21). In another experiment, efficacy of phosphorous acid was tested on susceptible (Kufri Jyoti) and moderately resistant (Kufri Himalini) cultivars.

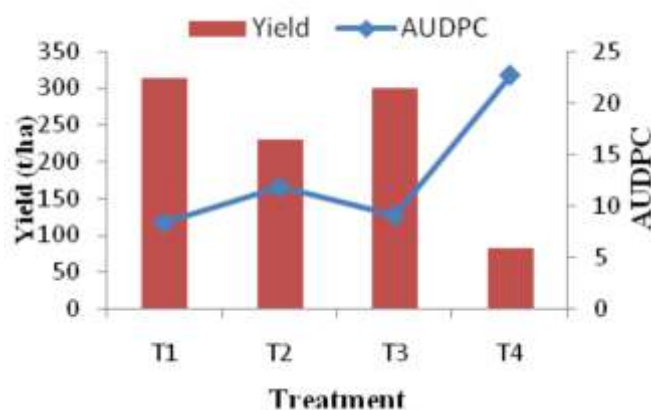


Fig. 21: Effect of different fungicides spray schedule on management of late blight

Table 7: Efficacy of spray schedules of fungicides against late blight of potato

Treatments	Terminal disease severity (%)	Disease control (%)
T1. Mancozeb 0.2% (Before)- Ametoctradin + Dimethomorph 0.2% (at onset) - Ametoctradin + Dimethomorph 0.2% (after 7days) - 3 spray	29.00	70.31
T 2. Mancozeb 0.2% (before) - Mandipropamid 0.1% (at onset) - Mandipropamid 0.1% (after 7 days) - 3 spray	35.00	64.70
T3. Mancozeb 0.2% (before) -Metalaxyl- M +chlorothalonil o.1% (at onset) - Metalaxyl- M +chlorothalonil o.1% (after 7 days)- 3 spray	33.33	65.87
T4. Mancozeb 0.2% (before) - Azoxystrobin+Tebuconozol- 0.1% (at onset) - Azoxystrobin+Tebuconozol 0.1% (after 7 days) - 3 spray	30.00	69.28
T5. Mancozeb 0.2% (before) -Captan+Hexaconazol-0.2% (at onset) - Captan+Hexaconazol-0.2% (after 7 days)- 3 spray	34.00	65.19
T 6. Mancozeb 0.2% (before) - Mancozeb 0.2%+0.1% dimethomorph (at onset) - Mancozeb 0.2%+0.1% dimethomorph (after 7 days)- 3 spray	30.00	69.28
T7. Control	97.67	
CD (0.05)	5.06	

Results revealed that application of phosphorous acid reduced blight severity considerably (20-23%) compared to untreated (42-85%). Reduction was more in susceptible than moderately resistant cultivar. Now-a-days biological control is gaining importance due to its eco-friendly nature. It is an important component in the organic potato production. In this context experiment was conducted under field conditions at Modipuram. The bacterial cells of different species (*Pseudomonas fluorescence* and *Bacillus subtilis*), two SAR activators (BABA and phosphoric acid) and mancozeb 75% WP for mangamnet of late blight of potato. The treatment consisted of seed treatment with *Pseudomonas fluorescence* + four spray, seed treatment with *Bacillus subtilis* + four spray, seed treatment with BABA + four spray, seed treatment with Phosphoric acid + four spray showed 63.33%, 58.33%, 71.67% and 58.33% disease severity, respectively as against of control (91.0%).

Inhibition of ToLCNDV-Potato DNA replication by Zinc Finger Proteins in response to artificial

zinc application in tissue culture raised plant under in -vitro conditions: Last year we reported that application of Zn inhibited ToLCNDV-potato in tissue culture raised plants under *in-vitro* conditions.

Further to know the role of zinc finger proteins in replication of ToLCNDV-potato DNA, seven genes belonging to zinc finger protein family were selected from microarray gene expression profile of cultivar Kufri Bahar and relative gene expression was analysed by real time PCR. Almost all genes were found up-regulated in response to artificial zinc application specially Zinc finger CCCH domain containing protein and CHP rich zinc finger protein found up to 8 fold (**Fig. 22**).

Developed scale for scoring resistance to ToLCNDV-[potato] in potato cultivars: Developed scale for scoring ToLCNDV-[potato] resistance in potato cultivars as there is no resistance source available against this disease. Plants were artificially inoculated with ToLCNDV-[potato] to induce symptoms and developed scale for scoring

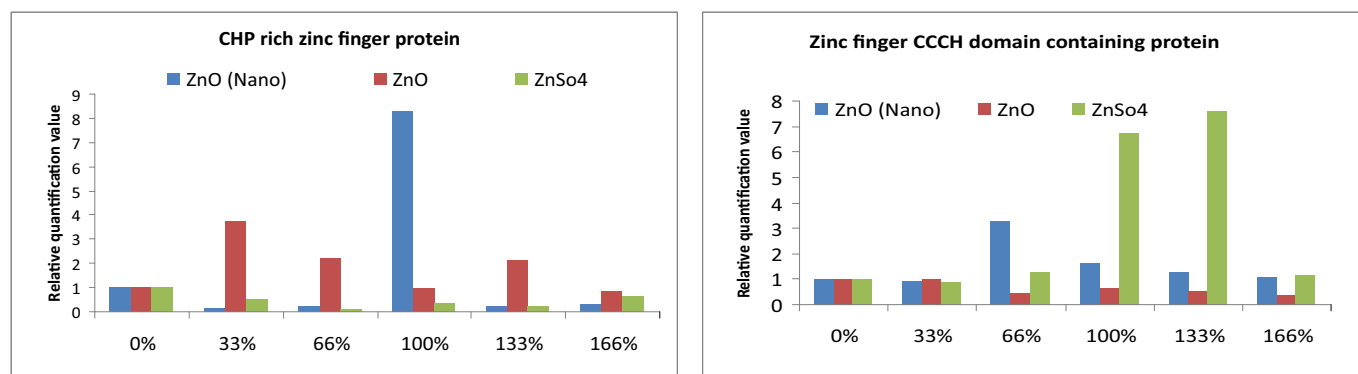


Fig.22: Real time analysis of zinc finger protein genes after 30 days of Zn application in different concentration.

(Table 8, Fig. 23).

Biotechnological approaches

dsRNA based fungicide for management of potato late blight: In earlier studies, demonstrated that spraying of potato plants with dsRNA encoding *Phytophthora infestans* genes imparts protection against late blight, therefore, efforts were made to synthesis dsRNA molecule with nanoparticles to enhance the stability of the dsRNA under *in vitro* conditions. The 200 ng of dsRNA was mixed with 5, 10 and 20 ppm of zinc oxide nanoparticle and assessed for disease development through detached leaf method. No symptoms were developed at 10 ppm of zinc oxide nanoparticle as compared to 5 and 20 ppm.

Table 8: Scale for scoring apical leaf curl disease

Scale	% infection	Symptoms	Disease reaction
0	No infection	No symptoms	Highly resistant
1	1- 10 % infection	Yellow spots in few leaves	Resistant
2	11-25 % infection	Mild mosaic in most of the leaves	Moderately resistant
3	26-50 % infection	Severe mosaic and crinkling	Moderately susceptible
4	51-75 % infection	Severe mosaic, crinkling, small leaves and rosetting	Susceptible
5	>75% infection	Severe mosaic, crinkling small leaves & rosetting, shortening of internodal length (stunted growth)	Highly susceptible

Control and only nanoparticle treated leaves produced lesion area of 5.6 cm² to 7.8 cm² (Fig. 24). Since research interests is RNAi mediated improvement of pathogen resistance, research efforts need to focus on its effective delivery, greater stability and development of commercial viable formulation (nanoparticle/plant hormone based) for the management of late blight.

RNAi transgenic potato for bacterial wilt resistance: In our earlier studies, reported that PAP2 gene is responsible for wilt disease, via degradation of the accumulation of reactive oxygen species / hypersensitive response and was demonstrated using VIGS technology. Based on this proof of concept, developed RNAi construct encoding PAP2 gene (Sense 436bp and antisense 308bp) driven by CaMV35S promoter (Fig. 25a) and genetic transformation was performed using Kufri Jyoti inter nodal stem cuttings. Regenerated positive putative transformants were confirmed through *NptII* PCR and microplants were subjected to bacterial wilt resistance assay. As a preliminary



Fig. 23: Pictorial representation of the developed scale

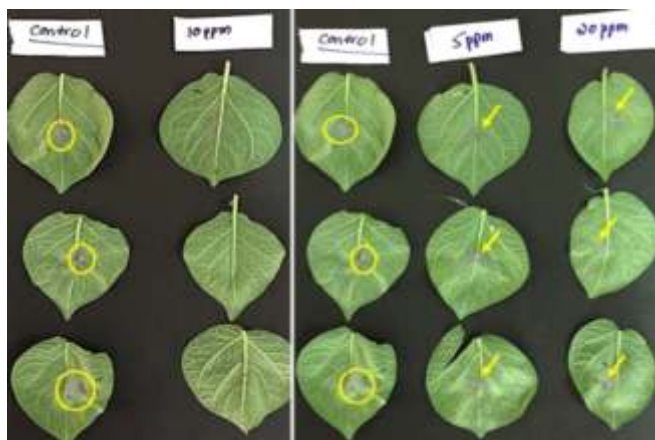


Fig. 24: Efficacy of dsRNA nanoparticle solution against late blight.

in-vitro assay, RNAi PAP KJ lines showed more than 90% resistance compared to 100% wilt symptoms in non-transgenic control Kufri Jyoti (**Fig. 25b**). This needs to be further validated under pot experiments.

Mass multiplication and screening of ToLCNDV-potato transgenic lines: Mass multiplication of transgenic lines of Kufri Badshah (2 lines- GTLC2-90, GTLC2-127) and Kufri Pukhraj (4 lines -KPLC2-13, KPLC2-37, KPLC2-53 and KPLC2-54) was done in tissue culture. Out of these, two promising transgenic lines GTLC2-127 and KPLC2-53 were screened for virus resistance through agro inoculation and confirmation of integration of transgene was done through event PCR analysis.

Biological approaches

Screening of microbes against *Phytophthora infestans*, *Ralstonia solanacearum* and *Streptomyces scabies*: One hundred and eleven new bacterial endophytes were isolated from potato and tested *in-vitro* against *P. infestans* through agar diffusion method. Out of these, 27 exhibited complete inhibition of *P. infestans* and 56 showed more than 80% inhibition. Among the seventeen cultures of endophytic bacteria, none was antagonistic to *R. solanacearum* when tested *in-vitro* through agar diffusion method. However, fourteen of them were effective against *Streptomyces scabies*. One culture completely inhibited the growth of *S. scabies* and rated as excellent, nine overgrew and inhibited the growth of *S. scabies* and rated as very good while four were rated as good (**Fig. 26**).

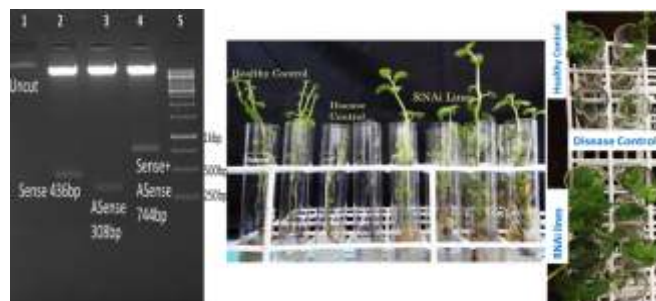


Fig. 25: a) pRI101AN: RNAi construct carrying 436bp sense and 308 bp antisense PAP2 gene 1b) *In-vitro* bacterial wilt resistance assay of PAP RNAi and control KJ lines.



Fig. 26: Antagonistic effect of endophytic bacteria against *Streptomyces scabies*

Bio-fumigation of soil with brassicas for the management of soil and tuber borne diseases: Field trails were conducted at ICAR-CPRI RS, 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 third year of experimentation, none of the five brassicas, i.e. Indian rape, rapeseed, taramira, Indian mustard and radish proved effective against black scurf at Jalandhar. However, a significant reduction in per cent disease severity was observed in radish bio-fumigation compared to control and other brassicas (**Fig. 27**). At Modipuram, taramira (68.67%), Indian rape (73.00%), Indian mustard (75.33%) and Radish showed (73.0%) less black scurf incidence as against control (87.0%). At Shimla, none of these five brassicas proved effective against brown rot/ bacterial wilt in the second year of experiment also. The trials will be repeated during the current year to see the cumulative effect

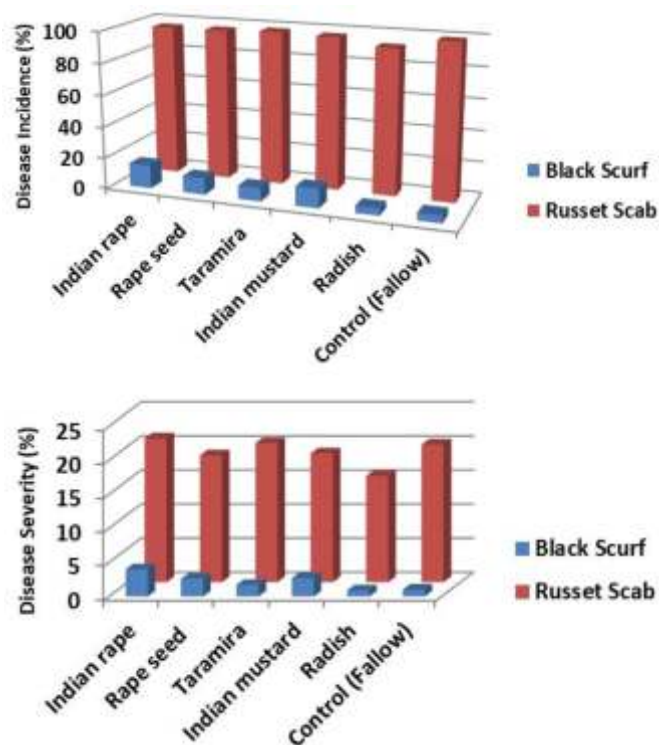


Fig. 27: Effect of brassica bio-fumigation on per cent disease incidence and severity of black scurf and common scab disease in the third year

of bio-fumigation on soil and tuber borne diseases over the years. The leaf juice of these plant species was extracted and evaluated at 5, 10, 15 and 20% in poison food test against *Rhizoctonia solani*. Result revealed that Indian rape, rapeseed and Indian mustard showed better inhibition at 20% than remaining species (Fig. 28).

Post entry quarantine testing of imported germ-plasm: Twenty two *in-vitro* cultures of potato imported by M/s PepsiCo India Holdings Pvt Ltd were tested for post entry quarantined pathogens. Testing of another 4 *in-vitro* cultures of potato, imported by M/s McCain Foods India Pvt Ltd and 5 cultures imported by M/s Technico Agri Sciences Ltd is in progress.

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



Fig. 28: Efficacy of rapeseed against *Rhizoctonia solani*

hundred and seven samples and 2030 mother cultures of potato of M/s Technico Agric Science Pvt Ltd. Baddi, Solan (HP), M/s Bhatti Tissue Tech. Jalandhar, M/s PepsiCo India Holdings Pvt. Ltd. Hoshiarpur (Punjab), M/s Mahindra HZPC Pvt. Ltd., Mohali, M/s Gogle Biotech Pvt. Ltd., Bangalore and M/s Jain Irrigation Systems Pvt. Ltd., Maharashtra were tested for PVX, PVS, PVY, PVA, PVM, and PLRV by DAS- ELISA and GBNV, PSTVd and ToLCNDV-potato by PCR/RT-PCR and certified about 7.0 lakh plants. Besides, 435 samples and 80 mother cultures of apple from M/s Nishant Biotech, Bilaspur, HP were tested for apple viruses namely ACLSV, AMV, ASGV, ASPV, PNRSV to certify the total batch size of 1.62 lakh plants under NCS-TCP (Fig. 29).



Fig. 29: Potato and apple crop at TCPUs

Programme: Biology, epidemiology, modeling and management of insect pests, vectors, and cyst nematodes of potato

Monitoring and population dynamics of potato pests

Aphids, whiteflies, leafhoppers and mites were monitored at Jalandhar, Modipuram and Gwalior on seed and ware potato crop including other solanaceous hosts using roving surveys and yellow sticky traps (YST).

Aphids: At Jalandhar, the population of aphids, *Myzus persicae* (Sulzer), *Aphis gossypii* Glover and *Aphis nasturtii* Kalténbach 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.1 & 2). Similarly, at Modipuram, *Aphis* spp. remains on potato throughout the cropping season including early and late sown potato. *Myzus persicae* and *Aphis gossypii* were the most common species and high population (298/100 compound leaves) of these aphids was recorded on potato during first week of February in Western Uttar Pradesh. Relatively low populations of *Myzus persicae* were recorded on ware and seed potato at Gwalior. A maximum of 20 aphids per 100 compound leaves was recorded on ware potato while as the population of aphids was maintained below 2 aphids per 100 leaves on seed potato.

Whiteflies: At Jalandhar, the population remained

above economic threshold till the 2nd week of November (Fig. 3) and by the end of January no adult whiteflies were recovered from potato plants. The average whitefly population 14.3 per 10 leaves was recorded on early crop in September and October at Modipuram while it was 4.2 per 10 leaves on main potato crop (Kufri Pukhraj). Whitefly was also recorded on other alternate crops like brinjal (*Solanum melongena*), on moong (*Vigna radiata*) in second week of June and in mid of June and on tinda (*Citrullus vulgaris*). In the month of July, tulsi (*Ocimum sanctum*) and urdbean (*Vigna mungo*) had very high population of whitefly in July as well as August. Later, in the month of September-October it congregated on early potato crop which was planted during 3rd week of September. Whitefly continued to move from one plant species to other depending upon its suitability. Relatively low population of *Bemisia tabaci* was recorded on ware and seed potato at Gwalior. A maximum of 10 whiteflies per 100 compound leaves were recorded on ware potato.

Leafhoppers: At Jalandhar, the population of leafhoppers, *Empoasca fabae* Harris and *Amrasca biguttula biguttula* (Ishida) was initially high (8-10 per plant) and declined overtime (Fig. 4). The population fell below economic threshold by the last week of November and disappeared from the crop towards the end of January. At Modipuram, the yellow sticky traps data revealed that maximum aphids (963/trap/week), whitefly

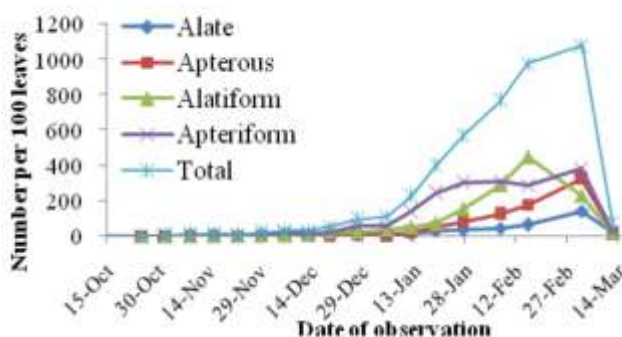


Fig. 1: Population dynamics of *Myzus persicae* on potato at CPRS, Jalandhar.

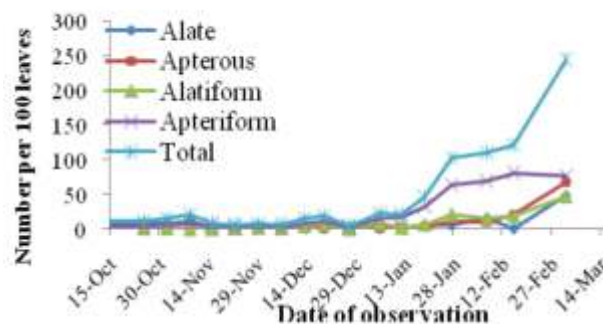


Fig. 2: Population dynamics of *Aphis* spp. on potato at CPRS, Jalandhar.

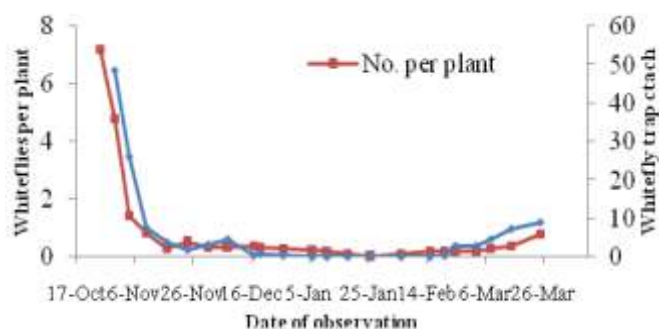


Fig. 3: Population dynamics of *B. tabaci* sampled by (a) leaf count method and (b) YST catch in potato at CPRS, Jalandhar.

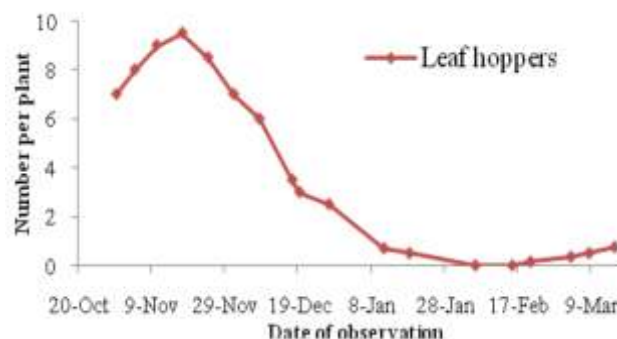


Fig. 4: Population dynamics of leaf hoppers infesting potato sampled by leaf count method, Jalandhar.

(108/trap/week) and hoppers (157/trap/week) was recorded in 51st, 48th and 47th standard week of the year 2017, respectively. At Meerut, mite infestation was recorded high on early crop. Severe mite burning and symptoms were recorded in Bijnore and Muzaffarnagar.

Morphological and molecular characterization of potato pests and nematodes

Insect pests: Aphids have been reported to be important vectors of potato viruses under diverged Indian 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. Fourteen distinct aphid species were reported on potato during last 4 years.

Whole genome sequencing of glasshouse potato aphid *Aulacorthum solani*: *Aulacorthum solani*

(Kaltenbach), the glasshouse potato aphid or foxglove aphid is an extremely polyphagous pest reported to infest 95 different plant species belonging to 25 families (Fig. 5). *A. solani* is a vector of 45 different plant viruses including most dreaded viral diseases like PVY and PLRV causing threat to seed and fresh potato production. Genome analysis matrix of *A. solani* is shown in Table 1. This whole-genome project has been deposited at DDBJ/EMBL/GenBank under the accession number PVM100000000. The data has been submitted under Bioproject PRJNA432320 and Biosample SAMN08443787.

LAMP assay for identification of Potato cyst nematode (*Globodera* species): A loop-mediated isothermal amplification (LAMP) primer Gr-EX, Gr-EXB for detection of *Globodera rostochiensis* (Gr-LAMP), and Gp-Cyt and Gp-Cytb for the detection of *Globodera pallida* (Gp-LAMP) was developed and

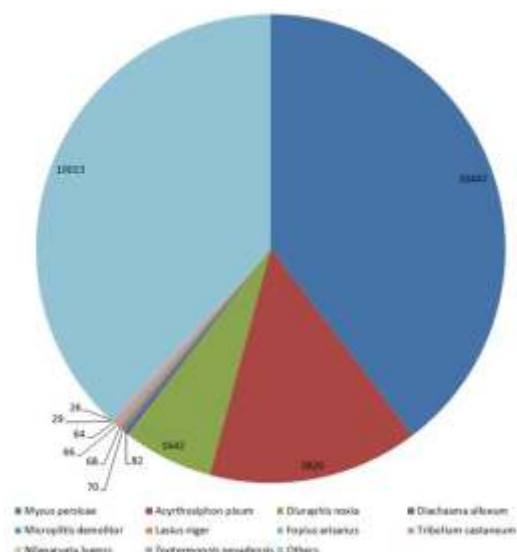


Fig. 5: Blast Top-Hit species distribution of aphids

Table 1: Genome analysis of glasshouse potato aphid *A. solani*

Scaffolds	89,260
Bases	—
GC content	42.63%
Protein coding genes	22,021
Functional annotation	20,359 (known genes)
BLAST2GO analysis	1,662 (unknown genes)
KEGG pathways	1139 (cellular component)
	835 (biological processes)
	754 (molecular functions)
	30 pathways (5,998 genes)
SNPs identified	17,485

validated with conventional PCR method (Fig. 6). The LAMP amplification of Gr-EX (225bp) for the identification of *Globodera rostochiensis* was achieved at 60°C isothermal conditions within 1 hr.

Identification of PCN species using ITS region specific primers: ITS region 5.8S specific forward and 28S specific reverse primers were designed and PCR analysis was performed using the primers, which generated expected size bands i.e. 527 bp amplicon (Lane 1 & 2) for *G. rostochiensis* and 924 bp for (Lane 3 & 4) *G. pallida* (Fig. 7).

Infestation pattern of whitefly, *Bemisia tabaci* in potato crop at plant level

The within-plant distribution of *B. tabaci* eggs, nymphs and adults was studied for the second year. 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

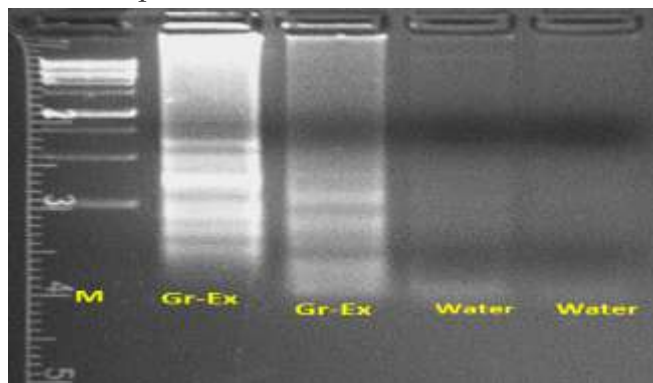


Fig. 6: Optimization of LAMP primer (Gr-Ex) for identification of *G. rostochiensis*.

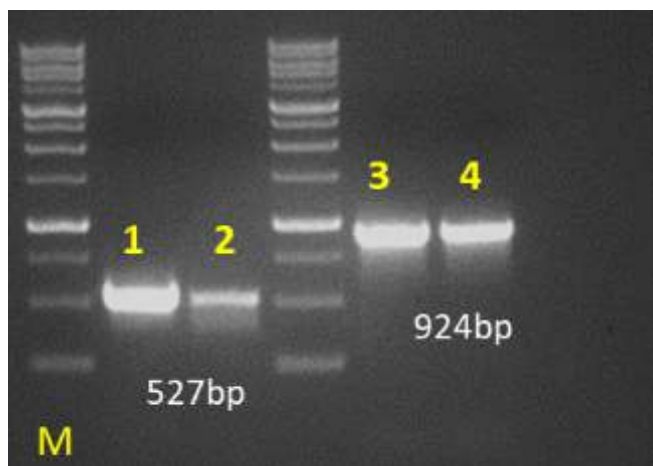


Fig. 7: Identification of PCN species with ITS primers, M=1 kb ladder, (Lane 1 & 2) *G. rostochiensis* and (Lane 3 & 4) *G. pallida*

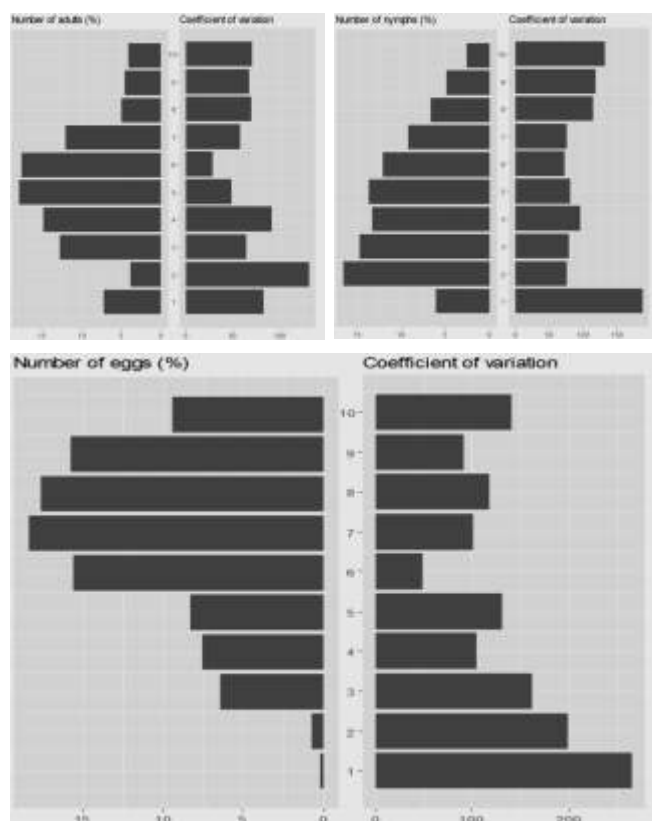


Fig. 8: Distribution and associated coefficients of variation of adults and immature stages of *Bemisia tabaci* along the main stem of potato in field (Leaf numbers 1-12, counting down from terminal leaf).

whitefly assemblage (Fig. 8). Similarly, highest proportion of nymphs was found assembled on leaf number 2 to 6 with minimum CV which represented around 72% of the assemblage. For eggs, highest proportion with least CV was found on leaf number 6 to 9 which represented more than 70% of the complement. These observations are in close agreement to those of the previous year. The nodal position of the most infested leaf was regressed to crop age and it was found that its position does not vary significantly over time. The position of most infested leaf was 4-6 for adults, 7-6 for nymphs and 2-4 for eggs (Fig. 9).

Integrated management strategies for suppression of insect pests and nematodes

Population build-up of whitefly in organic potato crop: Potato cultivars were grown under organic and inorganic crop management practices during main season to record the incidence of whitefly (Fig. 10 & 11). In general, the potato cultivars K. Mohan, K. Garima, K. Ganga, K. Khyati, K. Bahar and K. Chipsona -1 showed slightly high incidence

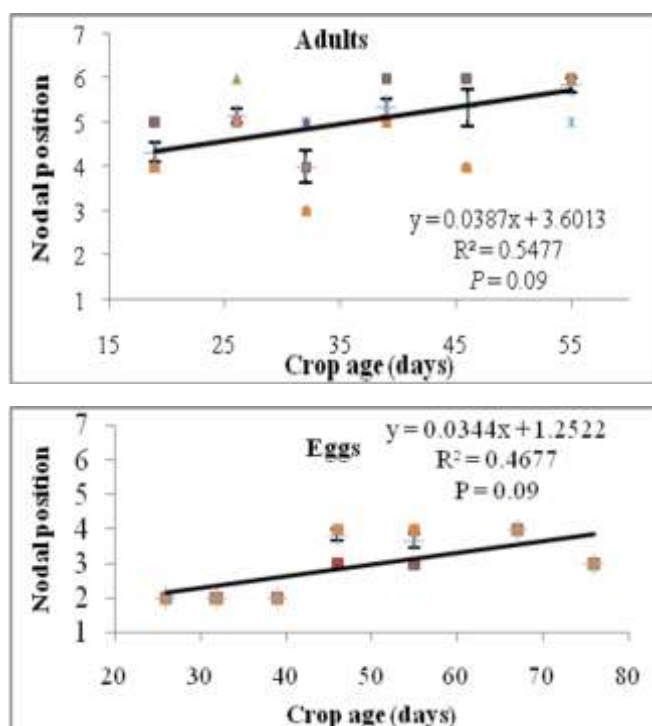
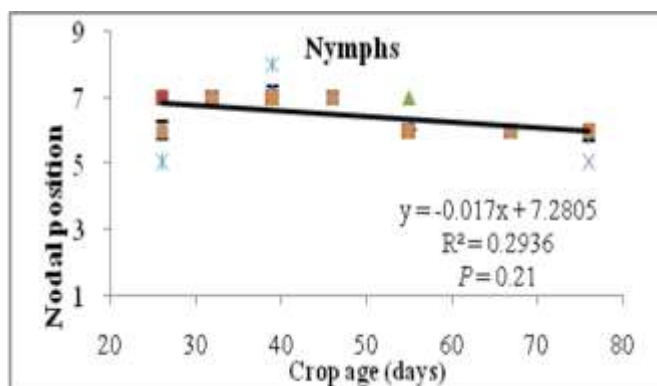


Fig. 9: Relationship between nodal positions of the most infested leaf and crop age.

of whitefly grown under organic condition (1.76, 2.06, 2.49, 2.01, 2.44 and 1.80 / 3plants, respectively) while other potato cultivars K. Anand (2.17), K. Pukhraj (2.29), K. Sinduri (2.07) and K. Chipsona-3 (1.98) recorded higher incidence under inorganic condition. Incidence of aphids on potato cultivars was almost insignificant under both the conditions.

Relative preference of whitefly to potato cultivars under net house: Six popular potato varieties, four newly released varieties viz., K. Neelkhant, K. Mohan, K. Ganga and K. Lima) and three



genotypes (MS/7-645, MS/8-1148 and MS/0042) were grown under net house at Modipuram. Adult whiteflies were released in net house with open/free choice of settlement/ multiplication on potato varieties and genotypes. The data revealed that least preferred genotype was MS/0042 with a mean number of 0.49 whiteflies per plant and the most preferred potato varieties were K. Mohan (1.41 adults per plant) and K. Neelkhant (1.33 adults per plant) throughout crop growth.

Chemical approaches

Evaluation of plant products and oils for management whitefly and aphids: The efficacy of plant products Nanma @ 7ml/L and Shreya @ 7ml/L was evaluated against whitefly on different potato cultivars at Modipuram. The population of whitefly remained low in sprayed treatments using plant products and insecticide (first spray of Nanma (7ml/l) followed by second spray of Shreya (7ml/l) and third spray of imidacloprid (4ml/10l)) on potato cultivars in comparison to unsprayed crop. The combination of plant product and insecticide showed maximum 15.2% increase in

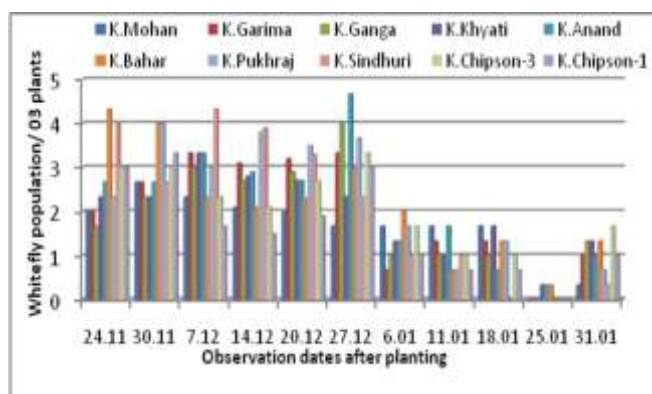


Fig. 10: Whitefly incidence on potato cultivars under inorganic conditions

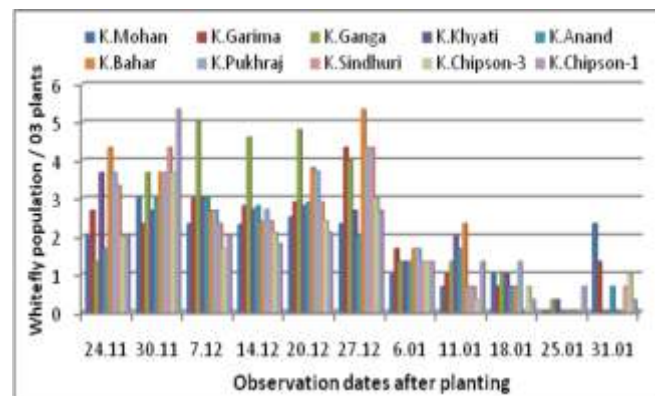


Fig. 10: Whitefly incidence on potato cultivars under inorganic conditions

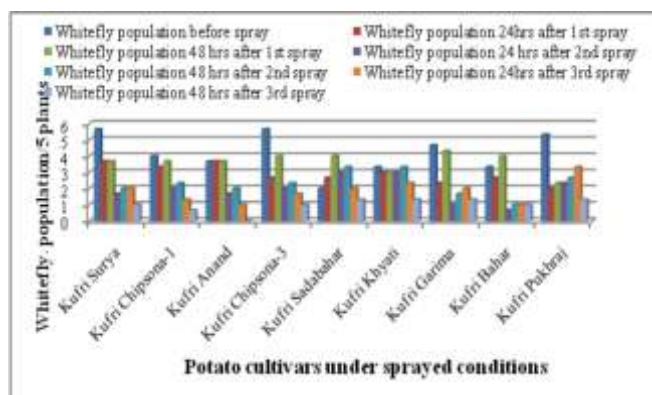


Fig. 12: Whitefly population on potato cultivars under sprayed condition

tuber yield (4.49 t/ha) of K. Sadabahar followed by 11.87% increase in yield (3.99 t/ha) of K. Bahar (Fig. 12 & 13). Further, a leaf bioassay was performed to evaluate the toxicity of Nanma and Shreya on whitefly adults at recommended doses. After 24 hrs, 0 and 44.4% mortality of whitefly was noted respectively for Nanma and Shreya. A mean % mortality of 17.8 and 76.6 % was noted after 48 hrs. No mortality was observed after 48 hrs in both the treatments. In another experiment the efficacy of Nanma and Shreya (@ 7 ml/L), Neem oil (@ 2ml/L) and Karanj oil (@ 2ml/L) along with control and check insecticide imidacloprid (@ 4ml/10L) was evaluated on build up of whitefly in early potato crop at Modipuram. None of the plant product and oils was as effective as insecticide. Nanma and neem oil were effective but lost their effectiveness within 2-3 days. Therefore, frequent spraying will be required to bring down the population of whitefly on crop. Data revealed that Nanma and neem oil treatments recorded 6.92 and 7.01 % increase in tuber yield as compared to imidacloprid treatment 20.54% increase in tuber yield (Fig. 14). Similarly, highest tuber yields 26.08, 26.10 and 29.40 t was recorded in the respective treatments with a C: B ratio of 1:2.01, 1:2.03 and 1:5.64, respectively. In another experiment the efficacy of mineral oil (@ 5ml/L) was compared with the plant products and organic oils for whitefly population suppression. Mineral oil was most effective in reducing the whitefly population as compared to control, while Nanma and neem oil were moderately effective against whitefly and lost their effectiveness within 2-3 days (Fig. 15). At Gwalior, two doses of mineral oil, two non-edible seed oils and imidacloprid along with control were

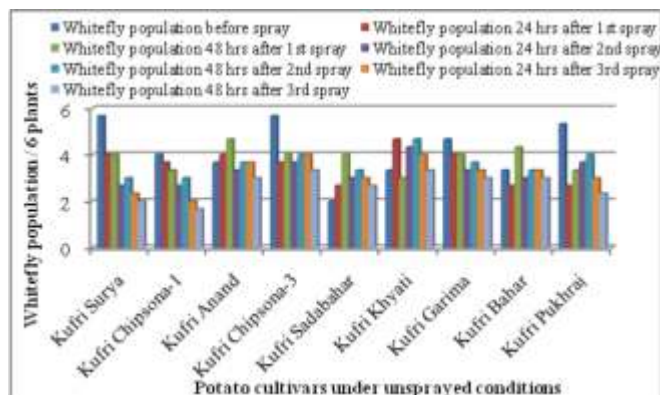


Fig. 13: Whitefly population on potato cultivars under unsprayed condition

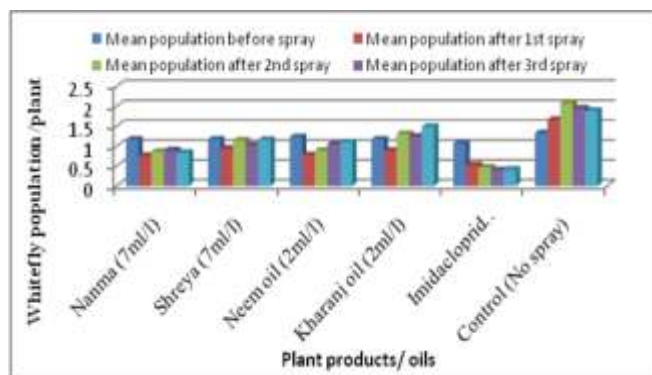


Fig. 14: Mean population of whitefly on early potato in plant products/ oils treatments

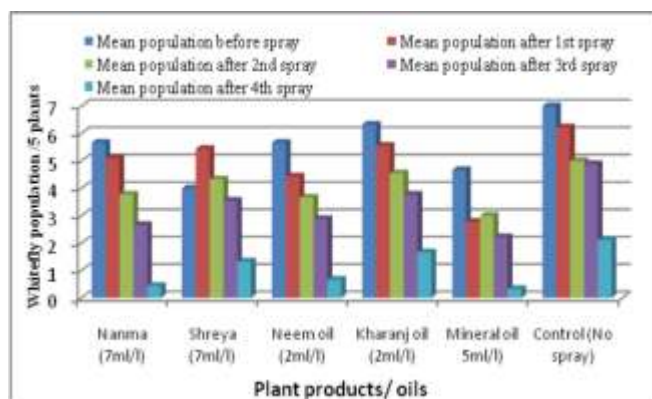


Fig. 15: Effect of plant products/ oils on whitefly during main potato crop

evaluated for management of aphids in potato. The results revealed that mineral oil (@ 3%), pongamia oil and neem oils reduced the aphid population by 30% percent. Imidacloprid was found to reduce aphid population by 80 percent.

Evaluation of new chemicals against whitefly and aphids: The knockdown and residual toxicity of Potassium silicate (technical grade) @ 0.1%, 0.2 % and 0.3%, Flonicamid 50 WDG @ 0.03 % and 0.04 %,

Clothianidin 50 WDG @ 0.01%, and Imidacloprid 17.8 SL @ 0.03 % and 0.04 % to adult whiteflies and the subsequent reduction in PALCV disease incidence was evaluated at Jalandhar. No significant adult knockdown was noted for the tested insecticides. Potassium silicate is not able to suppress the adult whitefly population by more than 50 % however; suppression in disease incidence is at par with other insecticides.

Only Imidacloprid 17.8 SL @ 0.04 % and Flonicamid 50 WDG @ 0.04 % have significant residual toxicity up to 14 DAT, rest of the insecticides/dosages need to be repeated 7 DAT. In another experiment, the knockdown and residual toxicity of Potassium silicate (technical grade) @ 0.2 % and 0.3%, Flonicamid 50 WDG @ 0.03 % and 0.04 %, Dimethoate 30 EC @ 0.1 % and Imidacloprid 17.8 SL @ 0.03 % and 0.04 % to Green Peach aphid (*M. persicae*) and the subsequent reduction in virus disease incidence were evaluated. Potassium silicate causes only 40-50 % reduction in population up to 3 DAT and much lower thereafter however; the virus incidence suppression is at par with other insecticides. Imidacloprid 17.8 SL @ 0.03 % provides high level of control for fewer days hence needs repeated applications. Highest reduction in aphid population is caused by Flonicamid 50 WDG @ 0.04 %, followed by Dimethoate 30 EC @ 0.1 % and Imidacloprid 17.8 SL @ 0.04 %, both as knockdown and as residual toxicity. A field experiment was carried out to assess the effect of three insecticides (Imidacloprid (@ 2, 4 & 6ml/10L), Thimethoxam (3, 5 & 7 g/10L) and Oxy-demeton methyl (@ 2, 3 & 4 ml/L) along with control on whitefly population on early planted potato crop (K. Pukhraj) at Modipuram. Data revealed that oxy-demeton methyl was almost not effective against whitefly, while slightly higher doses of imidacloprid (6ml/10L) and thimethoxam (7 g/10L) significantly reduced the whitefly population with maximum % increase in tuber yield of 18.04 and 17.71, respectively (Fig. 16). Similarly, highest tuber yields 28.52 and 28.44 t was recorded in the respective treatments with a C: B ratio of 1:8.32 and 1:6.62. The same experiment was repeated with main season potato crop (K. Bahar). Data revealed that oxy-demeton methyl was almost not effective against whitefly, while slightly higher doses of imidacloprid (6ml/10L) and

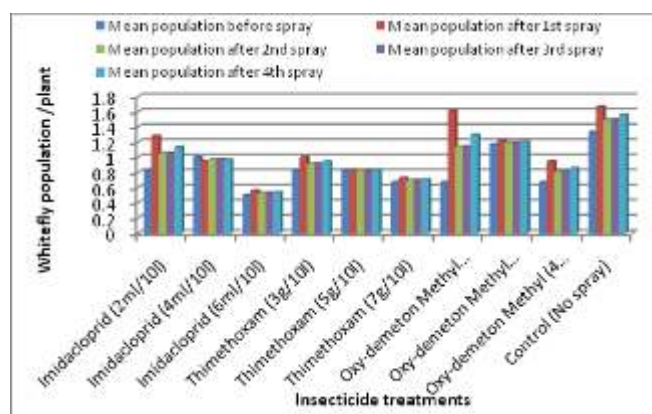


Fig. 16: Resurgence of whitefly population on early potato crop

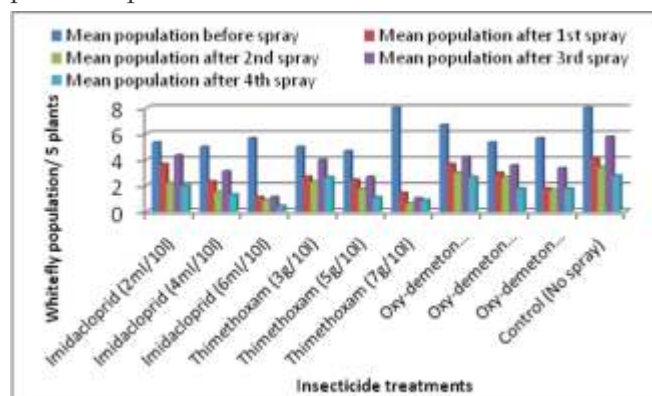


Fig.17: Effects of resurgence on whitefly during main crop

thimethoxam (7 g/10L) significantly reduced the whitefly population with maximum % increase in tuber yield of 10.7 and 13.1, respectively (Fig. 17). Similarly, highest tuber yields 31.10 and 31.77 t was recorded in the respective treatments with a C: B ratio of 1:5.73 and 1:5.69.

Evaluation of new chemicals against PC: A field experiment was conducted with application of new chemicals viz., AVANA, calcium cyanamide and hydrogen cyanamide each at four different doses (@ 20, 30, 40 and 50 gm/m²) with carbofuran 3G @ 65 kg/ha and untreated control at the time of planting for population suppression of PCN. No significant differences were observed in yield and PCN population as compared to carbofuran. The results were similar to that of previous trial. In another experiment, 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 @ 30 g/m² showed highest yield (38.44 t/ha) with significant reduction in PCN population (Rf value-1.47) followed by Dazomet @ 40 g/m² (37.22 t/ha) and 50 g/m² (34.22

t/ha). The reproduction factor was found lowest in the treatment with dazomet @ 40 g/m² (1.08) followed by Dazomet @ 50 g/m² (1.11) whereas in untreated control it was 3.71 (Fig. 18).

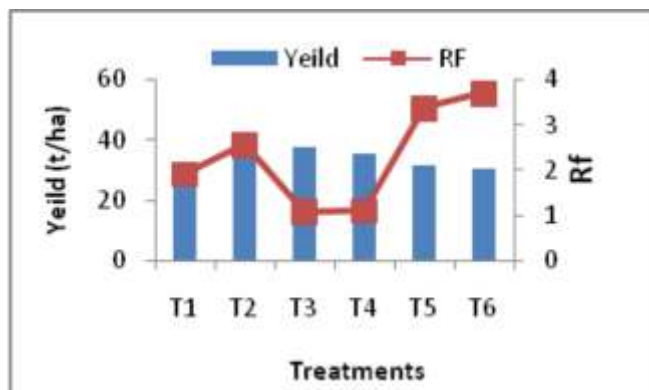


Fig.18: Evaluation of different doses of Dazomet (Basamid 95 G) on potato yield.

Cultural and biological approaches

Evaluation of *Solanum sisymbriifolium* as a trap crop against PCN: A pot study was conducted at Ooty during the year 2017-18 for evaluation of *S. sisymbriifolium* as a trap crop for PCN. The results with root ball technique revealed that *S. sisymbriifolium* has high degree of resistance against both the species of PCN as no PCN females were observed on roots. In the succeeding potato crop (Kufri Jyoti) root development (root length and root weight) was positively influenced in treated pots compared to control pots (Fig. 19). There was an increase of 42.85 % root length and 51.50% root weight in treated pots planted with Kufri Jyoti as compared to control. Root ball technique also revealed significant reduction in both the species of PCN in treated pots as at 60 DAP no yellow females (*G. rostochiensis*) and few (1.33) white females (*G. pallida*) were observed in treated Kufri Jyoti plants, whereas in control pots normal development of both the species of PCN (*G. rostochiensis*: 87.5, *G. pallida*: 43.5) was observed.

Bio-management of potato cyst nematodes: A field experiment was conducted during 2017-18 to evaluate the effect of different biocontrol agents on potato cyst nematodes. Different biocontrol agents used in the study were *Paecilomyces lilacinus* @ 20 kg/ha talc formulation, *Trichoderma viride* @ 20 kg/ha talc formulation and *Pseudomonas fluorescens* 20 kg/ha talc formulation along with untreated control and treated control (carbofuran 3G @ 65 kg/ha). The study revealed that the yield with all the bio-formulations was found at par with



Fig. 19: Root development of Kufri Jyoti at 35 DAP: a & b- Treated pots; c & d- Control pot

controls and no bio control agent was able to reduce the population of PCN (Rf ranging from 1.81-2.88) as compared to control (2.59).

Characterisation and evaluation of biocontrol potential of *Steinernema cholashanense* (Rhabditida: Steinernematidae)

A survey was conducted during 2017-18 to isolate the native strains/species of EPNs. From dead insects, EPNs were extracted using white trap method. Based on morphological and morphometrical studies (Fig. 20), *Steinernema* CPRSUS01 strain showed resemblance to *Steinernema cholashanense*. Further identity was confirmed with molecular characterization using the ITS-rDNA region. The ITS region of r DNA yielded a single fragment of approximately 735bp and sequence was deposited into the GenBank database (Accession no. MH065747). The sequence of this EPN revealed 99% similarity with *S. cholashanense* isolate from Nepal (GQ377419) and Pakistan (MF039642) and 96% with China population (EF431959).

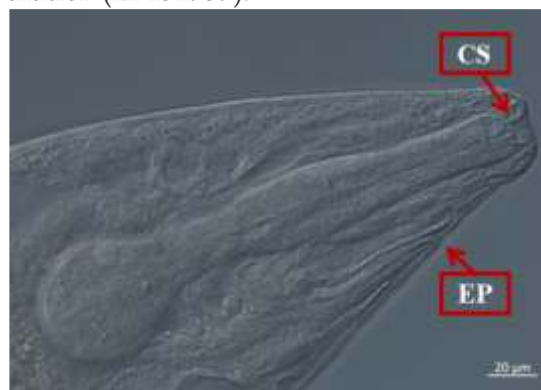


Fig. 20: Anterior part of *Steinernema* sp. female, [CS- Collapsed stoma; EP-Excretory pore].

Division of Crop Physiology, Biochemistry & 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 for estimating the post-harvest losses by interviewing 90 farmers, 45 each from Patna and Nalanda districts of Bihar. The results (Fig. 1) revealed that on an average, farmers reported that about 1.0% of harvested potatoes were damaged by insects/diseases, 1.2 per cent were rotten potatoes, 3.1 were cut, cracked and shrunken, 1.5% were green and about 1.8 % were left in the soil. Therefore, a total of about 8.6% were lost during harvesting itself. During curing, grading and

packaging, about 4% loss was reported due to weight loss and greening. About 0.4 percent was lost during transportation. Thus, the loss of potatoes from harvesting till transportation to cold storage was about 13%. The study also revealed that on an average, farmers kept their harvested potatoes for 200 days at cold storage (2-4°C) and the mean loss after removal from storage was about 6.4%. Considerable number of farmers also adopted traditional methods of potato storage like *chali*, heap and room storage methods. In these methods, farmers stored potatoes for about 50-78 days and the mean losses were reported between 6.2-6.5%.

Post-harvest losses in potatoes were also estimated through an experiment using two potato cultivars, Kufri Chipsona-3 and Kufri Khyati. Observation were recorded at different stages viz. harvesting, curing, grading and packaging, during cold storage at 2-4°C and 10-12°C for 3 months. Besides, the potatoes removed from store were kept at wholesaler's go-down/warehouse for 5 days, retailer's shop for 7 days and at consumer level for 10 days to assess the losses at these levels. The

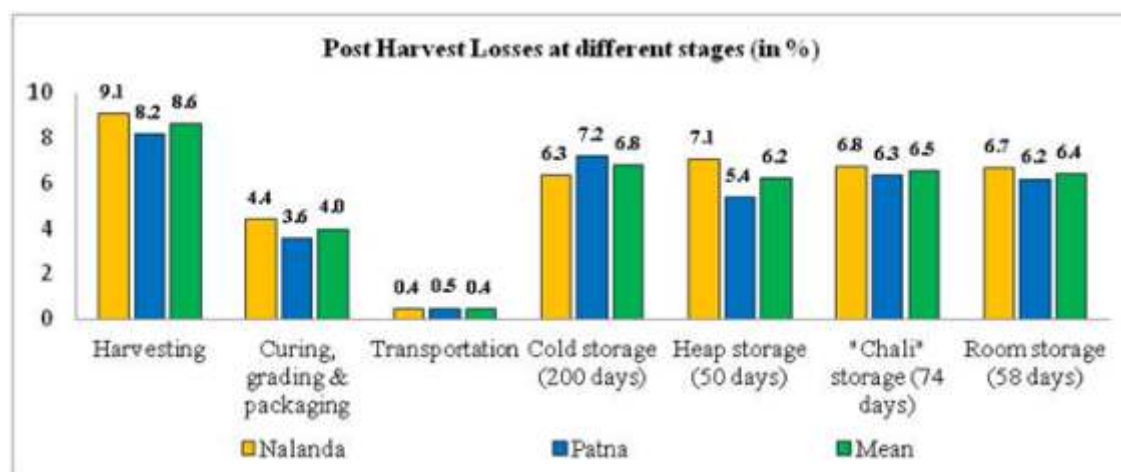


Fig.1. Assessment of PHL's based on survey with farmers

results (Fig. 2) revealed that on an average, about 10% losses occurred during harvesting till transportation stage which is similar with the losses reported by surveys with farmers. The mean total loss after removal from cold storage stored at 2-4°C and 10-12°C for 3 months were about 4.02% and 2.53%, respectively.

The losses of potatoes at wholesaler, retailer and consumer levels were minimum in potatoes stored at 10-12°C after 3 months of cold storage than those stored at 2-4°C. At wholesaler level, the mean losses of potato were 1.6% and 3.2% for potatoes stored at 10-12°C and 2-4°C, respectively (Fig. 3). At retailer level, the mean potato losses were observed to be

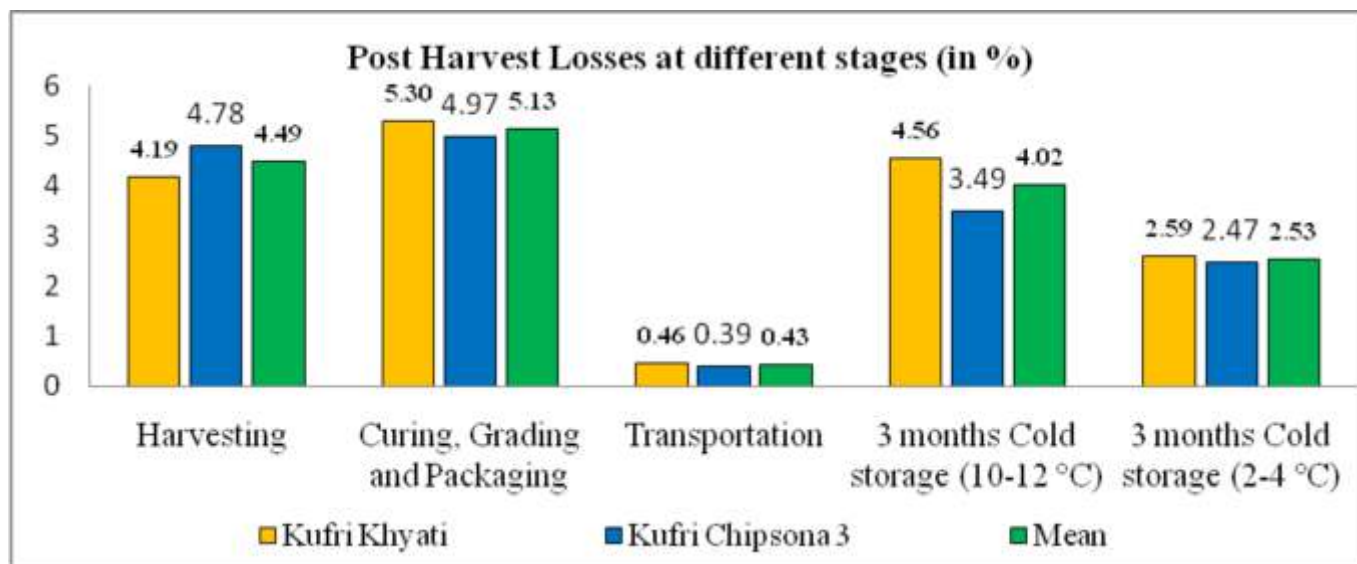


Fig. 2. PHL assessment at different stages from harvesting to storage (in %)

3.2% and 4.7% at 10-12°C and 2-4°C cold storage, respectively. Similar pattern was also observed at consumer level, where the loss at 10-12 °C cold storage was lesser (1.6%) than that at 2-4°C cold storage (3.3%).

Quantification of rot pathogens on tubers: The quantification of tuber contamination with erwinias (soft rot) and fusaria (dry rot) in two

potato varieties namely, Kufri Pukhraj and Kufri Chipsona-1 was done right from harvesting time till five months of storage under different temperatures at regular intervals i.e. in heaps under ambient temperature and in storage at 2-4°C and 10-12°C, at Jalandhar. The tubers of both the varieties were found free from Pectobacterium (erwinias) contamination during all the storage

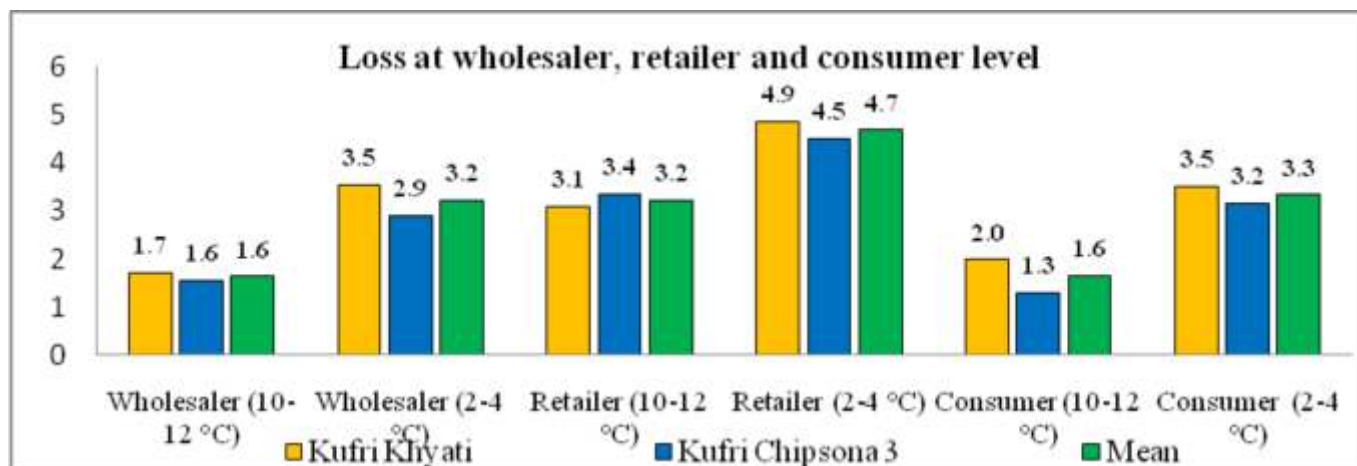


Fig. 3. PHL assessment at wholesaler, retailer and consumer level

stages. But as usual, the tubers of both the varieties were contaminated with *Fusarium* spp. In both the varieties, the population of *Fusarium* propagules was observed to be low at harvesting which

increased until 30 days of storage under different storage conditions and then decreased till 5 months of storage (Fig. 4) as was observed in the previous year also.

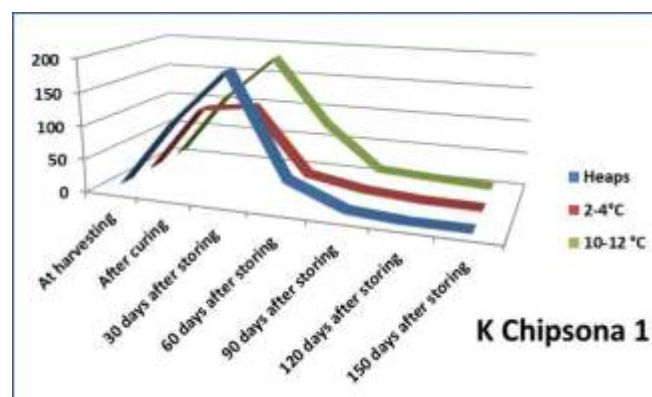
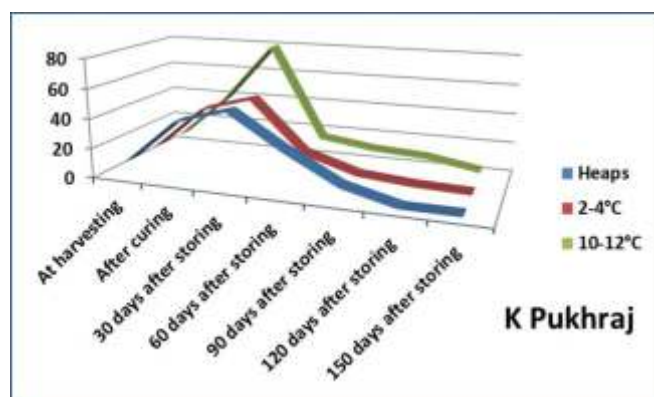


Fig. 4 Quantification of *Fusarium* population ($\times 10^2$ propagules ml^{-1} of peel extract) on tubers stored under various conditions

Sprout suppression in potatoes with volatile compound: CPRI is working on evaluation of different naturally occurring volatile compounds for their efficacy as sprout suppressants. One of such compounds found promising in laboratory viz. Menthol, was tried on large scale (25q of potatoes) on four cultivars to confirm its efficacy. Study revealed that treatment with menthol suppresses sprouting in all cultivars up to different storage period. Cultivar, K Chipsona-1 recorded minimum sprouting (Fig. 5) followed by K. Jyoti, K. Chandramukhi and K. Surya. In cultivar K. Chipsona-1, 11 % sprouting was recorded up to 6 months of storage at 12°C and eyes remained black in this variety. For other cultivars the treatment remained effective up to 2 months of storage. Among all cultivars sprout weight remained less than 19.5 g/kg tuber upto 6 months of storage. Whereas for control cultivars minimum 116 g/kg tuber sprout weight was recorded after 6 months of storage. For cultivar K. Chipsona-1 total mean weight loss remained at par with CIPC treated potatoes up to 6 months of storage. Whereas, for other cultivars percent weight losses were 50% of losses recorded in control cultivars.

Menthol treatment did not affect the processing quality of potatoes. Contents of reducing sugar, sucrose and chip colour remained within acceptable limits up to 6 months of storage.

Changes in other processing parameters i.e. free amino acids and phenol content were comparable with the CIPC treated potatoes. There was no change in flavour/smell and skin colour of whole potato tubers after removal from chamber. Organoleptic evaluation at monthly interval up to 6 months of storage showed no adverse effect on taste and flavour of boiled potatoes in comparison with CIPC treated potatoes. The results confirmed that tuber treatment with non-toxic compound, menthol may be a possible replacement for CIPC and can effectively control sprouting at 12°C up to 6 months of storage without any adverse effect on processing quality, taste and flavour of tubers.

Development of good keeping quality potatoes: It



Fig. 5. Effect of menthol treatment on sprouting behavior of potatoes after 90 days of storage at 12°C (Left: untreated, Right: Treated)

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. 14 varieties viz. K. Pukhraj, K. Chip-1, K. Chip-2, K. Bahar, K. Jyoti, K. Chandramukhi, K. Surya, K. Badshah, K. Pushkar, K. Dewa, K. Sutlej, K. Khyati, K. Arun and Lady Rosetta were selected including varieties with a range of keeping quality characters for this assessment. Different parameters including keeping quality characteristics (sprouting, weight loss, rotting and firmness), Periderm thickness using simple microscope, wound healing rates, Phenol conc., sugar analysis, Vitamin C conc., Dry matter, Calcium estimation and respiration rates were studied. Identification of morphological markers related to good keeping quality will augment selection in breeding programmes for good keepers.

Respiration rates: The respiration rates in the undamaged and damaged tubers was measured as a function of CO₂ emission rates (Time 0, 1 day, 3 days and 6 days were recorded) at 8 weeks after harvest using Nikon CO₂ infra-red gas analyser. The maximum respiration rate in undamaged tubers was recorded in Kufri Badshah and minimum in Kufri Chandramukhi. 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 up to 10 days due to wound healing (Fig. 6). Variety K.

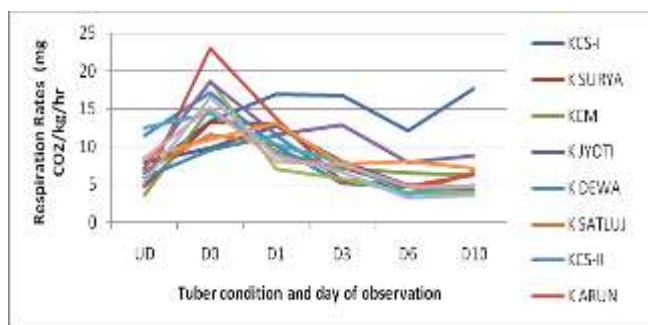


Fig. 6. Respiration rates in undamaged (UD) and damaged potato tubers of different varieties recorded at days 0 (D0), 1 (D1), 3 (D3), 6 (D6) and 10 (D10) after afflicting damage.

Arun showed maximum respiration rates at day 0 followed closely with K. Khyati, K. Pukhraj and K. Chipsona-2.

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, phellogen 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 (120 μ m). 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 total periderm and weight losses at 30 and 60 days with Pearson correlation coefficients of -0.298 and -0.381, respectively.

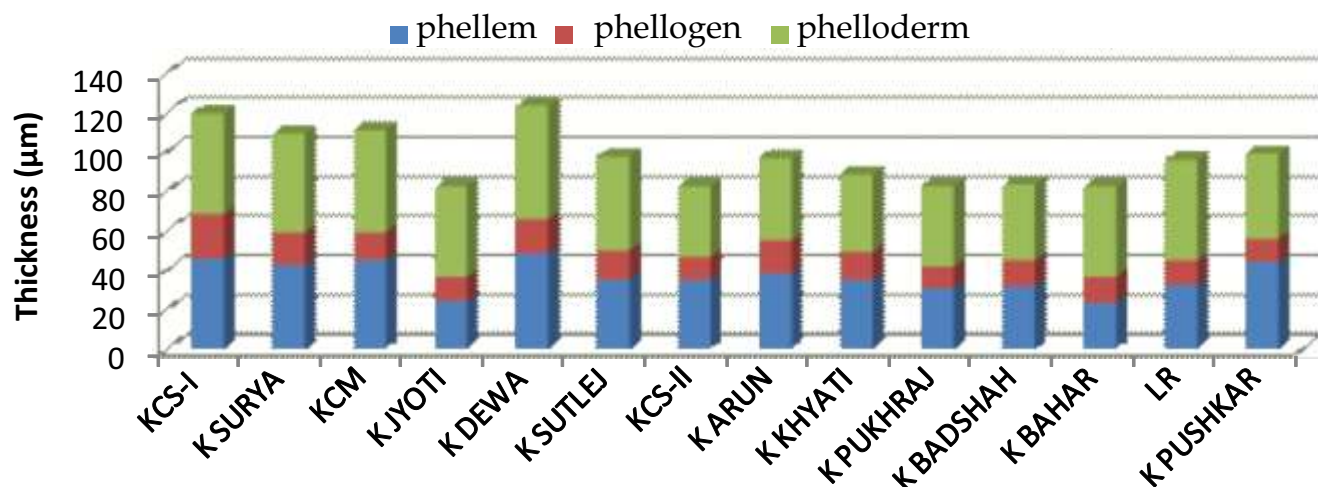


Fig. 6: Variation in potato periderm thickness (μ m) observed for 14 varieties constituting of outer phellem, middle phellogen and inner phelloderm.

Antihypertensive compounds in potatoes:

Angiotensin converting enzyme (ACE) increases the blood pressure by converting angiotensin I (inactive decapeptide) to angiotensin II (a potent vasoconstrictor), and bradykinin (a hypotensive peptide) to inactive components. High ACE activity leads to increased concentration of angiotensin II which in turn leads to hypertension. ACE inhibitors are used as first-line of treatment of hypertension. Plants and plant parts with high antioxidative capacity have the potential to act as ACE inhibitors. With this concept indigenous potatoes were checked for the presence of ACE inhibitory activity using HPLC. Water extract of dried flesh of 25 potato varieties was used to check ACE inhibitory activity. Activity was recorded from 25mg/ml extract. The inhibitory activity ranged from 0 to 56.23% in tested samples. Out of 25 varieties ACE inhibitory activity was recorded in six varieties viz. K. Sindhuri, K. Bahar, K. Jyoti, K. Kundan, K. Anand and K. Arun (Fig. 7). The ACE

inhibition was the maximum with K. Bahar extract followed by K. Sindhuri. Out of these six varieties, K. Kundan, K. Arun and K. Anand showed α -glucosidase inhibitory activity (antidiabetic activity) as well, in the previous studies. The results showed that indigenous potato varieties contained health promoting compounds such as antidiabetic and antihypertensive, however, further *in-vivo* studies are required to check the bioavailability and effectiveness of these compounds.

Effect of number of fryings on rancidity development in chips and frying oils:

Three types of frying oils viz. Olive oil, Ground nut oil and Sunflower oil were used for frying of chips of variety Kufri Chipsona-3. Chips were fried in all these three oils for five days regularly (once a day), so that in total five fryings per oil were done. Chips were packed in presence of nitrogen after every frying. Oil sample was also collected after every frying. Chips and oil was used for estimation of free fatty acid and thiobarbituric acid test (TBA). Results showed that the free fatty acid increased in fried chips as well as frying oil in all the tested samples with increase in number of frying. In case of chips, free fatty acid development was least in chips fried in olive oil and was maximum in chips fried in sunflower oil. In case of frying oils also, free fatty acid development was least in olive oil during 5th frying, however, was maximum in ground nut oil (Fig. 8). TBA development also showed same

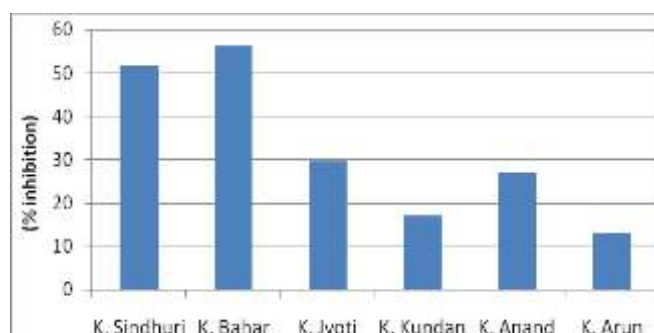


Fig. 7. ACE inhibitory activity in potato varieties

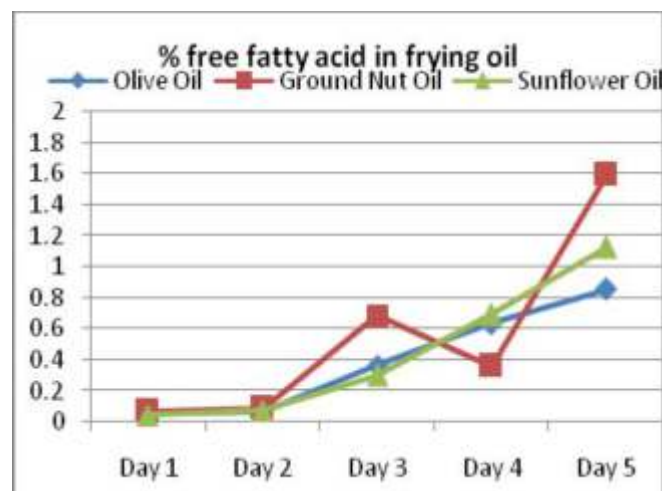
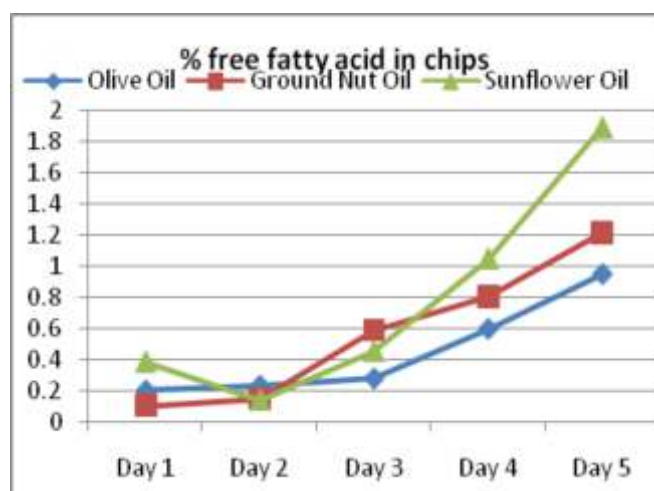


Fig. 8. Free fatty acid development in chips and frying oils

trend as that of free fatty acid (Fig. 9). Per cent of free fatty acid remained below 3% up to five numbers of frying in case of all oils as well as fried

chips. The results showed that these oils are safe to use up to five fryings.

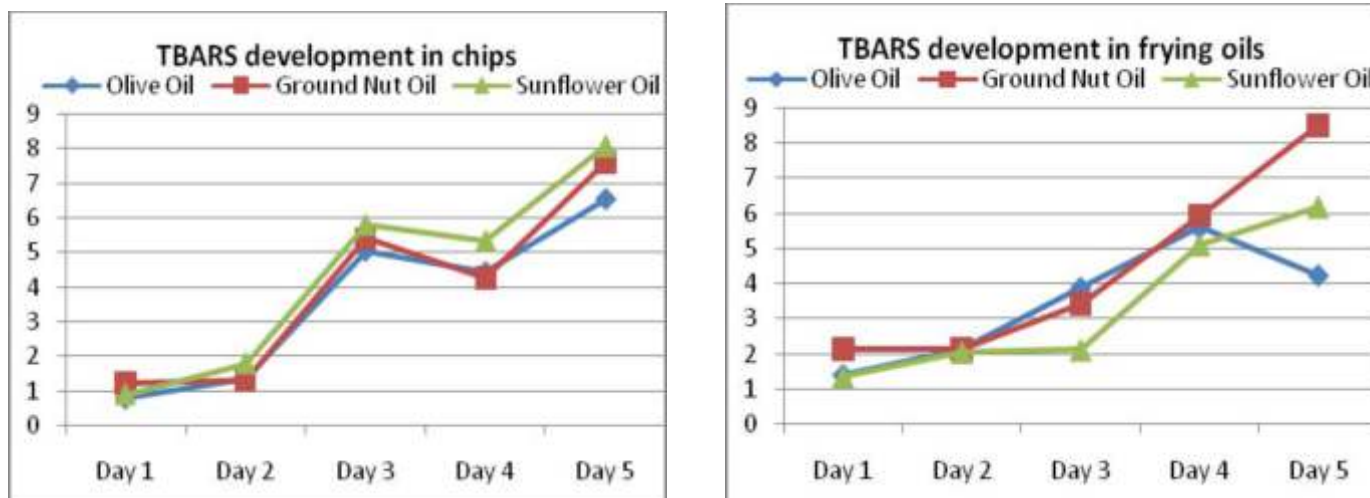


Fig. 9. TBA development in chips and frying oils

Cloning of zinc transporter gene (StZn Trp1) from potato: With the aim of having deeper insights of zinc (Zn) uptake and transport in potato plants NCBI databases was searched for nucleotide sequences of zinc transporter. Database search revealed the availability of 11 full length cDNA sequences of zinc transporter. Phylogenetic analysis showed the relationship among these 11 isoforms of zinc transporter in potato. Of these, complete coding sequence (CDS) of one zinc transporter gene (StZn Trp1) from *Solanum tuberosum* L. cultivar Kufri Chandramukhi was cloned and sequenced. The cloned StZn Trp1 sequence was submitted to NCBI Gene Bank and has been assigned accession number KY607427. The ORF consisted of 987 nucleotides encoding a protein having 328 amino acids. The deduced protein was predicted to have molecular weight of 35.2 kD and isoelectric point of 5.67. The

cloned StZn Trp1 gene sequence showed allelic variations for eight nucleotides when compared with the most identical sequence of zinc transporter gene available in NCBI GenBank (accession number XM_006355670).

Dipsticks for estimation of glucose in potato tubers: The glucose dipsticks developed during the previous year were tested with standards of glucose, sucrose and fructose (in the concentration of 0, 100, 250 and 500 ppm) solutions to find any interference of other sugars during glucose analysis. The strips reacted with glucose standards only. None of the strips reacted with known concentrations of sucrose and fructose (Fig. 10).

Evaluation of biochemical constituents in different sized tubers: An experiment was planned to know the quality characteristics of potato tubers based on their size. Tuber grading

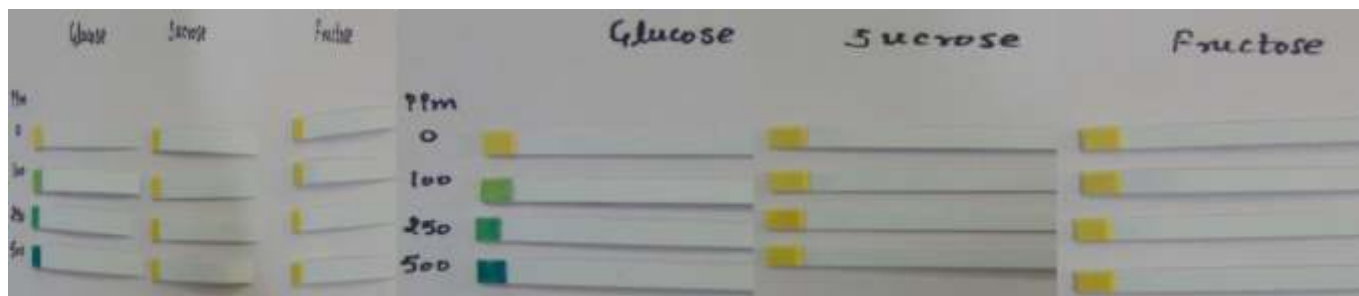


Fig. 10. Reaction of developed strips with glucose, sucrose and fructose standards of different concentration

size was taken as follows: Baby potato <50 gram (B), Small size 50-75 gram (S), Medium Sized 75-150 gram (M), Large sized 150-225 gram (L), Over Sized >225 gram (O) (Fig. 11). Three processing hybrids viz., MP/9-45, MP/9-73, MP/9-221 and six varieties namely, K.Chipsona-1, K.Chipsona-3, K.Chipsona-4, K. Frysona, Atlantic and Lady Rosetta were harvested at 75, 90 and 110 days of maturity. Samples were made composite by pooling three replications and these were then stored in leno bags at room temperatures (Fig. 11). Biochemical parameters viz., dry matter, chip colour, reducing sugars and sucrose contents were analysed. Dry matter (%) was found increasing from 75 days of planting (DAP) to 110 days of maturity irrespective of all the varieties. Among different sized tubers, baby potato retained more



Fig. 11. The grading of tubers of K. Chipsona-1, K. Frysona and Lady Rosetta

dry matter than in oversized potatoes (average basis). Chip colour too improved in all varieties from 75 to 110 days and on average slight decrease was also observed from baby potatoes to oversized potatoes. The hybrid MP/9-45 retained chip colour in all the graded potatoes except in medium sized potatoes at 75 days of planting. Desirable chip colour was found in medium sized potatoes in hybrid MP/9-73. Graded baby, small, large and oversized potatoes did not give acceptable colour at 75 DAP, whereas at 90 and 110 days of maturity of crop chip colour was improved. In general medium, and oversized potatoes indicated acceptable chip colour. Oversized potato grade in K.Chipsona-3 variety gave acceptable colour at 75, 90 and 110 days of planting. Results indicated that maximum reducing sugars were present at 75 days of harvest. The content decreased significantly from 90 days of harvest to 110 days of maturity.

Reducing sugars content in all tested hybrids and varieties were observed suitable in medium, large and oversized potatoes at 90 and 110 days of maturity. Sucrose, an indicator of chemical maturity, was maximum in immature tubers, which means that accumulation was more at 75 and 90 days of planting. Sucrose won't participate directly in Malliard's reactions during frying of chips/French fries at higher temperatures, but during prolonged storage it is an important parameter. With the growth of tubers, after 75 days, sucrose content decreased and was the lowest at 110 days of maturity.

Development of ready to eat steam cooked potatoes: Globally, the demand for ready-to-eat (RTE) food products has been increasing over the last few years on account of busy lifestyle of consumers and their rising income levels. According to "India Ready-to-eat Food Market Forecast & Opportunities, 2019" report, the Indian RTE food market is projected to grow at a CAGR of 21.99% during 2014-19, in value terms. CPRI is working on standardization of the pre-treatment process for the production of thermally processed RTE potato tubers (Fig. 12). The technology of RTE steam cooked potato tuber involves thermal processing of washed and peeled small size potato tubers in flexible retortable pouches which have long shelf life without any preservatives. RTE steam cooked potato tubers can be used for the preparation of curries, stuffing for parathas, kulcha and naans and can also be consumed in fasts. This product may find better marketability in remote areas such as North-Eastern areas, Andaman & Nikobar islands, Lakshadweep, J&K (especially



Fig. 12. Thermally processed RTE steam cooked potato (a) without pre-treatment; (b) after pre-treatment

those areas which are inaccessible due to unfavorable weather conditions). This product does not require cold storage facility and can be stored at ambient conditions without any specific storage requirement. This technology is applicable to fresh and cold stored potato tubers of any shape, size and variety. This technology has the potential to reduce the percentage of post-harvest losses. Hence, by using this technology, surplus production of table and processing potatoes can be converted into shelf stable RTE steam cooked potatoes. This technology can be easily adopted by industries involved in production of thermally processed and preserved food items.

Potato based gluten free cookies: Food allergies and food intolerances are a growing public health concern causing rapidly growing demand of gluten-free food. The target group for the gluten-free foods market includes people suffering from celiac disease or gluten sensitivity as well as people who are very health-conscious. Out of the considerable number of products accessible in the worldwide gluten free food market, the bakery products segment witnessed a healthy growth. Beside this in India's share of processed potato is very low and due to lack of proper storage facility, post-harvest loss are continuously increasing. Keeping in view of the above points CPRI is working on development of potato based gluten



Fig. 13. Potato based gluten free cookies

free and fasting friendly cookies having 50-80% potato flour. More than seven variants have been developed (Fig. 13).

Utilization of potato starch for development of biodegradable disposable tableware: The idea behind this concept is indirect way of utilizing waste potatoes for starch extraction which further can be utilized in development of tableware. Two concentration of potato starch i.e 25% and 50% were used for development of tableware at Windsor Industries, Kurali, Punjab. Potato starch was blended with coupling agent, plasticizer and coloring agent. The pellets created with this combination were melted in extruder at high temperature and pressure to generate smooth polymer sheets. The sheets were later moulded into different tableware such as plates and bowls using vacuum technology (Fig. 14). The strength of tableware seems quite good, however, further testing on its strength and biodegradability in soil needs to be checked. This work may open up new avenues in the field of 'potato waste utilization'.



Fig. 14. Potato starch based tableware

Division of Seed Technology

Programme: Production of nucleus and breeder seed of important notified varieties of potato.

To maintain the higher productivity as well as yields, it is essential to have a scientifically sound seed production system through which high degree of health standard of the seed crop is maintained. Therefore, a program entitled "Production of nucleus and breeder seed of important notified varieties of potato" has been started under Revolving Fund Scheme. The nucleus and breeder seed production is being monitor 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 2016-17 and hills 2017 is given below:

Seed Production

A. Plains (2016-17)

A total production of 28609.62 qtls nucleus and breeder seed was achieved from an area of 138.834 ha. Out of which, 23241.73 qtls production from 114.671 ha was through conventional and 5367.89 qtls from 24.163 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from conventional system was 81.24 and 18.76 through hi-tech system.

1. Conventional Seed Production System:

During 2016-17, total no. of 4609 clones/samples of indexed tubers of different commercial potato varieties were tested at regional stations in the plains (Table 1). Station/stage wise area and production of different potato varieties is given in table 2.

Table-1: Tuber indexing and Field ELISA (Stage-I) Testing (Plains 2016-17)

Name of Station	Indexed Tubers		Field ELISA	
Plains (2016-17)	No of clones/samples tested	Healthy clones No (%)	No of clones/samples tested	Healthy clone No (%)
Modipuram	1343	1312 (97.69)	1939	1890 (97.47)
Jalandhar	854	827 (96.84)	820	782 (95.37)
Gwalior	1962	1894 (96.53)	1694	1663 (98.17)
Patna	450	431 (95.78)	630	552 (87.62)

Table -2: Station & variety wise area and production (qtls) in Conventional system 2016-17 (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	26.15	1.27	253.00	4.00	897.00	17.20	4461.50	22.77	5637.65
K. Pukhraj	0.06	2.87	0.16	31.50	0.60	131.00	2.80	602.00	3.62	767.37
K. Anand	0.04	2.00	0.20	17.50	0.50	132.00	1.80	584.00	2.54	735.50
K. Sadabahar	-	-	0.16	19.35	0.40	82.90	0.60	110.90	1.16	213.15
K. Garima	0.04	2.25	0.28	32.50	0.50	170.50	2.50	521.90	3.32	727.15
K. Khyati	0.08	4.98	0.36	44.70	1.10	265.00	2.70	696.00	4.24	1010.68
K. Surya	0.06	2.35	0.13	18.70	0.30	73.90	1.35	290.00	1.84	384.95
K. Chipsona-1	0.06	7.35	0.35	41.50	0.60	149.30	1.80	438.00	2.81	636.15
K. Chipsona-3	0.02	3.28	0.18	21.50	0.30	73.50	1.20	304.50	1.70	402.78
K. Chipsona-4	0.02	1.10	0.10	12.0	0.30	59.80	1.90	380.25	2.32	453.15
K. Frysona	0.05	1.35	0.15	20.00	0.60	147.00	2.60	625.00	3.40	793.35
K. Mohan	0.07	3.32	0.16	29.80	-	-	-	-	0.23	33.12
Total	0.80	57.00	3.50	542.05	9.20	2181.90	36.45	9014.05	49.95	11795.00

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
II. Jalandhar										
KCM	0.01	0.48	0.04	9.5	0.20	53.50	1.00	282.00	1.24	345.48
K. Jyoti	0.30	4.42	0.60	115.35	2.50	456.50	11.00	2204.00	14.4	2780.27
K. Badshah	0.01	0.23	0.04	4.00	0.15	28.50	0.50	92.00	0.7	124.73
K. Pukhraj	0.02	2.52	0.05	29.03	0.50	171.50	4.50	1392.63	5.07	1595.68
K. Chipsona-3	0.01	0.50	-	-	0.05	8.63	0.10	20.72	0.16	29.85
K. Khyati	0.02	0.42	0.05	12.00	0.40	85.62	1.40	280.00	1.87	378.04
K. Himalini	0.01	0.23	0.04	5.50	0.20	33.00	-	-	0.25	38.73
K. Surya	0.01	0.40	0.05	5.50	0.20	46.00	1.05	158.00	1.31	209.9
Total	0.39	9.20	0.8	180.88	4.20	883.65	19.55	4429.35	24.99	5503.08
III. Gwalior										
KCM	0.12	5.74	0.30	44.50	0.98	100.50	2.16	202.30	3.56	353.04
K. Jyoti	0.21	11.74	0.50	68.00	1.55	232.00	4.11	385.40	6.37	697.14
K. Sindhuri	0.13	11.05	0.66	88.00	2.44	400.00	6.20	1173.10	9.43	1672.15
K. Lauvkar	0.10	6.54	0.20	16.84	0.67	71.85	0.68	69.75	1.65	164.98
K. Chipsona-1	0.12	8.20	0.36	48.00	1.04	146.50	4.01	597.05	5.53	799.95
K. Chipsona-3	0.10	7.95	0.28	35.00	0.76	76.00	3.38	596.1	4.52	715.05
K. Surya	0.04	5.94	-	-	-	-	-	-	0.04	5.94
Total	0.82	57.16	2.30	300.34	7.44	1027.35	20.54	3023.10	31.1	4407.95
IV. Patna										
K. Arun	0.012	0.50	0.029	3.50	-	-	0.20	39.50	0.241	43.50
K. Jyoti	0.027	2.00	0.067	8.00	0.40	75.00	2.00	339.00	2.494	424.00
K. Khyati	0.033	2.50	0.067	11.00	0.40	87.00	1.20	196.50	1.7	297.00
K. Lailt	0.012	1.00	0.020	2.00	0.35	57.20	-	-	0.382	60.20
K. Pukhraj	0.015	1.00	0.022	2.50	0.20	44.00	1.10	239.50	1.337	287.00
K. Sindhuri	0.027	1.50	0.050	7.50	0.40	79.50	2.00	335.50	2.477	424.00
Total	0.126	8.5	0.255	34.5	1.75	342.70	6.5	1150.00	8.631	1535.70
Gand Total	2.136	131.86	6.855	1057.77	22.59	4435.6	83.04	17616.5	114.67	23241.73

2. Hi-Tech Seed Production System: Station/ generation wise area and production of different potato varieties is given in Table 3.

Table 3: Station & variety wise area and production (Qts.) in Hi-Tech system 2016-17 (Plains)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
I. Modipuram						
K. Bahar	2.20	458.50	7.00	1840.00	9.20	2298.50
K. Frysona	0.01	2.00	0.05	13.25	0.06	15.25
K. Pukhraj	0.06	25.00	0.10	22.00	0.16	47.00
K. Sadabahar	-	-	0.13	22.00	0.13	22.00
K. Surya	0.35	112.50	0.45	94.00	0.08	206.50
K. Khyati	0.62	179.50	2.77	689.00	3.39	868.50
K. Chipsona-1	-	-	0.20	46.50	0.20	46.5
K. Chipsona-3	0.06	21.00	0.15	40.00	0.21	61.00
K. Chipsona-4	0.70	183.00	1.50	283.00	2.20	466.00
Total	4.00	981.50	12.35	3049.75	16.35	4031.25
II Jalandhar						
K. Chandramukhi	0.15	7.31	0.15	45.39	0.30	52.70
K. Jyoti	0.05	2.50	0.30	61.16	0.35	63.66
K. Badshah	0.15	4.30	0.20	24.26	0.35	28.56
K. Pukhraj	0.05	30.80	-	-	0.05	30.80
K. Pushkar	0.05	12.81	-	-	0.05	12.81

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
K.Chipsona-1	0.05	3.59	0.05	23.00	0.10	26.59
K. Chipsona-3	0.10	8.34	0.15	30.89	0.25	39.23
K. Khyati	0.40	5.70	1.00	199.07	1.40	204.77
K. Himalini	0.20	3.00	0.40	104.06	0.60	107.06
K. Surya	0.05	8.46	-	-	0.05	18.59
K. Gaurav	0.01	1.40	-	-	0.01	1.40
Total	1.26	88.21	2.25	487.83	3.51	576.04
III Gwalior						
K. Sindhuri	-	-	0.12	20.50	0.12	20.50
K. Lauvkar	0.18	25.50	0.43	52.00	0.61	77.50
K. Chipsona-1	-	-	0.02	3.00	0.02	3.00
K. Chipsona-3	-	-	0.01	1.50	0.01	1.50
K. Surya	0.13	19.50	0.01	1.10	0.14	20.60
Total	0.31	45.00	0.59	78.10	0.90	123.10
IV Patna						
K. Arun	0.03	6.50	-	-	0.03	6.50
K. Ashoka	0.06	17.00	0.40	97.50	0.46	114.50
K. Chipsona-3	0.013	2.00	-	-	0.013	2.00
K. Himalini	0.025	11.00	-	-	0.025	11.00
K. Jyoti	0.015	3.00	-	-	0.015	3.00
K. Kanchan	0.009	1.50	0.10	13.00	0.109	14.50
K. Khyati	0.023	5.50	1.00	160.00	1.023	165.5
K. Pukhraj	0.10	16.00	0.80	169.50	0.9	185.50
K. Sindhuri	0.088	17.50	0.20	40.00	0.288	57.50
K. Surya	0.14	30.00	0.40	47.50	0.54	77.50
Total	0.503	110.00	2.90	527.50	3.403	637.50
Grand Total	6.073	1224.71	18.09	4143.18	24.16	5367.89

3. Total supply of breeder seed

During 2016-17, total 22385.59 qtls breeder seed was supplied to various government and private agencies, from plains Table-4.

Table-4 : Station and variety wise supply (qtls) during 2016-17

S. No.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
1.	Kufri Jyoti	-	2277.31	378.40	339.00	2994.71
2.	Kufri Bahar	6528.50	-	-	-	6528.50
3.	Kufri Chipsona-1	498.30	22.37	598.10	-	1118.77
4.	Kufri Khyati	1464.00	461.01	-	351.00	2276.01
5.	Kufri Lauvkar	-	-	120.10	-	120.01
6.	Kufri Chipsona-3	367.00	49.35	588.55	-	1004.90
7.	Kufri Badshah	-	116.01	-	-	116.01
8.	Kufri Surya	395.40	169.21	0.10	42.00	606.71
9.	Kufri Sindhuri	-	-	1263.15	371.00	1634.15
10.	K. Chandramukhi	-	326.10	199.60	-	525.70

S. No.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
11.	Kufri Sadabahar	152.20	-	-	-	152.20
12.	Kufri Anand	607.00	-	-	-	607.00
13.	Kufri Frysona	657.25	-	-	-	657.25
14.	Kufri Chipsona-4	818.55	-	-	-	818.55
15.	Kufri Himalini	-	109.06	-	-	109.06
16.	Kufri Arun	-	-	-	39.50	39.50
17.	Kufri Ashoka	-	-	-	116.00	116.00
19.	Kufri Kanchan	-	-	-	13.00	13.00
20.	Kufri Garima	568.00	-	-	-	568.00
21.	Kufri Pushkar	-	1.30	-	-	1.30
22.	Kufri Pukhraj	634.50	1362.67	-	381.00	2378.17
Total		12690.70	4894.39	3148.00	1652.50	22385.59

B. Hills (2017-18)

1. Multiplication of basic material maintenance of mother stock: A total no. of 34 pots of 17 varieties were planted and tested with ELISA/PCR against different potato viruses. After carrying out series of testing through PCR/ELISA all healthy varieties were shifted *in vitro* & were included in the microplants multiplication and supply chain. A total of 87000 aeroponic minitubers of different varieties were produced under aeroponics.

2. Seed Production (Hills):

During 2017, a total production of 1019.49 qtls of nucleus and breeder seed was achieved from 5.01 ha area. Out of which, 808.58 qtls from 4.30 ha

(Table-5) was through conventional and 192.91 qtls from 0.71 ha through hi-tech (Table-6) seed production systems respectively. The percentage of nucleus and breeder seed was 79.31 through conventional system and 20.69 through hi-tech system in the hills. Stage wise/Generation wise area and production of different potato varieties is given in Table 6 & 7 respectively.

Tuber indexing and Field ELISA (Stage-I) Testing: During 2017, total no. of 288 clones/samples of indexed tubers were tested and 285 (99.00%) were found healthy whereas 257 samples of hills in stage-1 standing crop were tested and 254 (98.83%) were found healthy at Fagu

Table 5: Station & variety wise area and production (Qts.) under Conventional system 2017 (Hills)

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Kufri										
K. Jyoti	0.070	13.21	0.12	25.50	0.40	88.00	1.35	278.15	1.94	404.86
K. Himalini	0.010	2.36	0.10	11.00	0.18	49.23	0.75	131.25	1.04	193.84
K. Girdhari	0.010	1.88	0.09	9.50	0.15	33.85	0.55	106.62	0.80	151.85
K. Shailja	0.002	0.35	0.05	5.20	0.05	9.10	0.20	18.20	0.302	32.85
K. Kanchan	0.004	0.73	0.04	3.49	0.02	3.43	0.15	16.88	0.214	24.53
K. Giriraj	0.002	0.39	-	-	-	-	-	-	0.002	0.39
K. Himsona	0.002	0.26	-	-	-	-	-	-	0.002	0.26
Total	0.10	19.18	0.40	54.69	0.80	183.61	3.00	551.10	4.30	808.58

Table 6: Station & variety wise area and production (Qts) in Hi-Tech system 2017 (Hills)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
V. Kufri						
K. Jyoti	0.06	9.37	0.18	38.00	0.24	53.05
K. Himalini	0.12	15.05	0.25	85.50	0.37	88.37
K. Girdhari	0.02	2.87	0.07	24.00	0.09	51.49
Total	0.20	27.29	0.50	147.50	0.71	192.91

Table-7: Agency & Variety wise supply of breeder seed during 2017-18 from CPRS, Kufri

S. No.	Name of agency	K. Jyoti	K. Himalini	K. Girdhari	K. Shailja	K. Kanchan	Total
1.	HP	60.00	40.00	40.00	15.00	-	155.00
2.	J&K	120.00	100.00	20.00	-	-	240.00
3.	Uttaranchal	20.00	30.00	25.00	10.00	-	85.00
4.	Arunachal Pradesh	10.00	-	-	-	-	10.00
5.	Meghalaya	20.00	-	-	-	5.00	25.00
6.	University	22.00	5.00	4.00	4.00	5.00	40.00
7.	ICAR	19.05	22.50	26.90	0.70	2.00	71.15
8.	Farmers/Pvt.	73.25	32.98	24.94	2.00	5.43	138.60
Total		344.30	230.48	140.84	31.70	17.43	764.75

C. Production and supply of quality seed

At Ooty, total quality seed production was 705.8 qtls from 8.59 ha area during summer, autumn and spring season Ooty (Table-8). Out of this 480.1 qtls of quality seed was supplied to the Govt. /Pvt.

Agencies (228.8 qtls to farmers 218.5 qtls to Govt. & 32.8 qtls as table potato) and the remaining quantity was kept for own planting. Revenue of Rs. 15,71,573/- has been generated during the year 2017-18.

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

Sl. No.	Varieties	Summer season			Autumn season			Spring season		
		Area (ha)	Yield (qtls)	Av. Yield (t/ha)	Area (ha)	Yield (qtls)	Av. Yield (t/ha)	Area (ha)	Yield (qtls)	Av. Yield (t/ha)
1.	Kufri Swarna	1.73	187.0	10.80	0.80	40.8	5.10	1.30	21.2	1.63
2.	Kufri Girdhari	3.53	370.8	10.50	-	-	-	-	-	-
3.	Kufri Himalini	0.61	23.8	3.90	-	-	-	-	-	-
4.	Kufri Jyoti	0.22	31.3	14.20	-	-	-	-	-	-
5.	Os-01/497	0.40	30.9	7.70	-	-	-	-	-	-
Total		6.49	643.8	9.92	0.80	40.8	5.10	1.30	21.2	1.63

At Shillong, total quality seed production of six varieties was 226.13 qtls from 7.46 ha area through Conventional system and High-tech system (Table-9). Out of these 142 qtls of quality seed was supplied to the different states. Revenue of Rs. 3,55,000/- has been generated during the year 2017-18.

Table-9: Quality seed production and supply in Shillong

S. No.	Varieties	Conventional system		Hi-tech system		Total		Total Supply (t)
		Area (ha)	Yield (qtls)	Area (ha)	Yield (qtls)	Area (ha)	Yield (qtls)	
1.	Kufri Jyoti	0.6	42.43	0.42	29.51	1.02	71.94	7.9
2.	Kufri Giriraj	0.16	23.39	0.29	32.39	0.45	55.78	2.2
3.	Kufri Girdhari	0.38	6.51	0.71	18.98	1.09	25.49	0.7
4.	Kufri Himalini	0.3	6.71	2.65	25.93	2.95	32.64	0.77
5.	Kufri Megha	-	-	0.57	32.77	0.57	32.77	2.43
6.	Kufri Kanchan	-	-	0.43	7.51	0.43	7.51	0.2
Total		1.44	79.04	5.07	147.09	6.51	226.13	14.2

D. Supply of Indexed Tubers to PAU, Ludhiana

As per the MoU between ICAR-CPRI, Shimla and Punjab Agriculture University, Ludhiana, regarding the breeder seed production at their farm, Ludhiana, ICAR-CPRI has to supply virus free tubers of K. Jyoti from stage-1 after indexing for PVX, PVS, PVA, PVM, PLRV, PVY, PVYⁿ, PVY^c through ELISA and APLCV through PCR. 269 healthy indexed tubers of Kufri Jyoti were supplied to Punjab Agriculture University, Ludhiana during 2016-17 from CPRS-Jalandhar.

E. Supply of Microplants to Different Seed Agencies

A total 263 virus-free *in vitro* culture tubes of basic seed material of 14 varieties (Fig 1) were

supplied to 30 different seed producing organizations in India (Table-10) and a revenue of Rs. 13,15,000/- has been generated.

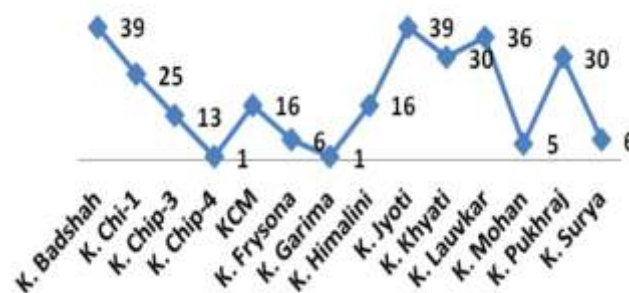


Fig 1. Variety wise supply to different seed organizations

Table 10: Microplants supply to different Seed Producing Organization

S.No	Firms	Varieties Supplied
1.	M/S Dauladhar Bioplants P.O-Bajarerh, Tehsil- Shahpur Distt- Kangra	K.C.M, K.Jyoti, K.Pukhraj
2.	M/s Bhatti Tissue Tech. Vill.-Alipur, PO-Mithapur, The & Distt.- Jalandhar, PB	K.Frysona, K.Chip-3, K.Surya, K.Pukhraj, K.Himalini, K.Jyoti, K.Khyati, K.Lauvkar, K.Badshah, K.Chip-1, K.C.M, K.Mohan
3.	M/S Sekhon Biotech, Jalandhar	K.Jyoti, K.Pukhraj
4.	M/S JPG Agritech, Jalandhar, Punjab	K.Pukhraj, K.Jyoti, K.Frysona

S.No	Firms	Varieties Supplied
5.	M/s Merino India, Potato Pre-basic Seed Production	K.Pukhraj, K.Lauvkar, K.Badshah, K.Chip-3, K.Chip-1
6.	M/s Dayal Seeds Pvt Ltd, Partapur, Meerut, U.P	K.Chip-1, K.Jyoti, K.Frysona, K.Surya
7.	Deputy Director Horticulture, Potato Technology Center, Shamghah, Karnal	K.Mohan, K.Khyati, K.Chip-1, K.Pukhraj
8.	M/s Sanga Farm, Jalandhar	K.Lauvkar, K.Jyoti, K.Pukhraj, K.Badshah, K.C.M
9.	Assistant Director of Horticulture, Dept of Horticulture, PRS Horticulture Farm, Karnatka	K.Chip-1, K.Chip-3, K.Himalini, K.Jyoti
10.	M/s Bhatti Tissue Tech. Vill.-Alipur, PO-Mithapur, The & Distt.- Jalandhar, PB	K.Pukhraj, K.Jyoti, K.Lauvkar, K.Himalini, K.C.M
11.	M/s Potato Grower Biotech, Jalandhar	K.Lauvkar, K.Himalini, K.C.M
12.	M/S Sagar Biotech, Tip Top complex, V.P.O Thakurdwara, Tehsil-Palampur Distt-Kangra	K.Pukhraj, K.Chip-1, K.Jyoti, K.Lauvkar
13.	M/s Shamsheer Singh Tanwar, Regional Manager, Distt-Ludhiana UTIL	K.Jyoti, K.Chip-1, K.Chip-3, K.Pukhraj, K.Badshah
14.	M/s Plant Biotechnology, Pallishree Ltd, Arambagh, Hooghly	K.C.M, K.Pukhraj, K.Jyoti
15.	M/s Himalayan Action Research Centre, Dehradun, Uttarakhand	K.Himalini, K.Jyoti
16.	M/s Potato Grower Biotech, Jalandhar	K.Pukhraj
17.	M/s Honda Biotech, Shahbad, Kurushetra	K.Pukhraj
18.	M/s HG Biotech V.P.O- Beas Pind Distt-Jalandhar, Punjab	K.Jyoti, K.Pukhraj
19.	Potato Technology Centre, Shamgarh, Karnal	K.Pukhraj, K.Chip-3, K.Chip-1, K.Frysona
20.	M/s Centre of Excellence for Potato, Dhogri, Distt-Jalandhar, Punjab	K.Jyoti, K.Badshah, K.Pukhraj, K.C.M, K.Chip-1, K.Himalini
21.	M/s Jain Irrigation Systems Ltd, Jalgaon, Maharashtra	K.Jyoti, K.Pukhraj, K.Khyati, K.Lauvkar, K.Badshah
22.	M/s Sidhivinayak Agri Proc. Pvt. Ltd.	K.Surya, K.Frysona, K.Chip-3, K.Chip-1, K.Pukhraj
23.	M/s Sandhu Biotech, VPO Udhampur, Jalandhar Punjab	K.Sukhyati
24.	Dr. P.K Joshi, IGKV, Raipur	K.Khyati, K.Surya
25.	M/s Cadila Pharmaceuticals Ltd., Agro Division, 755, Prakruti Farm, Village Hirapur, Ta. Dascroi, Dist- Ahmedabad	K.Himalini, K.Frysona
26.	M/s KF Biotech Pvt. Ltd., Theniyur Village, Sulibele Hobli, Hoskote Taluk, Bangalore Rural- 562129, Karnataka	K.Mohan, K.Garima, K.Badshah, K.Himalini, K.Jyoti, K.Pukhraj, K.C.M, K.Lauvkar

S.No	Firms	Varieties Supplied
27.	M/s Sungroove Maharastra	K.Pukhraj, K.Chip-1
28.	M/s Utkal Tubers India Pvt. Ltd., No. 306, The Arcade, Brigade Metropolis, Whitefield Road, Garudacharapalya, Bangalore - 560 048, India	K.Pukhraj, K.Jyoti, K.Lauvkar, K.Badshah, K.Chip-3, K.Chip-1, K.C.M
29.	M/s Mahindra HZPC Pvt. Ltd., Mohali, Punjab	K.C.M, K.Jyoti, K.Pukhraj, K.Lauvkar, K.Badshah, K.Khyati, K.Surya, K.Chip-1, K.Chip-3, K.Chip-4, K.Frysona, K.Himalini, K.Mohan
30.	M/s Technico Agri Sciences Ltd Tehsil- Baddi, Solan	K.Mohan

A total of 221 culture tubes of 15 varieties were supplied to different seed production

stations/centers i.e. Modipuram, Jalandhar, Patna Shillong and Ooty (Fig.2).

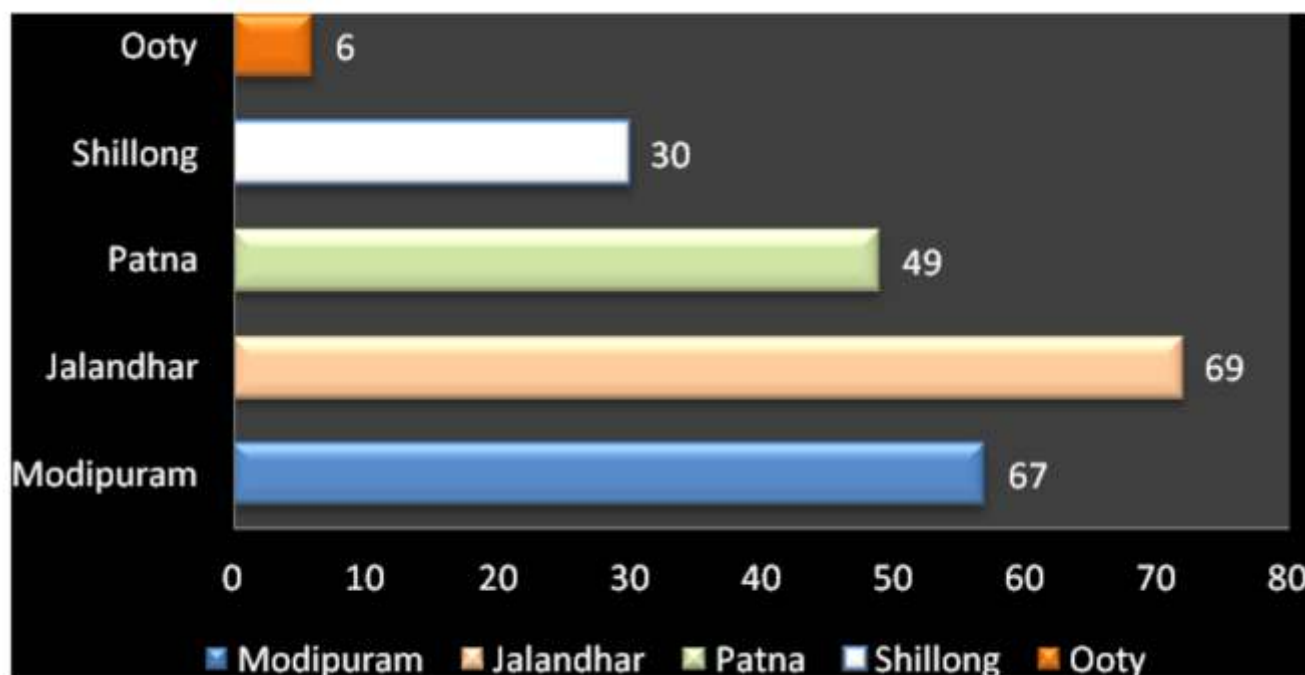


Fig 2. Station wise supply of virus-free cultures

F: Revenue under RFS:

A total of Rs. 8.9 crores/- has been generated by the sale of breeder seed/microplants/aerogenic minitubers under Revolving Fund Scheme (RFS).

Table- 4 (B) Variety/stage & agency wise breeder seed supply from plains (qtls) during 2016-17

S.No.	Variety	CG	HP	J&K	MP	Odisha	PB	UP	WB	UK	NSC	NHRDF	NABARD	Uni/KVK	ICAR/ FOC	Farmers/Pvt.	Auction/ Market	Total
1.	K. Anand	-	-	-	64.00	-	-	376.00	-	-	-	-	-	-	-	57.00	110.00	607.00
2.	K. Arun	-	-	-	-	-	-	-	30.00	-	-	-	-	-	-	8.50	-	39.50
3.	K. Ashoka	-	-	-	-	-	-	-	91.00	-	-	17.00	-	-	-	5.50	-	116.00
4.	K. Badshah	-	-	11.00	-	8.50	21.00	50.00	-	-	-	-	-	0.48	4.75	19.28	1.00	116.01
5.	K. Bahar	-	-	-	78.00	-	45.00	4165.50	-	-	213.00	106.00	-	1.00	18.00	795.00	1107.00	6528.50
6.	KCM	38.00	31.50	5.50	22.00	-	-	-	249.00	-	-	-	63.50	5.70	12.05	97.95	0.50	525.70
7.	K. Chipsona-1	-	-	-	148.50	-	61.50	641.00	6.5	-	-	32.00	-	-	20.13	157.64	51.50	1118.77
8.	K. Chipsona-3	389.50	-	-	181.50	-	-	-	13.00	-	-	-	-	1.03	12.90	321.47	85.50	1004.90
9.	K. Chipsona-4	450.00	-	23.00	-	-	-	-	38.00	-	-	-	-	5.00	25.75	165.00	111.80	818.55
10.	K. Frysona	-	-	-	-	-	-	-	4.00	-	-	-	-	-	11.25	533.00	109.00	657.55
11.	K. Garima	-	-	-	-	-	-	409.00	41.50	-	-	-	-	-	-	5.00	112.50	568.00
12.	K. Himalini	-	-	17.50	-	-	3.50	-	8.50	-	10.50	-	-	0.48	7.00	61.08	0.50	109.06
13.	K. Jyoti	-	329.50	159.00	85.00	33.00	70.00	-	1121.50	83.50	109.50	26.00	66.00	30.68	57.15	818.38	5.50	2994.71
14.	K. Khyati	-	-	20.00	16.00	-	139.50	1138.00	266.00	-	-	96.50	-	0.48	19.43	308.60	271.50	2276.01
15.	K. Kanchan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.00	-	13.00
16.	K. Lauvkar	-	-	-	90.50	-	29.50	-	-	-	-	-	-	-	-	0.10	-	120.10
17.	K. Pukhraj	65.50	-	-	24.00	65.50	139.50	131.00	554.00	-	131.00	87.50	-	135.48	42.53	919.66	82.50	2378.17
18.	K. Pushkar	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	0.30	1.30
19.	K. Sadabahar	-	-	-	-	-	-	116.50	-	-	-	-	-	-	-	-	35.70	152.20
20.	K. Sindhuri	340.00	-	46.00	-	-	64.00	500.00	-	-	-	-	125.00	6.55	253.00	299.60	-	1634.15
21.	K. Surya	-	-	9.00	19.96	-	-	318.00	73.00	14.00	-	50.00	-	4.28	25.40	55.67	37.40	606.71
Total		1283.00	361.00	291.00	729.46	107.00	573.50	7845.00	2496.00	97.50	464.00	415.00	254.50	191.16	513.84	4641.43	2122.20	22385.59

Seed Research (Programme: Resource optimization in potato based cropping system)

Project.1: Seed potato production through aeroponics and augmenting micro-propagation potential of potato cultivars in hills

Performance of aerial and aeroponic minitubers in polyhouse during Kharif season: In aeroponic seed potato production, large number of tubers develops as aerial tubers especially towards the end of growing season. Such aerial tubers vary in size and shape and are always green in colour. To judge the suitability of such aerial aeroponic tubers for use as seed; a comparative study of aerial and normal aeroponic tubers was conducted. The number of tuber obtained per m² were similar and statistically at par with both the types of seed sources. The results revealed that aerial aeroponic tubers can also be used as a source of seed like aeroponic minitubers without doubt.

Performance of *in vitro* plantlets and aeroponic minitubers under normal and late planting in polyhouse during Kharif season: To overcome the problem of low productivity due to high temperature in initial months of multiplication in Kharif season, *in vitro* plantlets and aeroponic tubers were tested under two planting dates. *In vitro* plantlets produced significantly higher tubers/m² than aeroponically produced tubers. The findings of the study revealed that basic seed material (*in vitro* plantlets and aeroponic tubers) should be planted late (first fortnight of August) in polyhouse conditions in high hills for higher tuber number and yield.



Fig.1. Aerial tubers

Production behavior of aeroponic tubers of K. Himalini from different harvests in polyhouse during Kharif season: At Fagu, a gradual increase in average tuber weight was observed with corresponding decrease in number of sprouts per tuber at planting when numbers of harvests were increased in aeroponics. Tuber number and yield/m² were maximum with the tubers of initial harvests and a decreasing trend was recorded with increased number of harvest for tubers produced. Increases in crop duration beyond 120 days in hills may result in higher productivity (Table 1)

Table 1. Performance of tubers (<3g) of K. Himalini obtained from different aeroponic harvests

Treatment	Planted tuber wt. (g)	Sprout /tuber	Emergence (%)	Plant height (cm)	Haulms wt./m ²	Total tubers/m ²	Yield (kg/m ²)
2 nd harvest	1.50	1.17	97.9	86.9	1.06	80.9	2.50
3 rd harvest	2.73	1.13	97.5	105.9	1.17	78.7	2.34
4 th harvest	2.73	1.07	99.6	111.1	1.48	70.1	2.12
7 th harvest	3.60	1.00	92.3	123.8	1.75	55.9	2.09
CD _{0.05}	-	NS	3.7	7.90	0.29	5.9	0.13

Effect of bio-fertilizer treatment on the production of potato mini-tubers of Kufri Himalini under polyhouse conditions: With the objective of increasing the rate of multiplication and size of progeny tubers during the multiplication of basic seed potato materials under protected conditions, an experiment was conducted to evaluate a commercially available bio-fertilizer from CSK HPKV-Palampur, HP. The different seed sources of basic seeds of potato variety Kufri Himalini viz. T1 (in vitro plantlets), T2 (aeroponic tubers), T3&T4 (<3g tubers from last year's multiplication of aeroponic tubers during Season 1 (Kharif), and Season 2 (Autumn) respectively); were treated with bio-fertilizer before planting. The results revealed that the treatment with bio-fertilizer didn't prove effective in improving the establishment as well as height of plants. However, the establishment as well as plant height was found to vary significantly among the different seed sources.

Effect of different pH levels on *in vitro* plantlet growth behavior of potato: Effect of pH levels on growth of *in vitro* plantlets for mass multiplication of healthy basic planting material was studied in two potato cv. Kufri Chandramukhi and K. Mohan. Significant interaction between pH levels and genotype for number of nodes was observed suggesting the need for standardizing variety/genotype specific pH levels of the media.

Effect of planting geometry on potato minitubers production in aeroponics: Two inter-rows and two intra-row spacing were compared to assess the effect on multiplication rate in aeroponic system. Highest tuber number/m² was produced with 15x10cm spacing, followed by 15 x 15 cm in spring-summer crop under Shimla conditions. Yield/m² was not affected significantly with the planting density.

Project-2: Augmenting production of minitubers in aeroponics and breeder seed in plains two crops in aeroponics under Jalandhar conditions: A feeder unit designed for indoor hardening of *in vitro* plants under artificial (LED) lights was tested to take two crops in one season. Process of hardening was standardized in which intensity is varied with the growth of plants. Results revealed that Feeder unit having provision of

variable light intensity, temperature control and three tier hydroponic/aeroponic system can be used for minituber curing/greening, seed tuber chitting and hardening of *in vitro* plants under artificial lights.

Potato canopy management in net house: At Jalandhar, the study on canopy management in net house was repeated in second year with three

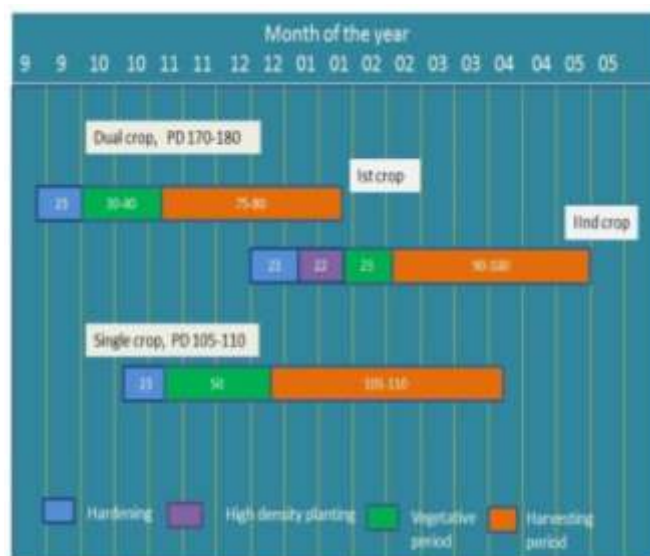


Fig 1. Time scale for single and two crops in aeroponics

varieties (K. Himalini, K. Gaurav & K. Chandramukhi) with three systems (control, single net and double net system). Number of undersized tubers (<3g) were significantly reduced by both treatments over control in all varieties. No effect on total tuber number by different treatments was recorded. In K. Chandramukhi, total tuber weight in double net increased by 26.3% and in single net system by 20.3% over control. In K. Himalini, increase was 23.8% in double net and 18.8% in single net over control. Under-size tubers in K. Chandramukhi reduced by 21.0% in double net over control. Similar was pattern in K. Gaurav and K. Himalini.

Evaluating two potato crop in net house: The experiment for feasibility of two crops in a year in net house was repeated at Jalandhar. Six potato varieties (K. Khyati, K. Surya, K. Chandramukhi, K. Jyoti, K. Badshah and K. Himalini) were compared in dual planting having first (02/10/17) and second (02/01/18) date of planting with single crop (10/10/17). Double crop significantly out yielded

single crop in performance (Fig. 2). On the basis of total tuber number and productivity per unit area, double crop recorded 3.2 times mean tuber number and 1.92 times mean yield.

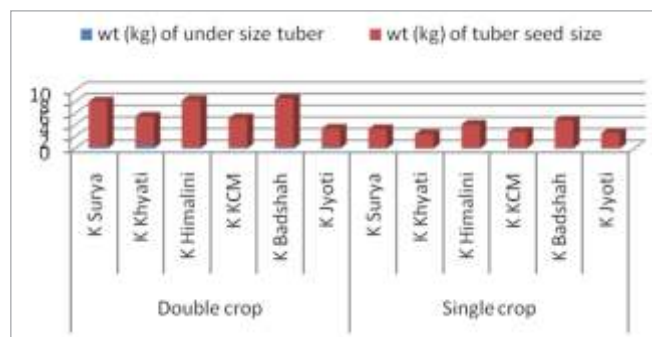


Fig 2. Yield in double and single crop under net house

Performance of potato crop in improved aeroponic system at Modipuram: A new design of commercial scale aeroponic system was fabricated and tested to augment minituber production for second time. Performance of four potato cvs. K. Khyati, K. Mohan, K. Chipsona-1 and K. Chipsona-3 were observed in this aeroponic system. Days taken for first harvest was minimum in K. Khyati (37) whereas maximum in K. Chipsona-3 (58). Maximum (43) and minimum (28) tuber number per plant were obtained in K. Chipsona-1 and in K. Khyati, respectively.

Effect of root zone environment on minituber production in aeroponics: Minituber production in aeroponics is affected by root zone environment of the system. Thus a study was conducted to evaluate the influence of electrical conductivity of the nutrient solution in the aeroponic system. Electrical conductivity of less than 3dS/m (EC 1) throughout the crop period was found to be superior. EC more than 3dS/m (EC 2) resulted in lower survival, shorter crop duration and lesser production of mini tubers per plant (Table 1).

Comparative performance of two different aeroponic systems at Modipuram: Performance of

K. Khyati, K. Mohan, K. Chipsona-1 and K. Chipsona-3 was compared in aeroponic system made of styrofoam sheet (old) and system made of brick and concrete (new). Nutrient solution parameter and spray time were kept same for four varieties in both the systems. Performance of new system was superior over old one. Crop duration of all four varieties was 13-23 days longer in the new system. This resulted in increased number of pickings and hence more number of tuber per plant.

Performance of aeroponic minitubers grown in net house at Modipuram: Crop of aeroponically produced minitubers of ten potato cultivars was raised in net house with standard package of practices to assess their field performance. Germination (>90%) of minitubers in all the cultivars was very good. Tuber production and number was highest (110g; 5.26 tubers/plant) in cv. K. Chipsona-1 followed by K. Mohan (89.0g) and K. Chipsona-3 (82.0g). Lowest tuber yield (51.0g) was recorded in cv. K. Chipsona-4, while lowest tuber number (4.30) was observed in cv. K. Khyati.

Response of seed physiological age to water deficit regime at Modipuram: Physiologically young seed is known to have higher yield potential than the physiologically old seed. Response of physiologically old seed to water deficit regime, however, is not much implicit. Keeping this in view, potato cv. K. Surya (heat tolerant) and K. Bahar (heat susceptible), having physiologically diverse nature were used to test the effect of physiological age on tuber yield under water deficit (25% less watering) in winter season. Mean tuber yield in water stress at 90 days harvest showed higher yield (38.1q/ha) in crop of physiologically old seed as compared to the young seed (33.1q/ha). Yield reduced by 22% in young seed crop and by 10 % in old seed crop over control. These results indicate that physiologically old seed may present better resilience to water deficit condition.

Table 1. Influence of electrical conductivity on performance of potato plants in aeroponics

Variety	Survival (%)		Crop Duration days		Tubers per plant		Tuber weight per plant (g)		Mean tuber weight (g)	
	EC>3	EC<3	EC>3	EC<3	EC>3	EC<3	EC>3	EC<3	EC>3	EC<3
K. Khyati	88.8	98.3	110	121	21.2	39.6	82.1	128.5	3.8	3.2

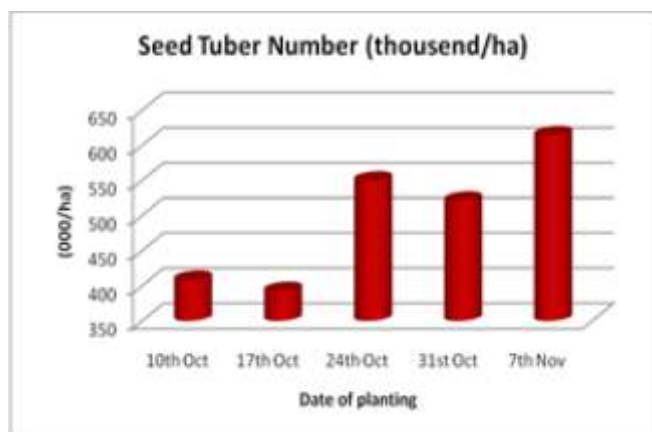


Fig. 3 Tuber number according to DOP (000/ha)

Optimizing planting time for disease free breeder seed production in west central plains: A field experiment was conducted at Gwalior with five dates of planting and three popular varieties. Increasing trend in total tuber number and weight was recorded with increase in date of planting and highest tuber number (614000/ha) and yield (22.4t/ha) was recorded in 7th November planting (Fig.3 & 4). Tuber number (637000/ha) and yield (20.9 t/ha) was highest in cv. K. Sindhuri

Studies on planting geometry and fertilizer for higher production of seed size tubers: A field experiment was conducted at Gwalior with eight treatments combinations of two planting distance (15 and 20 cm), two crop duration (70 and 80 days) and two nitrogen doses (120 and 150 kg/ha) having variety K. Khyati. Higher germination was recorded in 20 cm spacing plot (98%) than 15 cm spacing crop (90%). Highest seed size (306000/ha) and total tuber number (593000/ha), and yield (19.3 & 35.3 t/ha) was recorded with 15 cm x 80 days crop x 150 N Kg/ha treatment.

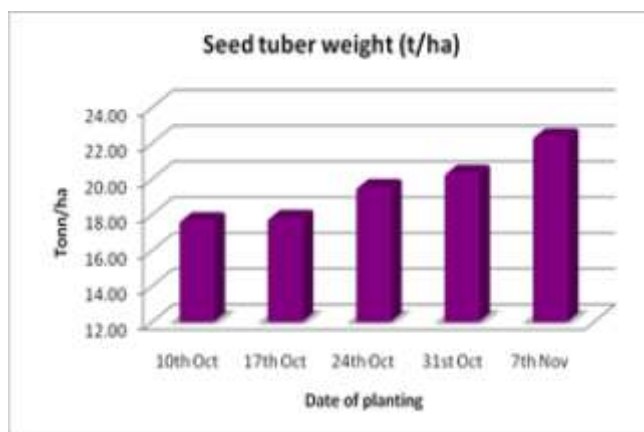


Fig. 4 Tuber weight according to DOP (t/ha)

Effect of soil solarization on aeroponic seed multiplication: At Gwalior, the trial was conducted in net house (G-0) having two mulch (polythene 50 µm thick, paddy straw 5mm thick and control) and three varieties K. Mohan, K. Chipsona-1 and K. Lauvkar. Plastic mulch recorded significantly higher tuber number (2195 thousand/ha) and yield (29.3 t/ha) over paddy straw and control. Among cultivars K. Chipsona-1 recorded non-significantly highest tuber number (2048 thousand/ha) and K. Lauvkar significantly highest yield (30.5 t/ha).

Seed production agronomy for aeroponic minitubers: A study was conducted at Gwalior under net house and open field conditions with three spacing (30 x10, 30 x15 and 45 x10 cm) and four N: P: K fertilizer levels (75:30:50, 120:60:100, 150:60:100 and 180:60:100 kg/ha). In net house, highest tuber number (19,59,000/ha) and yield (36.1 t/ha) were observed with 45 x 10 cm spacing and 180:60:100 nutrition level, while highest tuber number (1837000/ha) and yield (21.6 t/ha) was recorded with 45x10 cm spacing and 150:60:100 fertilizer level under open field conditions (Fig. 5 &6).

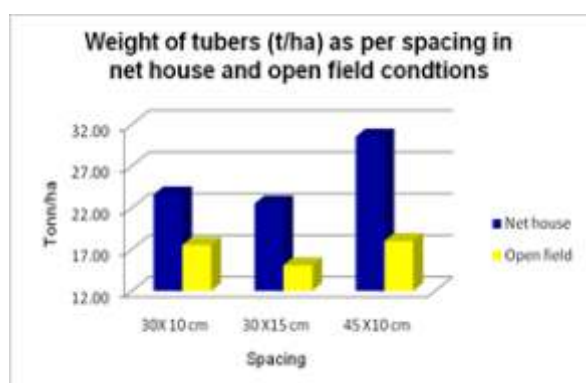


Fig.5 Spacing effect on tuber yield

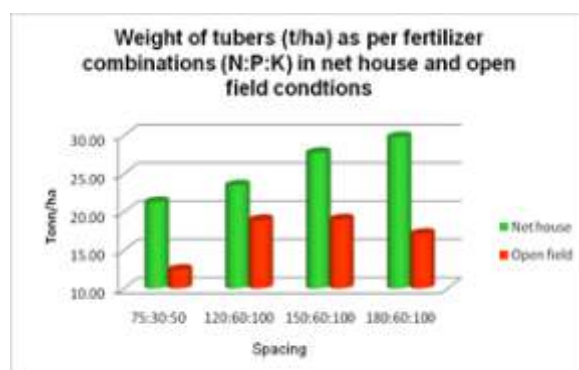


Fig. 6 Effect of nutrition on tuber yield

Division of Social Science

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

Assessment of varietal adoption pattern and cost of cultivation in Madhya Pradesh

A survey for assessing varietal adoption pattern and cost of cultivation of potato in Madhya Pradesh was conducted by interviewing 100 farmers of Indore, Ujjain and Dewas districts of Madhya Pradesh. It is evident from Figure 1 that Kufri Jyoti was the most popular variety in Indore

(49 %) and Dewas (48 %) districts. Other varieties adopted by farmers in these districts were Kufri Lauvkar, Atlantic and Kufri Chipsona-3. But, in case of Ujjain, processing varieties developed by CPRI viz., Kufri Chipsona-1 (51 %) and Chipsona-3 (41 %) were the most popular varieties among farmers.

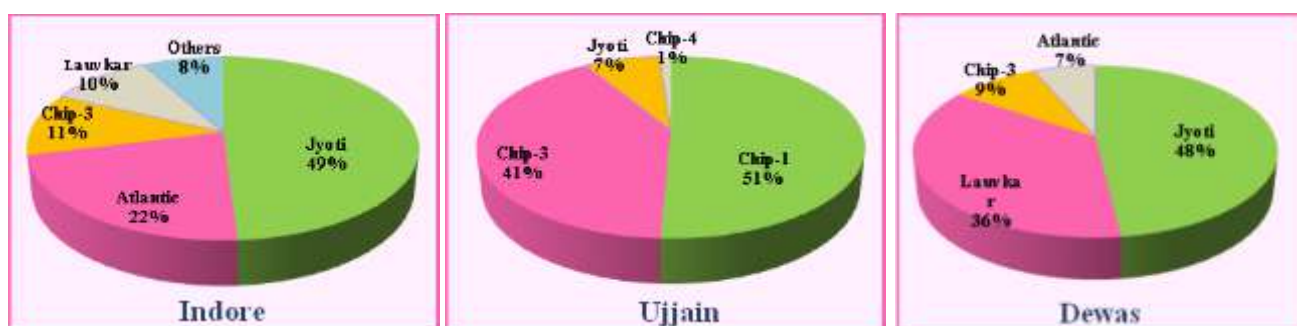


Fig.1. Proportion of different potato varieties in selected districts of Madhya Pradesh

Cost of Cultivation of potato was also worked out for these three districts of MP. On an average, cost of potato cultivation was found to be Rs. 1,08,085/- per ha. The highest cost contribution was that of seed (39 %) followed by fertilizers (22 %), machine

labor (13 %) and human labor (12 %). The highest cost of cultivation was in the district of Ujjain was due to higher seed cost and fertilizer cost. Overall, the B:C ratio was found to be only 1:13 during 2016-17.

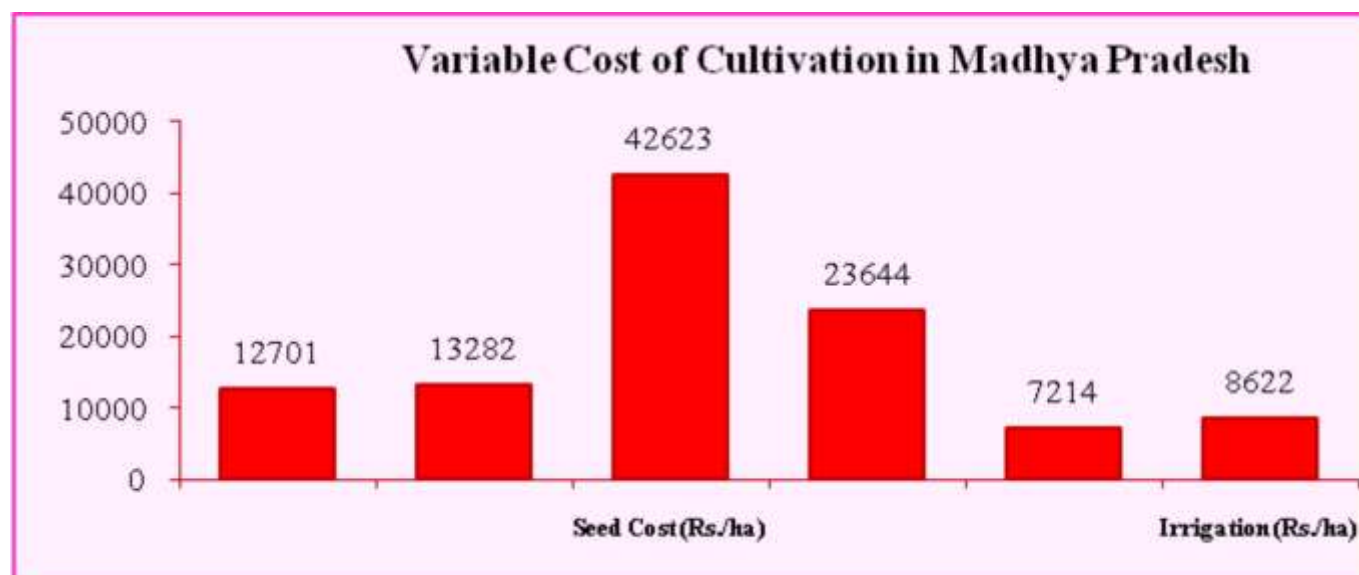


Fig. 2. Cost components in potato cultivation in Madhya Pradesh

Adoption level of potato technologies and adoption constraints in Uttar Pradesh

A survey from 85 farmers of Bulandshahr and Meerut districts of UP (Table 1) found that majority of farmers (76.47 %) have medium level of adoption, which was followed by low (12.94 %) and high (10.59 %). Furthermore, the Table also showed that the technologies like use of improved varieties, maintenance of plant to plant and row to row

spacing, optimum seed rate, pre-sprouting of tubers, irrigation interval and late blight management were followed by majority of farmers. However, there is very poor adoption of technologies like use of certified seeds and application of recommended dose of Nitrogen, Phosphorus and Potash fertilizers.

The varietal adoption pattern (Fig.3) in selected districts showed that varieties developed by the

Table 1: Extent of adoption of potato production technologies in selected districts

Improved production technologies	Bulandshahr	Meerut	Overall
Use of optimum seed rate	58.1	50.0	54.1
Use of improved varieties	90.7	97.6	94.1
Use of certified seeds	6.7	37.8	22.2
Pre-sprouting of seed tubers	79.1	73.8	76.5
Maintenance of plant to plant distance	88.4	57.1	72.9
Maintenance of row to row distance	90.7	90.5	90.6
First dose of Nitrogen fertilizer	30.2	14.3	22.4
Phosphatic fertilizers dose	18.6	26.2	22.4
Potash fertilizers dose	46.5	31.0	38.8
Second dose of Nitrogen fertilizers	30.2	26.2	28.2
Irrigation interval	55.8	81.0	68.2
Late blight management	67.4	81.0	74.1
Level of adoption (Percentage of respondents) : Low =12.94 %, Medium= 76.47 and High=10.59			

institute like Kufri Bahar (38 %), Kufri Pukhraj (21 %) and Kufri Khyati (12 %), Kufri Chipsona-1 (9 %) and Kufri Chipsona-1 (5 %) were the leading potato varieties in the study area. Local/traditional varieties like S-4, 302, S-1 were still adopted by some farmers. The major constraints as reported by

farmers in the study areas were lack of credit & subsidy, labor, production inputs and training on scientific potato production technology, heavy incidence of diseases/insects, highly fluctuating weather condition, low price of produce and price fluctuation every year.

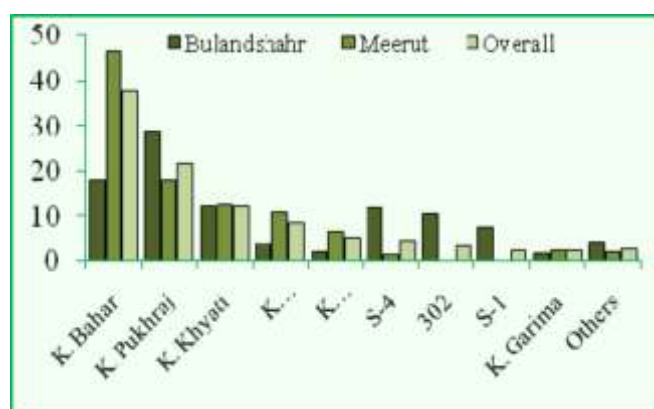


Fig.3. Varietal adoption pattern in UP

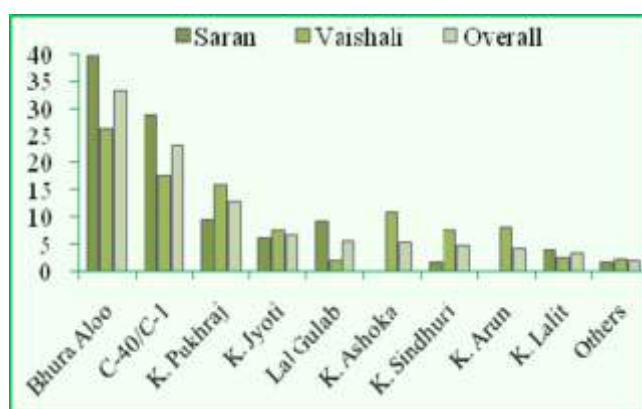


Fig.4. Varietal adoption pattern in Bihar

Assessment of varietal adoption pattern and reasons for low yield in Bihar

A survey for assessing varietal adoption pattern in Bihar was conducted from 90 farmers, 45 each from Vaishali and Saran districts. It is evident from Figure 4 that local varieties like *Bhura aloo* and C-1/C-40 were the major varieties covered more than 55 % of the total potato area. Other popular varieties were Kufri Pukhraj, Kufri Jyoti, *Lal gulab*, etc. Adoption of local/traditional varieties was the major reason for low yield of potato in the study areas. Moreover, farm saved seeds was used by majority of farmers for long time. The second major reason observed was late planting, as fields were not ready for timely planting due to water logging in some areas.

Estimation of consumers' preferences for potatoes

A study was conducted to investigate consumers' preferences by interviewing 60, 50 and 55 potato consumers in Jalandhar (Punjab), Meerut (UP) and Shimla (Himachal Pradesh), respectively. Based on weighted mean score (WMS), the study revealed that overall, taste (WMS=4.67) stood as the most important attribute for consumers' potato purchase decision (Figure 5). Tuber size and shelf life were equally ranked as the second important attribute (WMS=4.41) which was subsequently followed by cooking time (4.37) and skin color (4.3). The ranks of attributes in order of importance were: taste > shelf life = tuber size > cooking time > skin color > shape > flesh color > skin smoothness > texture > aroma > eye's depth.

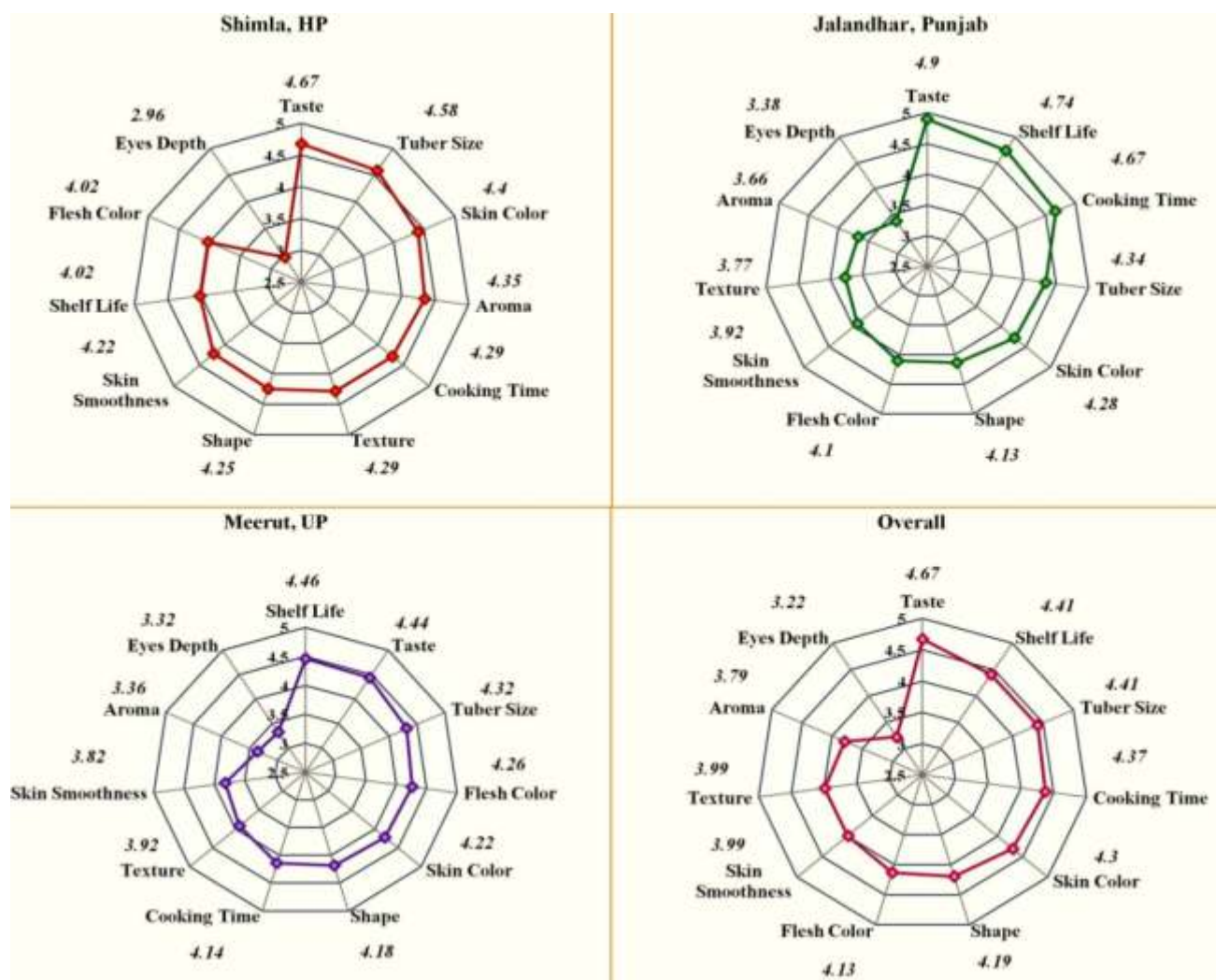


Fig.5. Consumers' preferences for potato attributes

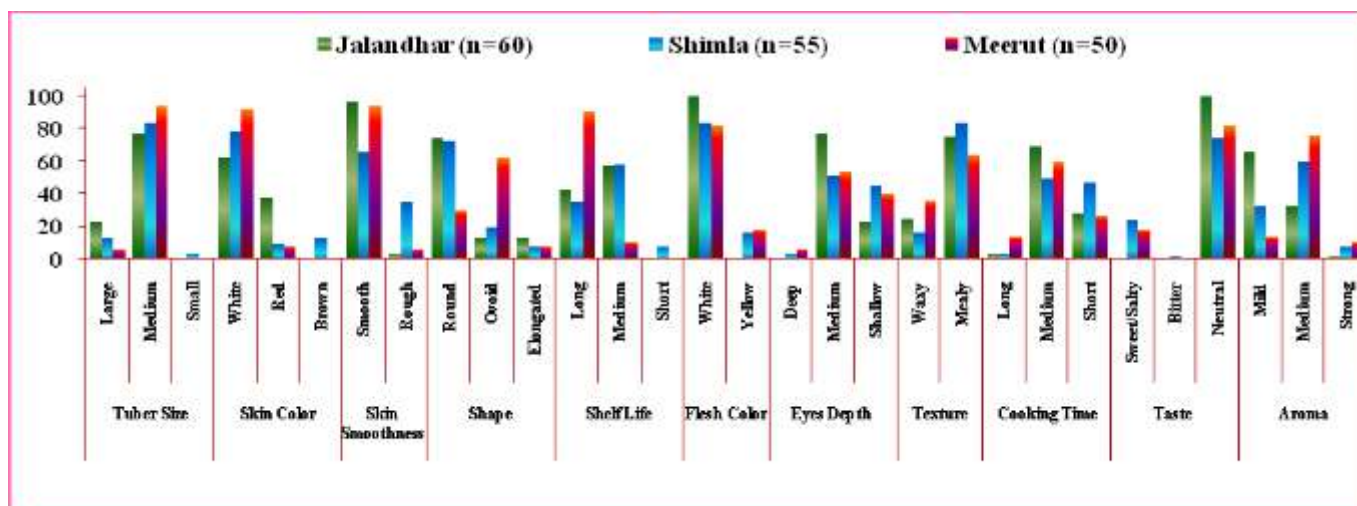


Fig.6. Preferences for different levels of potato attributes

Moreover, consumers' preferences for different levels of potato attributes were also studied. The results (Fig. 6) revealed that in all study areas, consumers preferred potatoes with medium size, red skin color, smooth skin, white flesh color, medium eye's depth, mealy texture, medium cooking time, neutral taste and medium aroma. While consumers of Jalandhar and Shimla preferred round shape potatoes with medium shelf life, Meerut's consumers preferred oval shape potatoes with long shelf life.



Fig. 7. Survey of farmers in Ranchi

Analysis of productivity constraints analysis in Jharkhand

A survey for identifying productivity constraints was conducted by interviewing 85 potato growers

from Nagri, Angara, Bero and Kanke blocks of Ranchi district. Farmers were asked to rank three major productivity constraints in potato cultivation. Based on Weighted Mean Score (WMS), it was identified that the major productivity constraints as perceived by farmers were lack of seeds of HYV's, irrigation water, labor, disease infection (especially late blight) and poor quality seeds (Fig.8).

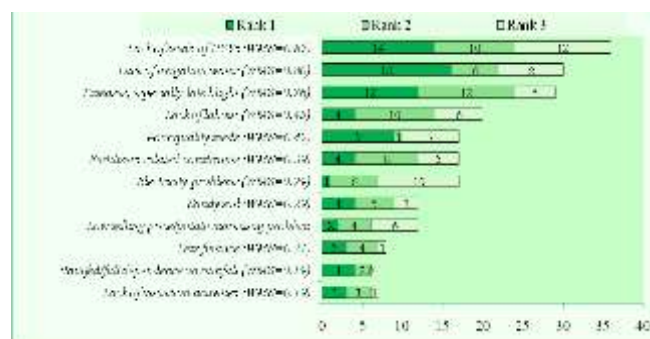


Fig. 8. Potato productivity constraints in Ranchi, Jharkhand

Assessment of improved potato varieties through FLDs

Frontline demonstrations at farmers' fields on new variety Kufri Mohan in Uttar Pradesh : In order to popularize the newly released potato variety K. Mohan, a total of 6 field demonstrations were conducted at 6 districts of Uttar Pradesh, namely, Meerut, Bulandshahr, Saharanpur, Agra, Kanpur Nagar and Baghpat district in an area of 0.02 ha. The agronomic practices were

supervised at farmers' fields by scientists and technical staffs at regular intervals. Yield of K. Mohan was compared with the existing varieties, *viz.*, K. Bahar, K. Anand and K. Pushkar. Results revealed that in every selected location, K. Mohan gave higher yield over the existing varieties. On an average, tuber yield of K. Mohan was found to be 460.42 q/ha, which is about 24.25 % higher than the average yield of the existing varieties (348.75). The results of FLDs conducted in Maharajganj revealed that the yields of K. Sindhuri and K. Pukhraj were respectively 37.49 % and 51.21 % higher over the existing local varieties.

In Himachal Pradesh, a total of 20 demonstrations, 10 each of potato varieties, cv. K. Himalini and K. Girdhari were laid out in different villages of Shimla district to assess their performance at farmers' fields. The average yield of demonstrated variety K. Himalini (273.4 q/ha) was about 28.85 percent higher than the control variety Kufri Jyoti (212.91 t/ha). Similarly, Late blight resistant variety K. Girdhari was also demonstrated to farmers using all the recommended package of practices in

demonstration plots. The incidence of late blight disease was negligible (0.5-1 %) in K. Girdhari as compared to Kufri Jyoti (10-20. %). As a result, K. Girdhari (278.86 q/ha) gave higher yield i.e., about 30.97 percent higher yield as compared to K. Jyoti. In addition, 25 more FLDs were laid out in East Champaran and Patna districts of Bihar, 10 FLDs in Varanasi district of UP, 7 FLDs in Meghalaya and 15 FLDs in Tamil Nadu for demonstrating the superiority of new/improved varieties over the existing/local varieties.



Fig.9. Recording observation of FLDs in Shimla

Table 2: Details of FLDs conducted at farmers fields (2017-18)

	Districts	Demonstrations		Control		% increased yield over local check
		Variety	Yield (q/ha)	Variety	Yield (q/ha)	
Uttar Pradesh	Meerut	K. Mohan (1)	550.00	K. Bahar (1)	400.00	27.3
	Baghpat	K. Mohan (1)	375.00	K. Bahar (1)	287.50	30.43
	Agra	K. Mohan (1)	375.00	K. Bahar (1)	312.50	20.19
	Bulandsher	K. Mohan (1)	350.00	K. Bahar (1)	300.00	14.29
	Saharanpur	K. Mohan (1)	525.00	K. Anand (1)	392.50	33.76
	Kanpur	K. Mohan (1)	587.50	K. Puskar (1)	400.00	46.88
	Overall	K. Mohan (6)	460.42	Control (6)	348.75	24.25
	Maharajganj	K. Sindhuri(5)	251.16	Local (10)	182.67	37.49
		K. Pukhraj (5)	276.22			51.21
HP	Shimla	K. Himalini (10)	273.43	K. Jyoti (10)	212.91	28.85
		K. Girdhari (10)	278.86			30.97

Transfer of Technology

As per its mandate, the Division of Social sciences organized a large number of technology transfer activities related to potato production. These extension activities include organization of training programmes for farmers, scientists and extension functionaries, laying out FLDs in farmers' fields, organization and participation in exhibitions, live phone in programmes on All India Radio as well as Doordarshan for farmers and other stakeholders. These kind of activities helped in creating awareness and improving knowledge of farmers as well as other stakeholders viz. scientists, teachers, processors, entrepreneurs in the field of potato Research & Development. Organization of innovative extension programmes

like Summer School, Model Training Course, *Aloo diwas*, etc. were the major highlights of Technology Transfer activities during the year 2017-18.

A. Organization of trainings: A large number of national and international training programmes for scientists, farmers, extension functionaries and other stakeholders were organized at CPRI, Shimla. Nearly all aspects of potato cultivation viz. seed preparation, planting, fertilizer application, intercultural operations, water management, disease/pest management, harvesting, processing, storage and marketing were covered during these trainings programmes. The details of trainings conducted during 2017-18 are given in the Table 1.



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

Sl. No.	Title of the training course	Date and duration	No. of Trainees
1.	Summer School training programme on "Recent advances in crop improvement, production and post-harvest technology in potato research"	July 18-August 7, 2017 (21 days)	25
2.	International training on "ELISA Test on Potato Seed"	August 14-28, 2017 (15 days)	3
3.	Scientific potato cultivation	September 7-8, 2017 (2 days)	15
4.	<i>Aloo ki unnat kheti</i>	November 14-16, 2017 (3 days)	15
5.	<i>Beej aaloo utpadan evam paudh sanrakshan</i>	December 5-7, 2017 (3 days)	7

Sl. No.	Title of the training course	Date and duration	No. of Trainees
6.	<i>Aloo ki unnat kheti</i>	March, 15-17, 2018 (3 days)	16
7.	National Training on Procurement & PFMS for ICAR Officers	September 11 -15, 2017 (5 days)	85
8.	Workshop on Office Procedures and Etiquette	February 26-27, 2018 (2 days)	35
9.	International training on recent advances in potato breeding and quality seed	July 31-August 4, 2017 (5 days)	6

B. Organization of National Potato Day: ICAR-CPRI organized one day “National Potato Day” on February 15, 2018 at ICAR-CPRI Regional Station, Modipuram, Meerut. A number of programme like potato recipe competition, *kisan goshti*, *krishi pradarshani*, quiz, prize distribution

ceremony etc. were organized. More than 550 visitors which include farmers from various states (Uttar Pradesh, Punjab, Haryana and Madhya Pradesh), VIPs, students, researchers, entrepreneurs, SHG's members, etc participated in this event.



C. Kisan Prashn Manch programme was organized on 18th May, 2017 under Mera Gaon, Mera Gaurav, at Cheog panchayat. In this

programme, more than 50 farmers and general public participated.



D. A Chat Show was organized at CPRS, Kufri on “Potato Cultivation: Problems & Remedies” in collaboration with Doordarshan Shimla. It was broadcasted by Shimla Doordarshan on 4th July, 2017 and DD Kisan on 13th July, 2017.

E. Exhibition during 69th Foundation Day: ICAR-CPRI Shimla organized an exhibition during 69th Foundation Day of the Institute on 28th August,

2017 at CPRI Shimla. Many progressive farmers also exhibited their produce. About 100 farmers and school children visited the exhibition stall.

F. Live phone in programme on Shimla Doordarshan: Expert scientists from different discipline of CPRI Shimla participated in live phone in programmes. A list of these programmes is given in Table 2.

Table 2: Live phone in programme on Doordarshan, Shimla during 2017-18

Date	Topic	Name of Experts
April, 2017	Varietal requirement and planting of potato in higher hills of HP	Dr. Rajesh Kumar Singh Dr. Ashwani Kumar Sharma
May, 2017	Intercultural operations of potato in HP	Dr. V.K Dua Dr. Jagdev Sharma
Jun, 2017	Storage and marketing of potato in HP	Dr. Brajesh Singh Dr. N.K Pandey
July, 2017	Diseases and pests of potato and their management	Dr. Vinay Sagar Dr. Ravinder Kumar
Aug, 2017	Intercultural operations in potato cultivation in HP	Dr. Jagdev Sharma Dr. Tanuja Buckseth
Sep, 2017	Harvesting, safe storage and marketing of potato	Dr. Pinky Raigond Dr. NK Pandey
Jan, 2018	Potato varieties, planting and nutrient management in higher hills of HP.	Dr. Rajesh Kumar Singh Dr. Vinod Kumar
Feb, 2018	Potato cultivation, harvesting and storage in lower hills of HP	Dr. Brajesh Singh Dr. Jagdev Sharma
Mar, 2018	Potato disease and pest management in mid hills of HP	Dr. Ravinder Kumar Dr. Aarti Bairwa

G. Participation in agricultural fair/exhibitions:

ICAR-CPRI, Shimla participated in many exhibitions organized at different locations to showcase varieties and production technologies of potato. List of these exhibitions is given below.

- Kisan Goshti cum Exhibition at Shyamlaighat, Ghanahti on May 11, 2017.
- Kisan Mela at ICAR-DMR Solan on August 19, 2017.
- Mushroom mela ICAR-DMR Solan on September 9, 2017.
- 2nd Himachal Pradesh Science Congress during November 20- 21, 2017.
- Kisan mela at Dalarghat on January 16, 2018.



Activities of Agriculture Technology Information Centre (ATIC)

Sale and distribution of CPRI technical and extension bulletins: A total of 579 technical and extension bulletins were sold through ATIC. Moreover, nearly 2000 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 5 CDs of PPM (Potato Pest Manager) were also sold through ATIC. Altogether revenue generated through sale of publications and CDs/Expert system was of value Rs. 27370/-.

Dissemination of knowledge to visitors: A total of 2359 persons visited the institute during 2017-18. The visitors included 1710 School B.Sc./M.Sc./Ph.D students from different states, 120 scientists/professors/teachers, 360 farmers and 169 extension workers/agriculture or horticulture officers. They visited various laboratories, institute museum as well as farmer's museum in which the technologies were displayed using posters, panels, live samples and models etc.

Extension activities at CPRI Campus, Modipuram

A. Training Programmes:

- A Model training course on “Quality potato seed production, certification and post-harvest management” was organized at Modipuram during 12-19 December, 2017 in which 21 officers of Agriculture/ Horticulture departments from various states participated.
- Five days training programme on “Beej Aloo Utpadan Evam Vipdan” was organized during 18-22 October, 2017 for 35 agriculture development /extension officers and progressive farmers.



- Three one-day training programmes on “Improved techniques of table and potato seed production and animal health” was organized for 180 farmers from various adopted village under *Mera Gaon Mera Gaurav*.

B. Celebration of important days:

- **Krishi Siksha Diwas** was organized on 3rd December, 2017 at this Station for popularization of Agricultural Education among the students. In this event 133 farmers, students, faculty members of various local schools/colleges/villages participated.
- **World soil Day** was organized on 5th December, 2017. A total 52 Soil Health Cards were distributed to the farmers of villages adopted under “Mera Gaon Mera Gaurav”.
- **World Environment Day** was organized on 05th June, 2018 at CPRI Campus, Modipuram. A Seminar on “Environment Awareness” and drive on plantation were conducted on this occasion.

C. One day Krishi Goshthi and Live broadcasting of Hon'ble Prime Minister on the



occasion of Krishi Unnati Mela -2018 at ICAR-IARI, New Delhi a Krishi Gosthi was organized on 17th March, 2018. More than 400 farmers participated in this event.

D. Participation in Kisan Mela, Krishi Pardarshini and Exhibitions: CPRI Campus, Modipuram participated in the following exhibitions to showcase potato technologies developed by the institute.

- All India Farmers' Fair and Agro-Industrial Exhibition at SVBPUAT, Meerut during October 8-10, 2017. The CPRI stall was awarded first prize in ICAR group.
- Krishi Unnati Mela-2017 at Pt. Deen Dayal Upadhaya Dham Farah, Mathura during September 26-29, 2017.
- World Food India 2017 at India gate, New Delhi during November 3-5, 2017.
- *Rabi kisan mela* at ICAR- CSSRI, Karnal on March 1, 2018.
- Krishi Unnati Mela-2017 at ICAR - IARI, New Delhi during March 16-18, 2018.

E. Exposure visit of potato farmers in *Kisan Unnati Mela-2017* at ICAR - Indian Agricultural Research Institute, Pusa New Delhi during March 16-18, 2018.

F. FLDs and Field Day – A Total of 6 FLDs were conducted on new variety Kufri Mohan at farmers' fields in Meerut, Baghpat, Saharanpur, Bulandsher and Agra districts of U.P. A field day was organized on December 12, 2017 at farmer field at village Lawar in which about 60 farmers participated.

G. Visitors and phone attended: Total 500 farmers and 421 students from various states visited CPRI-RS, Modipuram to know the potato farming and post-harvest activities at the campus. A total number of 250 queries of potato growers and stakeholders from various districts of U.P., M.P., Delhi, Rajasthan, Punjab, Uttarakhand, Maharashtra and Haryana states was answered through phone at Kisan Call Center of the station.



Extension activities at CPRS, Patna

A. Training Programme

• One day training cum exhibition programme at Piprakothi on October 21, 2018 at KVK Piprakothi (East Champaran).

• One day training programme on scientific potato cultivation on January 24, 2018 in association with KVK Maharajganj (U.P.).

• 11 days training programme for JEEVIKA women farmers during January 29 to February 8, 2018 at CPRS, Patna.

• 10 days training programme for JEEVIKA women farmers' during February 02 to 22, 2018 at CPRS, Patna.

• 4 days workshop cum training on "Processing and Value Addition" during April 10-13, 2017.

• One day training for ATM/BTM & farmers' of Bihar on February 27, 2018 at CPRS, Patna.

B. Participation in Kisan Mela, Krishi Pardarshini and Exhibitions: CPRI RS Patna participated in the following exhibitions to showcase potato technologies developed by the institute.

- Kisan Mela at Zila School, Motihari, East Champaran during April 15-19, 2017.
- Exhibition at Deep Narayan Cooperative Society, Patna on September 22-23, 2017.
- Exhibition at Dr. R.P.C.A.U, Pusa, Samastipur during December 3-5, 2017.

- Agri-Expo 2018 during January 11-13, 2018 at ICAR-RCER, Patna.
- Exhibition at Deen Dayal Hast Kala Sankul, Varanasi on 22-25 February, 2018.
- ICAR-RCER Patna's Foundation Day on February 22, 2018.
- North Zone Regional Farmers Fair at Trade Facilitation Centre, Varanasi on February 23-25, 2018.
- Regional *Kisan Mela* 2018 at BAU, Sabour on February 24-26, 2018.
- International Agri Tech Bihar from March 9-11, 2018 at Gandhi Maidan, Patna.
- Bihar Diwas-2018 from March 22-24, 2018 at Gandhi Maidan

Extension activities at CPRS, Jalandhar

A. Training Course

- Training on "Fabrication of Aeroponics" from April 5 to 6, 2017 for 4 participants.
- One day Awareness Programme on CPRI Technologies on September 26, 2017 for 65 stakeholders.
- Three days training programme on "Basics of Potato Processing and Scope of setting up of Business Unit" from January 4 to 6, 2018 for 10 participants.
- Workshop of CPRI-Aeroponic license holders on September 14, 2017 for managers and technical staff of five companies participated.



B. World Soil Day was organized on December 5, 2017. About 50 farmers and students participated.

Extension activities at CPRS, Shillong

A. Training: A three days training on "Improved Technology for Potato Cultivation" was organized at CPRS, Shillong from July, 4 to 6, 2017 for 30 farmers from West Siang district, Arunachal Pradesh.

B. Kisan Melas/Exhibition: Participated and put up stall in Kisan Mela at ATMA, East Khasi Hills district, Upper Shillong on January 17, 2018.

C. Demonstrations: 7 FLDs for evaluation of potato varieties K. Himalini and K. Girdhari were laid out in 5 villages of East Khasi Hills (6) and East Jaintia Hills (1) districts of Meghalaya.

Visitors: A total of 320 visitors visited the station during the period under report, which includes students (B.Sc./M.Sc./Ph.D), farmers, state agriculture/horticulture officers and foreign visitors.



Extension activities at CPRS, Ooty

A. Participation in Kisan Mela, Krishi Pardarshini and Exhibitions:

- Flower Show at Botanical Garden during May 18, 2017.
- International Symposium on Horticulture at ICAR-IIHR, Bengaluru, Karnataka during September 5-8, 2017.
- Exhibition at TCTCASM-2017 at ICAR-CTCRI, Thiruvananthapuram, Kerala during October 27-28, 2017.
- Exhibition at Radio Astronomy Centre, TIFR, Muthurai, Ooty on February 20, 2018.

B. Mera Gaon Mera Gaurav: Three villages viz., Kallakorai, Nedugula and Kallati were adopted under “Mera Gaon Mera Gaurav” and all the technical inputs related to potato production have been given during crop season.

C. FLDs Conducted: 15 FLDs were conducted in 3 places viz., Belgaum (Karnataka), Munnar (Kerala) and Kodaikanal (Tamil Nadu) for demonstrating the superiority of 4 varieties, cv. Kufri Jyoti, Kufri Himalini, Kufri Giridhari and Kufri Surya over local varieties.

Extension activities at CPRS, Kufri

Visitors attended: More than 1350 number of visitor visited the station in connection with the study tours of students, exposure visits of farmers and officials from the Agri./Hort. departments.

Extension activities at CPRS, Gwalior

Visitors attended: A total 1008 farmers and extension officers from various parts of Madhya Pradesh visited the station and were apprised about scientific methods of potato cultivation and post-harvest activities undertaken at the centre.



Kufri Ganga

Library and Documentation Services

Introduction: In accordance of one of the CPRI mandate *"To act as national repository of scientific information relevant to potato"* CPRI Library and Documentation Services unit was established in 1956 with a modest collection of 256 documents. Presently this library stacked more than 67 thousands documents and has attained the position of most sought-after library on potato R & D in India. Since its inception this library has acted as repository and 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 93 documents were purchased, procured and added to library resources. The total collection at Shimla stand at 39743 documents comprised of 16260 books, 15780 back volume of journals, 2711 serials, 2246 annual reports, 583 theses, 251 standards, 51 maps/atlas, 1663 reprints and 198 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 27575 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

Eleven serials title i.e. advances, annual reviews, reference annuals, yearbooks and statistical data

Table-1: Library Collection of CPRIC & CPRS

Regional Stations		Books	Back vols. of Journals	Other Documents (AR/Rpr/Bu ll)	Total	Current Journals subscribed (Indian)
1	CPRIC, Modipuram	4614	5888	2550	13052	10
2	CPRS, Jalandhar	3286	1591	446	5323	4
3	CPRS, Patna	2073	1280	-	3353	9
4	CPRS, Gwalior*	1150	4	71	1225	-
5	CPRS, Ooty*	1656	580	554	2790	10
6	CPRS, Shillong*	1521	-	167	1688	-
7	CPRS, Kufri	144	-	-	144	
	TOTAL	14444	9343	3788	27575	33

publications etc. were purchased. A total of 134 current journals comprising of 27 foreign and 107 Indian have been subscribed at Shimla. Out of which 9 foreign and 93 Indian journals were subscribed on payment basis and rest 32 on exchange or gratis. In all 971 issues of such journals were received, marked and kept in library for use. Besides, 24 titles of different journals were subscribed at CPRS libraries. 67 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, 9 institutes subscribed

foreign journals and more than 3900+ journals from 913 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 websites were visited and information and data were downloaded therefrom for scientists' use.

Readers and Reference Service

A total of 832 documents were circulated (borrowed and returned) for home studies and 6745 readers consulted 9998 documents within the library. Besides, 15 outside scientists and research scholars of various research organizations consulted the library resources. 1 new members were enrolled and 8 old members withdrew their library membership due to their transfer or retirement. At present 132 readers are active members of library including RAs/SRAs. Library received 9045 reference queries from the users of the library and responded to them satisfactorily. Besides, 306 job requests were received for 1,59,951 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

971 issues of journals (681 issues of national and 290 issues of international journals) were scanned for potato literature and 330 potato articles were

found and recorded. Approximately, 93 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 1,17,510 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. 94,507.00 which includes the amount charged on account of rendering CDROM searching & photocopying (Rs. 3,180.00), IGNOU computer practical (Rs. 25,650.00) and library discount (Rs.65,677.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 9,34,145.00 was spent on purchase of library resources like books (Rs.2,71,990.00), and subscription of journals (Rs.6,62,185.00) at HQ library Shimla and Rs 65,855.00 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 18th Aug.-7th Sept., 2017 for 7 MLIS and 21 BLIS students of IGNOU Study Center, Shimla.

Publications

Research articles published in journals

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 101. आशा ठाकुर, ब्रजेश सिंह, पिकी रायगोंड (2017) आलू एक-गुण अनेक। आलू मंजरी, प्र: सं: 35-37।
 102. देवेन्द्र कुमार, बन्दना, एवं संजय रावल 2017 . खादय तथा बीज आलू का भंडारण। स्मारिका। बदलते जलवायु परिवेश में कृषि के नए आयाम। बीज दिवस एवं रबी कार्यशाला। 10 अक्टूबर, 2017। भा. कृ. अ. प.- भारतीय गेहूँ एवं जौ अनुसंधान संस्थान करनाल (हरियाणा) 132 001, पृष्ठ संख्या 64-65।
 103. [http://www.icar.org.in/content/success-story/ICAR-CPRI, Shimla \(2017-18\). Hi-tech seed production system revolutionising the potato seed industry.](http://www.icar.org.in/content/success-story/ICAR-CPRI, Shimla (2017-18). Hi-tech seed production system revolutionising the potato seed industry.)
- In addition, Abstracts published in seminar/ symposia proceedings etc. and sequences submitted to the NCBI are about 130.

Institute Activities

First ever National Potato Day

ICAR-Central Potato Research Institute organized a one day-long “National Potato Day” on February 15, 2018 at ICAR-CPRI Regional Station, Modipuram, Meerut (UP). The purpose of this event was to disseminate awareness for increasing consumption and popularizing nutritional values of potatoes. "Potato Recipe Competition, Kisan Goshthi, Krishi Pradarshani and Prize distribution ceremony were the main highlights of the event. Shri Rajendra Aggarwal, MP, Meerut-Hapur Lok Sabha was the Chief Guest in the inaugural session. The Chief Guest praised the constant efforts and contribution of the Central Potato Research Institute in development of potato technology resulting into phenomenal increase in its production. The "Potato Recipe Competition" was one of the main attraction on the National Potato Day, in which about 100 participants from 17 various institutions presented various dishes made from potato in five categories. About 26 various public and private organizations displayed their



latest technology and information in the exhibition stalls.

National Seminar on Sustainable Potato Production

A one day seminar on “Sustainable Potato Production – issues and strategies” was held at BCKV, Kalyani (WB) on September 15, 2017. The inaugural function was presided over by Hon'ble Vice Chancellor, Dr. DD Patra. Sh. Pradip Majumdar, Advisor (Agriculture) to Chief Minister of West Bengal was the Chief Guest and Dr. Tapas Mandal, Hon'ble MP Lok Sabha, Prof Srikumar Pal, Director Research, BCKV, Kalyani, Dr. T. Janakiram, ADG (Horticultural Science-II) were the Guests of Honor. The seminar had focus on identifying suitable high yielding ware and processing varieties for different potato growing zones, innovative crop production technologies for doubling farmers' income, adaptation strategies to climate change and tropicalisation of potato, enhancing total factor



productivity, delineating areas with common agro-ecologies and varieties suitable for them, SWOT analysis of potential technologies, approaches, challenges and technologies to produce healthy potatoes and to reduce post-harvest losses.

Summer School at ICAR-CPRI, Shimla

ICAR-CPRI Shimla organized a 21 days Summer School training programme on “Recent advances in crop improvement, production and post-harvest technology in potato research” during 18th July to 7th August, 2017. A total of 25 trainees which include scientists and teaching staffs from SAUs and ICAR



attended the programme. A number of training methodologies like lecture cum discussion, practical sessions, skill demonstration, field visits and video film show, etc were implemented during the summer school. Majority of the trainees were highly satisfied with the training programme.

Model Training Course organized at CPRI RS, Modipuram

A Model Training Course on “Quality potato seed production, certification and post-harvest management” was organised at Modipuram during 12-19 December, 2017. A total of 21 officers of Agriculture / Horticulture departments of 10 states viz. Uttar Pradesh, Haryana, Uttarakhand, Punjab, Madhya Pradesh, Chhattisgarh, Telengana, Karnataka, Odisha and West Bengal participated in the training.



New India Manthan: Sankalp se Siddhi programme and 69th Foundation day

ICAR- CPRI Shimla celebrated “New India Manthan: Sankalp se Siddhi programme” and 69th Foundation day on 28th August, 2017. The programme was



inaugurated by the chief guest, Shri Virender Kashyap, Honorable Member of Parliament from Shimla constituency in the presence of Shri Rakesh Kumar Sharma, Deputy Mayor, Municipal Corporation, Shimla, Dr. H.C. Sharma, Vice Chancellor, Dr. Y.S. Parmar University of Horticulture and Forestry and other dignitaries. A pledge for New India by doubling farmer's income was taken by all participants. During the programme, progressive farmers were honored by the chief guest by presenting them awards. The CPRI Best Worker Awards were also given to the staffs in scientific, technical, administrative and supporting categories during the event.

Soil Health Day at CPRI RS, Modipuram

This Station celebrated World Soil Health Day on 05 December, 2017. More than 100 farmers from Harsinghpur, Distt-Hapur, Dabthala and Lawar villages of Meerut adopted by this station under “Mera Gaon Mera Gaurav” participated in the event. Hon'ble Shri Rajendra Agrawal, Member of Parliament was the Chief Guest of this function. Pamphlets related to the Soil Health Cards prepared by Ministry of Agriculture and Farmers Welfare,



Govt. of India were distributed among the participating farmers. Chief Guest distributed Soil Health Cards prepared on the basis of soil samples collected from farmer's fields to 52 farmers.

Krishi Shiksha Divas at CPRI RS, Modipuram

"Krishi Shiksha Divas" was organized on 03 December, 2017 at ICAR-CPRI, Regional Station, Modipuram for popularization of Agriculture education among the students. More than 100 students, 14 teachers of seven local higher secondary schools and 12 farmers participated in this occasion. On this day, essay writing competition on "Krishi



Shiksha evam Rojgar" for students of 11 & 12 class students and drawing competition on "Krishi evam Paryavaran" for students of 9 & 10 class was organized. Awards and certificates were distributed to the winner students and all other participants of both the competitions.

Kisan Prashn Manch programme

Kisan Prashn Manch programme under Mera Gaon, Mera Gaurav, a field based programme on recent initiatives of Central Govt. Schemes like 'Mera Gaon Mera Gaurav', 'Swachhata Abhiyan' and 'Beti Padhao Bet Bachao' was organized on 18th May, 2017 by ICAR-CPRI, Shimla at Cheog panchayat in collaboration with DD Kisan Channel of Prasar Bharti. In this programme, around 50 farmers and general public participated and awareness was created among the participants on different schemes by the experts from institute and other Govt. organization. The programme had been broadcasted by the DD Kisan Channel for the benefit of lakhs of farmers.



International Yoga day

The International Yoga day was celebrated on 21st June 2017 at ICAR- Central Potato Research Institute, Shimla in the auditorium. The Aasans, Pranayam and Dhayan of Yoga were demonstrated by Dr. Som Dutt, Senior Scientist of this institute. Dr. S.K Chakrabarti, the director of the institute also followed these practices and while addressing the gathering of around 200 people he emphasized on the role of "Yoga" in achieving the motive of "Health is Wealth" and "Prevention is better than cure" since he expressed that the "Yoga" is unique and a must use tool for everyone, not only in making him or her



healthy but in preventing many diseases too. Oath to make the "Yoga" as a regular practice in their daily routine was also taken by all the participants.

World Environment Day celebrated at CPRI RS, Modipuram

World Environment Day was observed as Environmental Awareness Day on June 05, 2017 at ICAR-Central Potato Research Institute-Regional Center, Modipuram. On this occasion, a seminar on environmental awareness was organized. Dr. Shanti



Swarup, Chairman Meerut Dahlia and Guldaudi Society, Meerut was the chief guests. He highlighted the importance of Environment Day in his address. In his address, Dr. Manoj Kumar, Joint Director of the station called upon present scientific and technical officers and emphasized the need to increase the quantity of organic matter in the soil by utilizing the efficient use of organic residues in agricultural land,



as well as to make meaningful contribution by planting and preserving them in the protection of the environment. Scientists, technical officers / employees took oath to give their meaningful contributions to the world environment protection.

A Chat Show was organized at CPRS, Kufri

A Chat Show was organized at CPRS, Kufri on "Potato Cultivation: Problems & Remedies" by Shimla Doordarshan. The programme was attended by 25 farmers (men & women) from Cheog panchayat adopted villages under Mera Gaon Mera Gaurav. The programme had been broadcasted by Shimla Doordarshan on 4th July, 2017 and DD Kisan on 13th July, 2017 for the benefit of farmers.

Two days Training Program on Scientific potato cultivation

A two day on campus Training Programme was organized by CPRI Shimla for 15 officers of Mahindra Agri. Solution Ltd. on 7th to 8th September, 2017. The training programme was sponsored by Mahindra Agri Solution Ltd., Mumbai. Different aspects of potato cultivation like planting, irrigation, disease pest management etc were delivered to the trainees by the expert scientists from the institute. Lecture-cum-discussion, video shows, demonstrations, practical exercises, field and lab visit, etc. were the modes for imparting training to the participants.



National Training on Procurement & PFMS

The rapidly changing scenario in public procurement and fund management system necessitated an extensive training program on Procurement & PFMS by way of bringing together the knowledge domains and utilizing it to smoothen the transition phase of adopting these new systems by ICAR institutes. ICAR-CPRI Shimla having implemented the changes in its work processes & having reasonable expertise in these areas conducted a national level training program for capacity building & abridging knowledge gap of ICAR personnel at Shimla from 11th Sept. to 17th September, 2017. The 5 day intensive training programme covered lectures on topics like Over view of purchase, Changes in GFR, Bid document framing, Bid evaluation, Procurement of services, Works, Import management, Contract labour hiring & management, Contract order drafting etc. Lectures as well as extensive hands on training on computers to all participants was imparted on PFMS, GeM, e-Procurement etc. Around 80-85 participants from 37 different institutes/ centres attended the training programme.



Hindi Pakhwada -2017

Hindi Pakhwada was organized during September 14-28, 2017 at Central Potato Research Institute, Shimla. On the occasion of inauguration ceremony, Dr. K.K. Pramanick, Head, IARI Regional station, Amartara Cottage, Shimla was the chief guest of the function. He first congratulated all officers/employees of the Institute for Hindi Pakhwada and also urged all staff of the Institute to participate eagerly during various competitions to be organized on the occasion of Hindi Pakhwada. Official language and prize distribution program was held in the Institute on 12.10.2017. On the occasion, cash prizes



were rewarded to the winners who received first, second, third and consolation place in Hindi competitions by the Chief Guest, Dr. Om Prakash Saraswat, Former Head of the Department of Hindi, H.P. University, Shimla. During the year 2016-2017, officers and employees working well in Hindi throughout the year were also awarded with cash prize money.

Swachhta Hi Sewa campaign

As per the instructions of the council, "Swachhta Hi Sewa" campaign was observed at ICAR-CPRI, Shimla. Under the campaign, cleaning of all toilets was done at the HQ and its regional stations. Whole staff of the Institute participated in the activity. On 25th September, 2017, Sarwatra Swachhta was celebrated at the Institute. During this celebration, every employee of the Institute and its regional stations participated in the swachhta activities like cleaning of drains, retaining walls, roofs, surroundings roads nearby the campus etc. Apart of these activities, tree plantation was also done at regional stations of the institute during the campaign period.



Research Advisory Committee meeting 2017

The twenty fourth meeting of the Research Advisory Committee (RAC) was held at the ICAR-Central Potato Research Institute, Shimla during 15-16 December, 2017 under the chairmanship of Dr. PL Gautam, Vice Chancellor, Career Point University, Hamirpur. RAC members Dr. SK Pandey, Ex. Director ICAR-CPRI, Dr. MS Palaniswami, Former Project Coordinator, AICRP on Tuber Crops, ICAR-CTCRI, Thiruvanthapuram, Dr. C. Vishwanathan, Head, Plant Physiology, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi and Dr. T Janakiram, Asstt. Director General (Hort. Science-II), ICAR, New Delhi attended the meeting. Director,



ICAR-Central Potato Research Institute, Shimla, Programme Leaders, Heads of Divisions and all the scientists from Headquarter also participated in the meeting. Chairman, Dr. PL Gautam, showed satisfaction over the fact that Institute responded to 90-100% on the last year's meeting decisions. He said that Institute should take up studies to reduce the production cost of potato. He also emphasized that every technology generated in the Institute should end up in the fields. The progress of ongoing 11 programmes was reviewed and work plan for the next year was also discussed.

Institute Research Committee-2017

The Institute Research Committee (IRC), Meeting 2017 was held at ICAR-Central Potato Research Institute, Shimla during 31st August to 2nd September, 2017 which was attended by 52 scientists from the Headquarters and Regional Stations. The basic objective of this meeting was to review the achievements of 2016-17 and finalize the work plan for 2017-18 of ongoing research programmes. Dr. SK Chakrabarti, Director, ICAR-CPRI and Chairman, IRC stressed upon the need of collaborative projects with internationally recognized institutes/laboratories by which one can get exposed to



researches being done at global level. He expressed his satisfaction on the research work done during the last year. Some important decisions were taken during the meeting which were communicated later to all the concerned.

DG, ICAR & Secretary (DARE) visited CPRS, Gwalior

Dr. Trilochan Mahapatra, Secretary (DARE) and Director General (ICAR) visited, ICAR-CPRS, Gwalior on 29.07.2017 along with Dr. SK Srivastava, Director, Extension, Rajmata Vijay Raje Scindia Krishi Vishwavidyalaya, Gwalior and



Dr. Anupam Misra, Director, ATARI (Zone-VII), Jabalpur. Hon'ble DG, ICAR discussed about activities of the station along with staff members in relation to seed production, scientific activities / achievements and its impact in the state of Madhya Pradesh. He appreciated the efforts of the station for breeder seed production, especially for catering the need of Madhya Pradesh as well as other states of the Country. He graced the occasion by planting saplings of Mango and Guava along with other dignitaries.

Visit of Dr. Zum Felde Thomas, at ICAR-CPRI, Regional Station, Modipuram

Dr. Zum Felde Thomas, Scientist: Genetics, Genomics and Crop Improvement Sciences from CIP-Lima, Peru visited Modipuram on 20 December 2017. Dr SK Chakrabarti, Director, ICAR-CPRI, Shimla and Dr Manoj Kumar, Joint Director, ICAR-CPRI, Regional Station, Modipuram along with Scientists of Station welcomed Dr. Zum Felde Thomas. He visited experimental trials of projects collaborated with ICAR-CPRI and CIP. He also visited Seed Production Units of the Station. In the afternoon Dr Thomas delivered a lecture on



"Potential of mineral biofortified potato to help overcome micronutrient malnutrition in developing countries" for CPRI scientists.

DG, ICAR & Secretary (DARE) visited CPRS, Modipuram

Dr Trilochan Mahapatra, Secretary, DARE & Director General, ICAR, New Delhi visited the station on 31st October, 2017. The honorable DG visited the center's tissue culture plant, potato processing units, etc. Hon'ble DG, ICAR discussed about various activities of the station with all staff members. He was happy with the performance of the station and appreciated the efforts of all the staffs of the station.



6th National Potato Stakeholders Meeting

The 6th National Potato Stakeholders Meet was held at ICAR-Central Potato Research Station, Jalandhar on 17th February 2018 under the chairmanship of Dr. S K Chakrabarti, Director, ICAR-CPRI, Shimla. A total of 43 stakeholders participated. The issues of developing a better mechanism for nomenclature /certification of produce from aeroponic minitubers was raised by the stakeholders. There were discussions on topics like tuber cracking in varieties like *Kufri Chandramukhi* and *Kufri Jyoti* in some areas, revisiting the planting schedules of Seed Plot Technique, disease-pest resistance scoring of varieties on numerical scale, export suitability of different CPRI varieties, nutrient profiling of aeroponically produced mini tubers, organizing national level seed health programmes, evaluation of change in population structure of *Rhizoctonia spp.*, *Sclerotinia spp.* and *Fusarium spp.*

World Soil Day at CPRS Jalandhar

ICAR-Central Potato Research Station celebrated "World Soil Day" on 5th December, 2017. On this occasion, Chaudhary Surinder Singh, MLA, Karatarpur, was the Chief Guest. Dr Raj Kumar, Head of Station, ICAR-CPRS, Jalandhar highlighted the achievements of the Station and need for better



soil health. More than 50 farmers, about 20 students, Vice-Principle, Government Senior Secondary School, Khambra, and Village representative Badsahpur participated in this programme. During the programme, 24 Soil Health Cards were distributed to the farmers mentioning recommended dose of fertilizer for different crops.

Visit of Agriculture Minister and Director General, Agriculture, Myanmar

Hon'ble Minister of Agriculture, Livestock and Irrigation, Myanmar HE Dr. Aung Thu, Hon'ble Ambassador of Myanmar HE Shri Moe Kyaw Aung and Dr Ye Tint Tun, Director General, Department of Agriculture, Myanmar visited CPRI Regional Station, Modipuram, Meerut on 11 January, 2018. Vice president of Indo-Myanmar Chamber of Commerce



& Industries Shri Ashok Murarka and Dr BS Prakash, ADG (AN&P), ICAR, New Delhi accompanied them. Dr Manoj Kumar, Joint Director of Regional Station formally welcomed all delegates and gave brief presentation about potato production scenario in India and potato research activities and achievements of ICAR-CPRI.

Live broadcast on the occasion of *Kisan Unnati Mela 2018*

A live broadcast of the speech of Honorable Prime Minister was arranged on the occasion of Kisan Unnati Mela 2018 (16-18 March, 2018) which was organized at CPRS Modipuram on 17th March, 2018. Professor Gaya Prasad, Vice Chancellor, Sardar Vallabh Bhai Agricultural and Technology University, Meerut was the Chief Guest. On this occasion, about 400 farmers and students



participated in the program. All the queries of the farmers on different aspects of crop production were satisfactorily answered by the scientists of the station.

The Institute Revolving Fund Scheme management committee meeting

The RFSMC meeting was held at ICAR-CPRI, Shimla on 22-23 May, 2017 & 30th August, 2017 to review the seed production programme in order to strengthen over all seed health standard. Director, ICAR-CPRI, Shimla & chairman RFSMC emphasized that enhancing the breeders seed production to increase the revenue by cutting down the cost of production and to economize the use of inputs cost without compromising the quality / health of seed crop.



Training and Capacity Building

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

Sl. No.	Name and Designation	Name of Training Programme/workshop/short course
A.	<i>Scientific Staffs</i>	
1.	Dr. Divya K Lekshmanan	CAFT Training Programme on Statistical Advances for Agricultural Data Analysis
2.	Dr. Sunayan Saha	Advances in Simulation Modelling and Climate Change Research towards Knowledge Based Agriculture
3.	Sh. Bapi Das	CAFT Training Programme on "Recent Advances in Sample Surveys and Survey Data Analysis using Statistical Software"
4.	Sh. Paresh Chaukhande	Summer School on "Recent advances in crop improvement, crop production and post harvest management in potato"
5.	Sh. Paresh Chaukhande	Winter School on "Advanced Technology In Natural Resource Management To Mitigate Climate Change Impacts"
6.	Dr. Gaurav Verma	Winter School on "Use of biotechnological and conventional tools in understanding virus-host interactions"
7.	Dr. Salej Sood	Recent advacnes and accomplishments in heterosis breeding of crops
8.	Dr. Subhash Katare	Innovative Strategies of Plant Protection for Insect-Pests Management in Changing Agriculture Scenario
9.	Sh. P.Kharumnuid	Summer School on "Statistical Analysis for Decision Making in Agriculture" and Summer School Training on "Advanced analytical tools for decision making in agriculture" during July 10-30, 2017 at ICAR-NIAP, New Delhi.
10.	Dr. Arvind Jaiswal	Challenges and opportunities in food processing in context to value addition (Nutraceuticals & functional foods)
11.	Dr. Som Dutt	Phenomics
12.	Sh. HB Kardile	Winter School on "Net Generations sequencing and its applications in crops sciences"
B.	<i>Technical Staffs</i>	
1.	Smt Vineet Sharma	Challenges and oppurtunities in Food processing
2.	Sh. Rakesh Patyal	Pesticides application techniques
3.	Sh. CM Bist	Computer application
4.	Sh. Radha Krishan	Automobile maintenace
5.	Shyam Kumar Gupta, Surinder Shekhawat, Dinesh Singh, Jaswinder Singh	Procurement and PFMS

6.	Sh. Kapil Kumar Sharma and Sh. Sh. Udaivair Singh	Identification of insect pests/ vectors/their damaging symptoms and management
7.	Sh. Ram Singh	Seed Health Testing
8.	Sh. Krishan Pal Singh	Use & maintenance of advanced instruments in soil and plant analysis
9.	Sh. Harvir Singh	Good agricultural practices for enhancing resource use efficiency an farm productivity
10.	Sh. Ompal Singh	Climate smart agriculture for enhancing crop and water productivity under abiotic stress conditions
11.	Sh. Arjun Kumar Sharma	Good practices in extension research
12.	Sh. Dharminder Verma	Communication and scientific writing for technical officers of ICAR
C.	Administrative	
1.	Sh. G.C Prasad	PFMS and other related issues
2.	Sh. Suresh Kumar	Enhancing efficiency and behavior skill
3.	Sh. Sandeep	Income Tax
4.	Sh. Sandeep Dudi	MDP on Public procurement
5.	Sandeep , Sukh Pal, Jeevan, Jagbir Singh, Dillip Kumar, Shashi Thakur, Ashish Dhangar, CP Sharma, Babli Bhawani, Parwartika Das, Shyam Lata, Sandeep Verma, Kamal Chand Verma, Geeta, Sonia Chauhan, Chanda Ram, Krishan Lal, Jagdish Chand, Hans Raj, Mohinder Singh, Gokal Ram, Kundan Lal, Amar Chand, Reeta Walia, Tej Singh, Ashwani Gupta, Raghubir Singh, Urmila Verma, Pawan Kumar, Poonam Jyoti, Narinder Paul, Joginder Thakur, Poonam Sood, Meena Verma, Om Prakash, Kanta Rani, Naresh Kumar, Sanjib Kumar, M Rani, Chandni Bhagta	Procurement and PFMS
6.	Smt. Meena Verma	Administration and finance management

Education, Awards and Honours

Conference/Seminar/Symposium/others attended by ICAR-CPRI Staffs

Sl. No	Name & Designation	Conference/Seminar/Symposium etc. Date & Venue
1.	Dr. Shambhu Kumar	National Conference on “Perspective of challenges and options in Litchi Production and utilization” during June 6-7, 2017 at NRC Litchi, Muzzafarpur
2.	Drs. SK Chakrabarti, SK Luthra, Kamlesh Malik,	Stakeholders Meeting on Potato Export during August 18, 2017 at NASC complex, New Delhi
3.	Drs. Prince Kumar, Dalamu & Tanuja Buckseth	International symposium on “Horticulture: Priorities and emerging trends” IIHR, Bengaluru during 4- 8 September, 2017
4.	Dr VK Gupta	World Food India, 2017 during November 3 to 11, 2017 at India Gate, New Delhi
5.	Er. Sunil Gulati	National Symposium on “Innovations in Horticulture: Production to Consumption” during September 14-15, 2017 at GBPUAT, Pantnagar Uttarakhand
6.	Drs. SK Chakrabarti, VK Dua, SK Luthra, Sanjay Rawal, RK Singh, Sharma Jagdev, Kamlesh Malik, Manoj Kumar, Davender Kumar, VK Gupta, Ravinder Kumar, NK Pandey, Mehi Lal, Raj Kumar, Vinod Kumar, Vinay Bhardwaj, Shambhu Kumar, RK Singh, Name Singh, Paresh Chaukhande, Prince Kumar, SP Singh, Clarissa Challam, Shashi Rawat, EP Venkatsalam, P.Kharumnuid, Aarti Bairwa, M A Shah, Dutt Som, Kardile, HB Bapi Das	National Seminar on “Sustainable Potato Production - Issues and strategies” during September 15, 2017 at BCKV, Kalyani
7.	Drs. SK Chakrabarti, VK Dua, SK Luthra, Sanjay Rawal, RK Singh, Sharma Jagdev, Kamlesh Malik, Manoj Kumar, Davender Kumar, VK Gupta, Mehi Lal, Raj Kumar, Vinod Kumar, Vinay Bhardwaj, Shambhu Kumar, RK Singh, Name Singh, SP Singh, Clarissa Challam, Shashi Rawat, EP Venkatsalam, EP Venkatasalam, M A Shah, Bapi Das	XXXV group meeting of AICRP on Potato during September 15 to 18, 2017 at BCKV, Kalyani (WB)
8.	Er. Gulati Sunil and Er. Nare Brajesh	National Symposium on “Innovations in Horticulture: Production to Consumption” held on September 14-15, 2017 at GBPUAT, Pantnagar Uttarakhand

9.	Drs. Das Bapi and Clarissa Challam	National Seminar on “Smart Farming for Enhancing Input Use efficiency, Income and Environmental Security” at ICAR-RC for NEH Region, Umiam during September 19-21, 2017
10.	Dr. Shambu Kumar	National seminar on “Improved technology & Method for increasing production usages and processing of potato & onion in Bihar” on September 22-23, 2017 at Patna
11.	Dr. Shambhu Kumar	Seminar on “Change the future of migration – Invest in food security & Rural Development” on October 16, 2017 at Bihar State Productivity Council, Patna (Bihar)
12.	Er. Sukhwinder Singh	Tuber Crops Conclave and Agri Start-up Meet October 27-28, 2017, 2017 at CTCRI, Thiruvananthapuram
13.	Drs. Lal M, S K Luthra, VK Gupta and S Yadav	International conference on “Advances in Agricultural and Biodiversity Conservation for Sustainable Development” during October 27-28, 2017 at C. C. S. University, Meerut
14.	Dr. SP Singh	Third international Conference on “Bioresource and Stress Management” in Jaipur during November 8-11, 2017
15.	Dr NK Pandey and Sh. P Kharumnuid	Workshop on “Impact Assessment of Agricultural technology” November 13, 2017 at ICAR-NIAP, New Delhi.
16.	Sh. P. Kharumnuid	2 nd Himachal Pradesh Science Congress on “Science & Technology for Sustainable livelihood in Indian Himalayan Region” in during November 20-21, 2017
17.	Dr. M.A Shah	Indo-US Symposium on “Curbing Whitefly-Plant Virus Pandemics: The Departure from Pesticides to Genomics Solutions” held at PAU, Ludhiana from December 4-5, 2017
18.	Dr. S Yadav	Seminar on “Food and nutritional security through vegetable crops in relation to climate change” from December 9-11, 2017 at ICAR-IIVR, Varanasi, U.P.
19.	Dr. A. Bhatnagar	New vistas in vegetables research towards nutritional security under change climate scenario at TNAU, Coimbatore during December 6-9, 2017
20.	Drs. VK Dua and Jagdev Sharma	International conference on “Opportunities and Challenges of 21 st Century” at Shimla, December 7-9, 2017

21.	Dr. A. Bhatnagar	National Seminar on “Innovative technologies and value chain management in onion, garlic and potato for enhancing farmers income” at NHRDF, New Delhi.
22.	Drs. SK Chakrabarti, Sunil Gulati, Sukhwinder Singh, Brajesh Nare, RK Singh, SK Luthra, Raj Kumar, Prince, Arvind Jaiswal	Sixth National potato Stakeholders during February 17, 2018 at CPRS, Jalandhar

Awards, Honors and Recognitions

CPRI best worker award for year 2017-18

S.No.	Category	Name of the awardee
1.	Scientific	Dr. Vinay Bhardwaj, PS, CPRI, Shimla Dr. Ashwani Kumar Sharma, PS, CPRS Kufri
2.	Technical	Sh. Pushpinder Kumar, Sr. TO, CPRS, Modipuram Dr. SK Sharma, Sr. TO, CPRS, Gwalior.
3.	Administrative	Sh. HN Sharma, AO, DMR Solan (Ex-AAO, CPRO, Shimla) Sh. Ashwani Gupta, UDC, CPRI Shimla
4.	Supporting	Sh. Bir Bahadur, SSS, CPRI, Shimla Sh. Mani Ram, SSS, CPRI RS, Modipuram

Other Awards, Honors and Recognitions

- ❖ Dr. Jagesh Kumar Tiwari received National Academy of Agricultural Sciences (NAAS) ASSOCIATE 2018 Award.
- ❖ CPRI RS, Gwalior bagged first award for excellently implementation of Rajbhasa (official language).
- ❖ CPRI RS Patna bagged best PSO in “*Krishi Sansthan Sammah*” 2018 on the 8th edition of the awards.
- ❖ CPRI stall was awarded first prize in ICAR group in All India Farmers' Fair and Agro-Industrial Exhibition at SVBPUAT, Meerut during October 8-10, 2017.
- ❖ Dr. Shambhu Kumar was conferred winner of the 8th Mahindra Samriddhi India Agri Award 2018.
- ❖ A. Bairwa *et al.* was awarded with Jagar Nath Raina Memorial All India Best Publication Award 2017 for the paper entitled “Effect of cultural practices on potato cyst nematode population dynamics and potato tuber yield” by Society for advancement of human and Nature (SADHNA).
- ❖ Best Poster Award to the paper “Population dynamics of cotton whitefly, *Bemisia tabaci* (Gen.) infecting potato crop in the Indo-Gangetic plains” by Mh. Abbas Shah and Sanjeev Sharma in Indo-US Symposium on 'Curbing whitefly-plant virus pandemics: The departure from pesticides to genomics solutions' held at PAU, Ludhiana on 4-5 December, 2017.
- ❖ Best poster paper award to the paper “Visual Detection of *Potato virus S* by Reverse transcription loop mediated isothermal amplification” by Ravinder Kumar, P Kaundal, B Raigond, S Sharma and SK Chakrabarti in the National Seminar on Sustainable Potato Production -Issues and Strategies held at BCKV, Kalyani on September 15, 2017.
- ❖ 2nd Best poster paper award on “Identification of multiple disease resistant hybrids in potato using MAS” by A Kumar, P Kanwar, S Sood, V Bhardwaj, Dalamu, G Vanishree, H Kardile., B Raigond, Ravinder Kumar, A Bairwa, S Sharma, T Buckseth, RK Singh and S K Chakrabarti in the National Seminar on

Sustainable Potato Production -Issues and Strategies held at BCKV, Kalyani on September 15, 2017.

- ❖ Sood, *et al* was awarded with second best poster award on “Identification of a stable, late blight resistant promising potato hybrid for Indian hills” in “National Seminar on Sustainable Potato Production Issues and Strategies” at BCKV, Kalyani on 15th September, 2017.
- ❖ Sanju Suman, Thakur Aditi, Siddappa Sundaresha, Sharma Sanjeev, Shukla Pradeep Kumar, Srivastava Nidhi, Pattanayak Debasis, Singh Bir Pal received IPA Gold Medal for Best Paper published in Potato Journal during the year 2016 Vol 43 entitled “*In vitro* detached leaf assay of host mediated RNAi lines carrying *Phytophthora infestans* Avr3a effector gene for late blight resistance” during Annual Conference of Indian Potato Association held at BCKV, Kalyani on 15th September, 2017.



Received **ISNS (International Society for Noni Sciences) Fellowship** on 23.03.18 at MPKV, College of Agriculture, Pune (Maharashtra)

- ❖ Best poster award for the work on “RT-LAMP an innovative technique for the detection of *Apple chlorotic leaf spot virus*” (Santosh Watpade, Anil Handa, Pooja Bharadwaj, Baswaraj Raigond, Usha Sharma, Rakesh Kumar and KK Pramanick) National symposium Biorational approaches in plant disease management & Annual meeting of INSOPP during 27-28th October, 2017 at Dr. Y.S Parmar University of Horticulture and Forestry Nauni, Solan.

Patent:

1. Bairwa Aarti, Buckseth Tanuja, Venkatasalam, EP, Singh Brajesh, Singh RK and Chakrabarti SK (2018). The technology “A composition for management of potato cyst nematode infestation” was submitted for patenting and the same was assigned with a patent Application No. 201811008478 by Indian Patenting Authority, New Delhi-110012
2. Filed a patent application entitled, “Design and development of tractor operated potato combine harvester” by inventors Manjit Singh, Sunil Gulati, JS Minhas, Tarlochan Singh and Jagdish Chand, on 15-01-2018 (application no. 201811001686).
3. Filed a patent application on ““Modular structure for covering an area with a net”, by inventors Sukhwinder Singh and Brajesh Nare on 20-Feb-2018 (Patent application No.- 201811006494).
4. Filed a patent application entitled “Device for hydroponic culture of plants”, by inventors Sukhwinder Singh in Indian patent office on 6 Mar, 2018 (Patent application no. 201811008286).

Station-wise staff position

Name of staff at CPRI, Shimla & its Regional Stations as on 31.03.2018

SCIENTIFIC

AICPIP Unit

1. Dr. Vinod Kumar, Pr. Scientist

Division of Crop Improvement

2. Dr. Vinay Bhardwaj, Pr. Scientist & officiating Head
3. Dr. Jagesh Kumar Tiwari, Sr. Scientist
4. Sh. Virupakshagauda U Patil, Scientist
5. Dr. (Mrs.) G Vanishree, Scientist
6. Sh. Hemant Balasaheb Kardile, Scientist
7. Dr. Salej Sood, Scientist

Division of Seed Technology

8. Dr. Rajesh Kumar Singh, Pr. Scientist & Head
9. Dr. (Mrs.) Tanuja Buckseth, Scientist

Division of Crop Production

10. Dr. VK Dua, Principal Scientist & Head
11. Dr. Jagdev Sharma, Pr. Scientist
12. Dr. (Ms.) Pooja Praful Mankar, Scientist
13. Sh. Paresh Baldeorao, Scientist

Division of Social Sciences

14. Dr. NK Pandey, PS & Head
15. Sh. Pynbianglang Kharumunid, Scientist

Division of Plant Protection

16. Dr. Sanjeev Sharma, Pr. Scientist and Officiating Head
17. Dr. Vinay Sagar, Principal Scientist
18. Dr. Baswaraj R., Scientist
19. Dr. Sundersha S, Scientist
20. Dr. Ravinder Kumar, Scientist
21. Dr. Gaurav Verma, Scientist
22. Dr. (Ms.) Aarti Bairwa, Scientist
23. Sh. Kailash Chandra Naga, Scientist

Division of Crop Physiology & PHT

24. Dr. Brajesh Singh, Pr. Scientist & Head
25. Dr. Som Dutt, Sr. Scientist

26. Dr. (Mrs.) Pinky Raigond, Scientist
27. Sh. Changan Sushil Sudhakar, Scientist

ARIS Cell

28. Dr. Shashi Rawat, Pr. Scientist

CPRI RS, Modipuram

29. Dr. Manoj Kumar, Pr. Scientist & Joint Director
30. Dr. Devendra Kumar, Pr. Scientist
31. Dr. (Mrs.) Kamlesh Malik, Pr. Scientist
32. Dr. SK Luthra, Pr. Scientist
33. Dr. Name Singh, Pr. Scientist
34. Dr. Vinay Singh, Pr. Scientist
35. Dr. Anuj Bhatnagar, Pr. Scientist
36. Dr. Sanjay Rawal, Pr. Scientist
37. Dr. Dhruv Kumar, Pr. Scientist
38. Dr. Vijai Kishore Gupta, Pr. Scientist
39. Dr. Babita Chaudhary, Pr. Scientist
40. Dr. Mehi Lal, Scientist
41. Dr. (Ms) Bandna, Scientist

CPRS, Jalandhar

42. Dr. Raj Kumar, Pr. Scientist & officiating Head
43. Er. Sukhwinder Singh, Scientist SG
44. Er. Sunil Gulati, Scientist (SG)
45. Dr. (Ms) Ratna Preeti Kaur, Scientist
46. Dr. Prince Kumar, Scientist
47. Dr. Mohd. Abas Shah, Scientist
48. Dr. (Mrs.) Sugani Devi, Scientist
49. Er. Brajesh Nare, Scientist
50. Dr. Arvind Kumar Jaiswal, Scientist
51. Dr. Sunayan Saha, Scientist

CPRS, Gwalior

52. Dr. S Roy, Pr. Scientist & Head
53. Dr. Shiv Pratap Singh, Pr. Scientist
54. Dr. Murlidhar J. Sadawarti, Scientist
55. Dr. Subhash Katore, Sr. Scientist

CPRS, Shillong

56. Ms. Clarissa Challam, Scientist
57. Sh. Bappi Dass, Scientist

CPRS, Muthorai

58. **Dr. EP Venkatsalam, Pr. Scientist & Incharge**
59. Mrs. Divya K Lekshmanan, Scientist
60. Dr. Mhatre Priyank Hanuman, Scientist

CPRS, Kufri

61. **Dr. Ashwani Kumar Sharma, Pr. Scientist & Incharge**
62. Dr. (Ms.) Dalamu, Scientist

CPRS, Patna

63. **Dr. Shambhu Kumar, Pr. Scientist & officiating Head**
64. Dr. Raj Kumar, Sr. Scientist
65. Sh. Rahul R. Bakade, Scientist
66. Dr. Sarla Yadav, Scientist

TECHNICAL CPRI, Shimla

1. Dr. Rakesh Mani Sharma, CTO
2. Dr. Sushil Kumar, ACTO
3. Smt. Tarvinder Kochhar, ACTO
4. Sh. Dharminder Verma, ACTO
5. Smt. Shelly Chopra, ACTO
6. Sh. Rajdeep Bux, STO
7. Dr. Sumita Sharma, STO
8. Sh. Pravesh Jassal, STO
9. Sh. Kameshwar Sen, ACTO
10. Sh. Avnish Kumar Atrey, STO
11. Sh. Chander Mohan Singh Bist, STO
12. Sh. Yogesh, STO
13. Sh. Harvinder Singh, STO
14. Sh. Vinod Kumar, STO
15. Smt. Shruti Gupta, TO
16. Sh. Tilak Raj, TO
17. Sh. Dharm Prakash Gautam, TO
18. Sh. Kana Singh Chauhan, TO
19. Sh. Sheesh Ram, TO
20. Sh. Yashpal Sharma, TO
21. Sh. Naresh Kumar Sharma, TO

22. Sh. Rajinder Kumar, TO
23. Sh. Rakesh Kumar Patyal, TO
24. Sh. Sushil Singh, STA
25. Sh. Naresh Chand Sharma, STA
26. Smt. Manjeet Syal, STA
27. Smt. Madhu Bala, STA
28. Smt. Asha Thakur, STA
29. Sh. Hari Kishore, STA
30. Sh. Ram Singh, STA
31. Sh. Dharminder Kumar Gupta, STA
32. Sh. Naresh Kumar, STA
33. Sh. Ranjesh Bhardwaj, STA
34. Sh. Roop Lal, TA
35. Sh. Ravinder Kumar, TA
36. Sh. Ashok Kumar, TA
37. Sh. Deep Ram, TA
38. Sh. Rakesh Kumar, TA
39. Sh. Prithi Raj, TA
40. Smt Jitender Kaur Arora, TA
41. Sh. Jagdish Chand, TA (Welder)
42. Sh. Jagdish Chand, Sr. Technician (Balksmith-cum-Carpenter)
43. Sh. Dev Raj, Sr. Technician
44. Sh. Ram Dayal, Sr. Technician
45. Sh. Parmesh Dutt, Sr. Technician
46. Sh. Anil Kumar Dubey, Sr. Technician
47. Sh. Neem Chand, Sr. Technician
48. Sh. Sita Ram, Sr. Technician
49. Sh. Laiq Ram, Sr. Technician
50. Sh. Surinder Pal, Technician
51. Sh. Mansha Ram, Technician
52. Sh. Arjun Dass, Technician

CPRS, Kufri

53. Sh. Kapil Kumar Sharma, ACTO
54. Sh. Kedar Singh, TO
55. Sh. Ajit Singh, TA
56. Sh. Ramjivan, TA
57. Sh. Mohan Lal, Sr. Technician

CPRI RS, Modipuram

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

CPRS, Jalandhar

92. Sh. Munna Lal, ACTO
93. Sh. Jaswinder Singh, ACTO

94. Sh. Yogesh Kumar Gupta, STO
95. Sh. Akhilesh Kumar Singh, STO
96. Sh. Praveen Kumar, STA
97. Sh. Som Dutt, STA
98. Sh. Narinder Mayer, STA
99. Sh. Kulwinder Singh, STA
100. Sh. Anil Kumar Chandel, TA
101. Sh. Pradeep Kumar Upadhaya, TA
102. Sh. Vijay Kumar, TA
103. Sh. Pawan Kumar, Sr. Technician

CPRS, Gwalior

104. Dr. Yogendra Pal Singh STO
105. Sh. Sanjay Kr. Sharma, STO
106. Sh. Shyam Kumar Gupta STO
107. Sh. Rajinder Kumar Samadhiya, STO
108. Sh. Surendar Singh, STA
109. Sh. Radha Kishan, TA
110. Sh. Nihal Singh, TA
111. Sh. Bijendra Singh, Sr. Technician
112. Sh. Tara Chand, Sr. Technician
113. Sh. Chet Ram, Sr. Technician

CPRS, Patna

114. Sh. Arun Kumar Singh, ACTO
115. Sh. Arjun Kumar Sharma, STO
116. Sh. Rakesh Srivastava, TO
117. Sh. Anil Kumar, STA
118. Sh. Alekh Narain, STA
119. Sh. SDA Rizvi, TA
120. Sh. Narinder Kumar, Sr. Technician
121. Sh. Lal Babu Dass, Sr. Technician
122. Sh. Sunil Kr. Singh, Sr. Technician
123. Sh. Parvesh Kumar Yadav, Sr. Technician

CPRS, Shillong

124. Sh. Hesting Jyrwa, STA
125. Sh. PR Khongbuh, TA
126. Sh. Ram Dass Rai, TA
127. Sh. S.Nongrum, Sr. Technician

CPRS, Muthorai

- 128. Sh. V Rajendran, TO
- 129. Sh. R Lakshmanan, TA
- 130. Sh. B Suresh, Technician

ADMINISTRATIVE

- 1. Sh. Ratnesh Kumar, CAO
- 2. Sh. Sandeep Singh Dudi, AO

Establishment-I Section

- 3. Sh. Joginder Singh Thakur, AAO
- 4. Smt. Sunita Thakur, Asstt.5.Sh. Om Parkash, Asstt.

Establishment-II Section

- 6. Smt. Poonam Sood, AAO
- 7. Smt. Urmila Verma, Asstt.

Bill & Cash Section

- 8. Sh. Jai Ram, AAO/DDO
- 9. Sh. Amar Chand, Asstt.
- 10. Ms. Reeta Walia, Asstt.
- 11. Sh. Ashwani Gupta, UDC- Cum -Cashier
- 12. Sh. Tej Singh, UDC
- 13. Sh. Raghubir Singh, UDC

Audit Section

- 14. Sh. G.C. Prasad, Sr. F & AO
- 15. Sh. Chander Prakash, AF&AO
- 16. Dr. Ashish Dhangar, AF&AO
- 17. Sh. Jagdish Chand, Asstt.
- 18. Miss Prawartika Das, Asstt.
- 19. Smt. Shyam Lata Beakta, Asstt.
- 20. Sh. Sandeep Verma, Asstt.
- 21. Sh. Kamal Chand Verma, UDC
- 22. Smt. Geeta Devi, UDC
- 23. Smt. Sonia Chauhan, UDC

Work & Contract Section

- 24. Smt. Meena Verma, AAO
- 25. Sh. Narender Paul, UDC
- 26. Smt. Punam Jyoti, UDC
- 27. Sh. Pawan Kumar, UDC

Store Section

- 28. Sh. Chanda Ram, AAO

- 29. Sh. Jagdish Chand, Asstt.
- 30. Sh. Krishan Lal, Asstt.
- 31. Sh. Hans Raj, UDC
- 32. Sh. Kundan, LDC
- 33. Sh. Mohinder Singh, UDC
- 34. Sh. Gokal Ram, UDC

PME Cell

- 35. Sh. Deep Ram, Asstt.
- 36. Sh. Sachin Kanwar, UDC
- 37. Sh. Rakesh Negi, LDC

Vigilance Section

- 38. Sh. Shashi Thakur, Pvt. Secretary

AICPIP Unit

- 39. Smt. Nirmala Chauhan, UDC

Engineering Section

- 40. Smt. Kanta Rani, Asstt.

Division of Plant Protection

- 41. Sh. Gurjeet Singh, Pvt. Secy.

Director Cell

- 42. Sh. Ram Chand, Pvt. Secy.

Hindi Section

- 43. Sh. Suresh Kumar, PA

CPRS, Kufri

- 44. Smt. Babli Bhawani, AAO
- 45. Smt. Chandni Bhagta, Asstt.

CPRI RS, Modipuram

- 46. Shri Jaspal Singh, AO
- 47. Sh. Jagbir Singh, AAO
- 48. Sh. Sandeep, AAO
- 49. Sh. Santosh Kumar, Asstt.
- 50. Smt. Sneha Lata, UDC
- 51. Smt. Seema Verma, UDC
- 52. Sh. Ashok Kumar, UDC
- 53. Sh. Ashish Kalyan, LDC
- 54. Sh. Rajesh Kumar, Pvt. Secy.

CPRS, Jalandhar

- 55. Sh. Jeevan Kumar, AAO (Retired in the afternoon of 31.03.2018)
- 56. Sh. Suresh Kumar Verma, PA

57. Sh. Sukhpal Sharma, Asstt.
58. Smt. Sandhya Kapila, Asstt.
59. Sh. Rakesh, Asstt.
60. Smt. Bimla Salhotra, UDC
61. Smt. Daishey Tuli, UDC
62. Sh. Naresh Kumar, LDC
63. Sh. Daljeet Singh, UDC

CPRS, Gwalior

64. Sh. Surender Singh, Asstt.
65. Sh. Pradhuman Kumar Sarswat, UDC
66. Sh. Shri Krishan, LDC

CPRS, Muthorai

67. Smt. IC Dharmapaul, AAO
68. Smt. M. Rani, Asstt.

CPRS, Patna

69. Sh. Sanjib Kumar, Asstt.
70. Sh. Ramesh Kumar Gupta, UDC

CPRS, Shillong

-NIL-

SKILLED SUPPORT STAFF

1. Sh. Maharaj Singh, SSS (SS Gr. III)
2. Sh. Charan Dass, SSS (SS Gr. III)
3. Sh. Roshan Lal, SSS (SS Gr. III)
4. Sh. Kanhiya Prasad, SSS (SS Gr. III)
5. Sh. Bir Bhadur, SSS (SS Gr. III)
6. Sh. Subhash Chand, SSS (SS Gr. III)
7. Sh. Mansa Ram, SSS (SS Gr. III)
8. Sh. Babu Ram, SSS (SS Gr. III)
9. Sh. Ramesh Kumar, SSS (SS Gr. III)
10. Sh. Rajinder Kumar, SSS (SS Gr. II)
11. Sh. Kulwant Singh, SSS (SS Gr. II)
12. Sh. Sanjeevan Kumar, SSS (SS Gr. II)
13. Sh. Ashok Kumar, SSS (SS Gr. I)
14. Sh. Narender Kumar, SSS (SS Gr. I)
15. Smt. Kajal, SSS (SS Gr. I)
16. Sh. Padam Dev, SSS (SS Gr. I)
17. Sh. Roshan Lal, SSS (SS Gr. I)
18. Smt. Manjit, SSS (SS Gr. I)

19. Sh. Amar Nath, SSS (SS Gr. I)
20. Sh. Hira Singh, SSS (SS Gr. I)
21. Sh. Rajinder Singh, SSS
22. Sh. Padam Chand, SSS (SS Gr. I)
23. Sh. Nand Lal, Wash Boy
24. Smt. Kiran

CPRS Kufri

25. Sh. Hira Singh, SSS (SS Gr. III)
26. Sh. Saran, SSS (SS Gr. III)
27. Smt. Muni Devi, SSS (SS Gr. II)
28. Smt. Indira Devi, SSS (SS Gr. II)
29. Sh. Madan Lal, SSS (SS Gr. I)
30. Sh. Sita Ram, SSS (SS Gr. I)
31. Sh. Roop Singh, SSS (SS Gr. I)
32. Sh. Jia Lal, SSS (SS Gr. I)
33. Smt. Sodha Devi, SSS

CPRIC Modipuram

34. Sh. Satya Pal Singh, SSS (SS Gr. II)
35. Sh. Amiruddin, SSS (SS Gr. II)
36. Sh. Jagtey, SSS (SS Gr. II)
37. Sh. Som Pal, SSS (SS Gr. II)
38. Sh. Krishan Pal, SSS (SS Gr. I)
39. Sh. Mani Ram, SSS (SS Gr. I)
40. Sh. Rajpal, SSS (SS Gr. I)
41. Sh. Rajvir Singh, SSS (SS Gr. I)
42. Sh. Raj Kumar, SSS (SS Gr. I)
43. Sh. Sudesh Pal, SSS (SS Gr. I)
44. Sh. Tej Bir Singh, SSS (SS Gr. I)
45. Sh. Gyanendra Kumar, SSS (SS Gr. I)
46. Sh. Ramphal, SSS (SS Gr. I)
47. Sh. Mukesh, SSS (SS Gr. I)
48. Sh. Murari, SSS (SS Gr. I)
49. Sh. Rajpal Singh, SSS (SS Gr. I)

CPRS Jalandhar

50. Sh. Komal, SSS (SS Gr. III)
51. Sh. Gian Singh, SSS (SS Gr. II)
52. Sh. Satnam Singh, SSS (SS Gr. II)
53. Mrs. Passo, SSS (SS Gr. II)

54. Smt. Rashpal Devi, SSS (SS Gr. II)
55. Sh. Ram Lubhaya, SSS (SS Gr. II)
56. Sh. Sukhwinder, SSS (SS Gr. II)
57. Sh. Jagai Ram, SSS (SS Gr. II)
58. Sh. Paramjit Singh, SSS (SS Gr. II)
59. Sh. Ram Sarup, SSS (SS Gr. I)
60. Sh. Joginder Pal, SSS (SS Gr. I)
61. Sh. Ram Nath, SSS (SS Gr. I)
62. Sh. Jagan Nath, SSS (SS Gr. I)

CPRS Patna

63. Smt. Tara Devi, SSS (SS Gr. III)
64. Sh. Tapan Burman, SSS (SS Gr. III)
65. Sh. Ram Kisun Ram, SSS (SS Gr. II)
66. Sh. Teka Rai, SSS (SS Gr. II)
67. Sh. Jagat Kumar, SSS (SS Gr. II)
68. Sh. Ram Balak Rai, SSS (SS Gr. II)
69. Sh. Bishun Rai, SSS (SS Gr. I)
70. Sh. Akhilesh Singh, SSS (SS Gr. I)

CPRS, Gwalior

71. Sh. Ram Babu, SSS (SS Gr. II)
72. Sh. Mohan Lal, SSS (SS Gr. II)
73. Sh. Shiv Singh, SSS (SS Gr. II)
74. Sh. Niranjana Singh, SSS (SS Gr. II)
75. Sh. Kailash, SSS (SS Gr. II)
76. Sh. Ram Singh, SSS (SS Gr. II)
77. Sh. Jagdish, SSS (SS Gr. II)
78. Sh. Shyam Singh, SSS (SS Gr. II)
79. Sh. Parkash Tomar, SSS (SS Gr. II)
80. Sh. Virendra Singh, SSS (SS Gr. II)

81. Sh. Ranbir Singh, SSS (SS Gr. II)
82. Sh. Kallu, SSS (SS Gr. II)
83. Sh. Ashok Kumar, SSS (SS Gr. II)
84. Smt. Vimla Devi, SSS (SS Gr. I)
85. Sh. Jaswant Singh, SSS (SS Gr. I)
86. Sh. Kedar, SSS (SS Gr. I)
87. Sh. Sonpal, SSS (SS Gr. I)
88. Sh. Parasu Ram, SSS (SS Gr. I)
89. Sh. Punjab Singh, SSS (SS Gr. I)
90. Sh. Ram Parkash, SSS (SS Gr. I)
91. Sh. Bharat Singh, SSS (SS Gr. I)
92. Sh. Munnu Singh, SSS (SS Gr. I)
93. Sh. Lala Ram, SSS
94. Sh. Kali Charan, SSS
95. Sh. Tilak Singh, SSS
96. Sh. Net Ram, SSS
97. Sh. Mangal, SSS
98. Sh. Jandel Singh, SSS
99. Sh. Bhagirath, SSS
100. Sh. Ramdin, SSS
101. Sh. Sikander Singh, SSS

CPRS Shillong

102. Smt. Theibet Thawmuit, SSS (SS Gr. III)
103. Mrs. Tellinora, SSS (SS Gr. III)
104. Km. Thapa, SSS (SS Gr. III)

CPRS Muthorai

105. Sh. K. Ramasamy, SSS (SS Gr. I)
106. Sh. J. Bhojan, SSS (SS Gr. I)
107. Smt. S Pankajam, SSS (SS Gr. I)
108. Smt. M. Anagamma, SSS

Sanctioned, Filled and Vacant Positions at CPRI & its Regional Stations as on 31.3.2018

Scientific

Sl. No.	Discipline	Scientist (Including Sr. Sci. & PS promoted Through CAS)			Senior Scientist (DR)			Principal Scientist (DR)			Total		
		S	F	V	S	F	V	S	F	V	S	F	V
1.	AGRICULTURAL BIOTECHNOLOGY	4	3	1	-	-	-	-	-	-	4	3	1
2.	AGRONOMY	4	4	-	-	-	-	1	1	-	5	5	-
3.	AG. ENTOMOLOGY	6	3	3	1	2	(-)1	-	-	-	7	5	2
4.	AG. ECONOMICS	3	-	3	-	-	-	-	1	(-)1	3	1	2
5.	AG METROLOGY	1	1	-	-	-	-	-	-	-	1	1	-
6.	AGRICULTURAL MICROBIOLOGY	3	-	3	-	-	-	-	-	-	3	-	3
7.	AG. STATISTICS	1	-	1	-	-	-	-	-	-	1	-	1
8.	COM. APPLN.	1	1	-	-	-	-	-	-	-	1	1	-
9.	AG. EXTENSION	3	1	2	-	-	-	1	-	1	4	1	3
10.	AGRI. PROCESS ENGINEERING	1	-	1	-	-	-	-	-	-	1	-	1
11.	AG. ENGG.(FM&P)	3	3	-	-	-	-	-	-	-	3	3	-
12.	AG. ENGG (ASPEE)	-	-	-	-	-	-	-	-	-	-	-	-
13.	AG. CHEMISTRY	-	-	-	-	-	-	-	-	-	-	-	-
14.	PL.BIOCHEMISTRY	2	2	-	1	1	-	-	-	-	3	3	-
15.	FOOD TECHNOLOGY	2	1	1	-	-	-	-	-	-	2	1	1
16.	FRUIT SCIENCE	-	-	-	-	-	-	-	-	-	-	-	-
17.	GEN. & CYTOGEN	-	-	-	-	-	-	-	-	-	-	-	-
18.	VEG. SCIENCE	14	12	2	2	-	2	4	1	3	20	13	7
19.	NEMATOLOGY	2	2	-	-	-	-	1	-	1	3	2	1
20.	GENETICS AND PLANT BREEDING	9	7	2	4	2	2	1	-	1	14	9	5
21.	PL. PATHOLOGY	10	6	4	2	2	-	1	1	-	13	9	4
22.	PL. PHYSIOLOGY	4	2	2	1	-	1	-	1	(-)1	5	3	2
23.	SOIL SCIENCE SOIL CHEM./ FERT. MICRO	5	1	4	-	-	-	-	-	-	5	1	4
24.	SOIL PHY. & SOIL WATER CONSERV.	-	-	-	-	-	-	-	-	-	-	-	-
25.	S EED SCIENCE AND TECHNOLOGY	5	3	2	-	1	(-)1	1	-	1	6	4	2
26.	FLEXI DISCIPLINES	-	-	-	2	-	2	-	-	-	2	-	2
27.	JOINT DIRECTOR	-	-	-	-	-	-	1	1	-	1	1	-
	TOTAL	83	52	31	13	8	5	11	06	5	107	66	41

S-Cadre Strength F-In position V-Vacancy

Technical																			
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
Field Farm Technician (FFT)																			
Cat. I		29	28	5	2	8	6	13	10	4	4	12	7	4	3	8	4	83	64
Jr. Tech. Asstt. /Sr. Field Asstt./Field Asstt.																			
Cat. II		9	8	-	-	4	3	13	11	2	2	3	2	-	-	-	1	31	27
Sr. Tech. Asstt. (T-4) Tech. Asstt. (T-3)																			
Cat. III		-	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	2	2
Farm Supdt. T-6																			
Lab. Technician-																			
Cat. I		2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	3
Computer (T-2)																			
Projector Operator, T-2		1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Cat. II		3	2	-	-	1	-	1	1	1	1	-	-	-	-	-	-	6	4
Lab. Tech. (T-4)/ Lab. Tech. (T-3)																			
Cat. III		1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1
Computer programmer T-6																			
Lib. Information / Documentation																			
Cat. II		1	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2
Lib. Asstt. (T-3)																			
Asstt. Librarian (T-5)		1	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1*
Documentalist, T-2		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Tech. Asstt. (Stat.) (T-3)		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Photography																			
Cat. I		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Photographer /																			
Press & Editorial Staff Cat. II																			
Hindi Translator, T-3		1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	1
Workshop & Engg. Staff																			

[illegible]

Cadre	Administrative																		
	Shimla		Jalandhar		Modipuram		Gwlor		Shillong		Kufri		Patna		Ooty		TOTAL		
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	
Chief Admn. Officer	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	01	-
	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	01	-
Admn. Officer	2	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	02	02	-
	3	5	1	-	2	2	1	-	1	-	1	1	-	1	1	10	09	01	
Asstt. Fin. & A/Cs Officer	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	02	-
Asstt. Director (OL)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	-	01
Private Secretary	3	3	-	-	1	1	-	-	-	-	-	-	-	-	-	-	04	04	-
	7	1	1	1	-	-	1	-	-	-	-	1	-	-	-	-	10	02	8*
Personal Assistant	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01	+1
Stenographer Grade-III	20	13	1	3	3	1	1	1	2	-	1	1	1	1	1	1	30	21	9
Assistant	5	14	3	3	3	1	1	1	1	-	1	1	-	2	1	1	-	18	22
UDC	14	2	1	1	3	1	-	1	2	-	-	-	-	2	-	1	-	23	05
LDC	59	44	8	8	12	9	4	3	6	0	2	2	7	2	4	2	102	70	32

* Requisition for filling up posts of Stenographer Grade-III in lieu of PA has already sent to ICAR. Requisition for filling up posts of Lower Division Clerk has also been sent to ICAR. The recruitment action is at advanced stage.

Skilled Support Staff

Grade	Sanctioned	Filled	Vacant
SS Grade-I	85	56	29
SS Grade-II	65	34	31
SS Grade-III	39	17	22
SS Grade-IV	18	1	17
Total	207	108	99

Station-wise/Grade-wise list of the Skilled Supporting Staff

Station	Sanctioned Strength	Grade IV	Grade III	Grade II	Grade I	Total
Shimla	75	-	10	03	11	24 (including Canteen staff)
Kufri	12	-	02	02	05	09
Modipuram	42	-	00	04	12	16
Jalandhar	26	-	01	08	04	13
Patna	20	-	02	04	02	08
Gwalior	12	-	-	13	18	31
Shillong	12	-	03	-	-	03
Muthorai	08	-	-	-	04	04
Total	207*	-	18	34	56	108

* 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 will be reverted back to CPRI, Shimla as and when these posts are vacated by the present incumbents employed against these posts.

Appointments/Promotions/Transfers/Retirements/Deaths during 1.4.2017 to 31.03.2018

Scientific

New Joining

1. Sh. Paresh B. Chaukhande, Scientist, Veg. Science joined at CPRI Shimla on 01.04.2017.
2. Dr. Sunayan Saha, Scientist, Agril. Meteorology joined at CPRS, Jalandhar on 03.04.2017
3. Sh. Kailash Chandra Naga, Scientist, Entomology, joined at CPRI, Shimla on 16.10.2017.
4. Sh. Changan Sushil Sudhakar, Scientist, Plant Biochemistry, joined at CPRI, Shimla on 16.10.2017.

Transfers

1. Dr. Dhiraj Kumar Singh, Scientist(Agril. Extn.), CPRI, Shimla relieved to join at ICAR-RCER, Patna from 28-06-2017(AN).

2. Dr. (Mrs.) Jeevalatha, Scientist(Plant Pathology), CPRI, Shimla relieved from 01.07.017 (AN) to join at ICAR-Indian Institute of Spices Research, Calicut, Kerala.
3. Dr. Raja Shankar, Senior Scientist (Veg. Sci.) PC Unit relieved from 07.07.02017 to join at ICAR-Indian Institute of Horticultural Research, Bengaluru-560089.
4. Dr. Sridhar Jandrajupalli, Scientist (Entomology) relieved from 05.07.2017 to join at National Institute of Biotic Stress Management, Chattisgarh-493225.
5. Sh. Maharishi Tomar, Scientist (Plant Bio-Chemistry) relieved from 04.07.2017 (AN) to join at ICAR-Indian Grassland and Fodder Research Institute, Jhansi.

Transfers with in Institute

1. Dr. Vinod Kumar, PS (Genetics & Plant Breeding) joined at CPRI Shimla (PC Unit) from 06.07.2017 (FN) after relieving from CPRS,

Kufri.

2. Sh. Pynbianglang Kharumnuid, Scientist joined at CPRI, Shimla on 10.08.2017 (FN) after relieving from CPRS, Patna.
3. Dr.(Ms.) Dalamu, Scientist (Vegetable Science), joined at CPRS, Kufri on 18.08.2017 after relieving from CPRI, Shimla.

Promotions

1. Dr. Sanjeev Sharma, Sr. Scientist, CPRI, Shimla, promoted to the next higher grade of PS (RGP 10,000/-) under CAS w.e.f. 02.07.2015.
2. Dr. Vinay Sagar, Sr. Scientist, CPRI, Shimla, promoted to the next higher grade of PS (RGP 10,000/-) under CAS w.e.f. 28.07.2015.
3. Dr. E. P. Venktasalam, Sr. Scientist, CPRS, Ooty promoted to the next higher grade of PS (RGP 10,000/-) under CAS w.e.f. 10.09.2016.
4. Dr. Shashi Rawat, Senior Scientist, CPRI, Shimla promoted to the next higher grade of PS(RGP Rs. 10,000/-) under CAS w.e.f. 29.11.2016.
5. Dr. Babita Chaudhary, Senior Scientist, CPRI Regional Station, Modipuram promoted to the next higher grade of PS(RGP Rs. 10,000/-) under CAS w.e.f. 30.12.2016.
6. Dr. Jagesh Kumar Tiwari, Scientist, CPRI, Shimla promoted to the next higher grade of Sr. Scientist(RGP Rs. 8,000/-) under CAS w.e.f. 07.01.2017.
7. Dr.(Ms.) Dalamu, Scientist (RGP Rs. 6,000), CPRI, Shimla promoted to the next higher grade of Scientist(RGP Rs. 7,000/-) under CAS w.e.f. 27.04.2015.
8. Dr. Ravinder Kumar, Scientist(RGP Rs.6,000), CPRI, Shimla promoted to the next higher grade of Scientist(RGP Rs.7,000/-) under CAS w.e.f. 02.05.2015.
9. Dr.(Mrs.) Ratna Preeti Kaur, Scientist(RGP Rs.6,000), CPRS, Jalandhar promoted to the next higher grade of Scientist(RGP Rs. 7,000/-) under CAS w.e.f. 15.12.2015.
10. Dr. (Ms.) Aarti Bairwa, Scientist(RGP Rs.6,000), CPRI, Shimla promoted to the next higher grade of Scientist(RGP Rs. 7,000/-) under CAS w.e.f. 01.01.2017.
11. Dr. Raj Kumar Singh, Sr. Scientist(Rs.8,000 RGP), CPRS, Patna promoted to the next higher

grade of Sr. Scientist (RGP of Rs.9,000) under CAS w.e.f. 23.10.2015.

12. Dr. Name Singh, Sr. Scientist, CPRI-RS, Modipuram, promoted to the next higher grade of PS (RGP 10,000/-) under CAS w.e.f. 27.07.2011.

Technical

Promotion:

1. Sh. Sita Ram, Technician, CPRI, Shimla promoted to Sr. Technician
2. Sh. Laiq Ram Technician, CPRI, Shimla promoted to Sr. Technician.
3. Sh. Tara Chand, Technician, CPRS, Gwalior promoted to Sr. Technician
4. Sh. Satpal Singh, Technician, CPRS, Modipuram promoted to Sr. Technician
5. Sh. Parvesh Kumar, Technician, CPRS Patna promoted to Sr. Technician.
6. Sh. Bijendra Singh, Technician, CPRS, Gwalior promoted to Sr. Technician.
7. Sh. Pawan Kumar, Technician, CPRS, Jalandhar promoted to Sr. Technician.
8. Sh. Jagdish Chand, Sr. Technician, CPRI, Shimla promoted to Tech. Asstt.
9. Sh. Pawan Kumar Malik, Tech Asstt. CPRS, Modipuram promoted to Sr. Tech. Asstt.
10. Sh. Naresh Kumar, Tech. Asstt. CPRI, Shimla promoted to Sr. Tech. Asstt.
11. Sh. Ranjesh Bhardwaj, Tech. Asstt. CPRI, Shimla promoted to Sr. Tech. Asstt.
12. Sh. Naresh Kumar Sharma, Sr. Tech. Asstt, CPRI, Shimla promoted to Tech. Officer.
13. Sh. Rajinder Kumar, T-I-3 CPRI, Shimla promoted to T-3, T-3 to T-4 and T-4 to T-5
14. Sh. Rakesh Kumar Patyal, T-2, CPRI, Shimla promoted to T-3, T-3 to T-4 and T-4 to T-5
15. Sh. Kedar Singh, T-I-3 CPRS, Kufri promoted to T-3, T-3 to T-4 and T-4 to T-5
16. Sh. Vinod Kumar, T-3, CPRI, Shimla promoted to T-4 and T-4 to T-5 and T-5 to T-6
17. Sh. Udavir Singh, Tech. Officer, CPRIC, Modipuram promoted to Sr. Tech. Officer.
18. Sh. Ompal, Sr. Tech. Officer, CPRIC, Modipuram promoted to ACTO.
19. Sh. Santosh Kumar, Sr. Tech. Officer, CPRIC Modipuram promoted to ACTO.

20. Smt. Kusum Singh, Sr. Tech. Officer, CPRIC, Modipuram Promoted to ACTO.
21. Sh. Kameshwar Sen, Sr. Tech. Officer, CPRI, Shimla promoted to ACTO
22. Sh. Jaswinder Singh, Sr. Tech. Officer, CPRS, Jalandhar promoted to ACTO
23. Sh. Balak Ram, ACTO , CPRIC Modipuram promoted to CTO.
24. Dr. Rakesh Mani Sharma, ACTO, CPRI, Shimla promoted to CTO.

Transfer:

1. Sh. Kehar Singh, Sr. Tech. Asstt, CPRIC Modipuram to Karnal (Inter- Institute transfer.)
2. Sh. Vinod Gir, Technician CPRI, Shimla to CPRS Patna
3. Sh. Kapil Kumar Sharma, ACTO, CPRS, Jalandhar to CPRS, Kufri.
4. Sh. SDA Rizvi, Tech. Asstt. CPRS Patna to CPRI RS, Modipuram

Retirements

1. Sh. Bhag Singh, T-I-3 (Driver), CPRS Jalandhar retired on 31.7.2017
2. Sh. NK Sud, Tech. Officer, CPRIC, Modipuram retired on 31.10.2017
3. Sh. Gurdev Singh, Tech. Officer, CPRS, Jalandhar retired on 31.12.2017
4. Sh. Vinod Gir, Technician, CPRS, Patna VRS on 1.1.2018
5. Sh. Prakash Ram, Technician(Driver), CPRS, Gwalior compulsory retired on 16.1.2018
6. Sh. Bosterwell Langestieh, Sr. Tech. Asstt, CPRS, Shillong retired on 28.2.2018

Death :

7. Sh. Satander Kumar, Sr. Tech. Officer, CPRIC, Modipuram died on 5.8.2017

Administrative

Grant of MACP benefit

1. Sh. Pawan Kumar, UDC, ICAR-CPRI, Shimla, granted 2nd MACP w.e.f 01.3.2017
2. Sh. Hans Raj, UDC, ICAR-CPRI, Shimla, granted 2nd MACP w.e.f 04.3.2017
3. Sh. Kamal Chand Verma, UDC, ICAR-CPRI, Shimla, granted 2nd MACP w.e.f 04.3.2017

4. Sh. Ashwani Gupta, ICAR-CPRI, Shimla, granted 2nd MACP w.e.f 01.3.2017
5. Sh. Ashok Kumar, LDC, CPRIC, Modipuram granted 2nd MACP w.e.f 31.3.2017
6. Sh. Ramesh Kumar Gupta, UDC, CPRS, Patna, granted 2nd MACP w.e.f 12.3.2017 (on review)
7. Sh. Sukh Pal Sharma, Asstt. CPRS, Jalandhar, granted 3rd MACP w.e.f. 31.10.2017
8. Sh. Jagdish Chand, Asstt. CPRI, Shimla, granted 3rd MACP w.e.f. 28.10.2017
9. Sh. Tej Singh, UDC, CPRI, Shimla, granted 2nd MACP w.e.f. 16.09.2017
10. Sh. Rakesh Negi, LDC, CPRI, Shimla, granted 2nd MACP w.e.f 18.10.2017
11. Sh. Raghubir Singh, LDC, CPRI, Shimla, granted 2nd MACP w.e.f 19.11.2017
12. Sh. Naresh Kumar, LDC, CPRS, Jalandhar, granted 2nd MACP w.e.f 27.12.2010

Promotions

1. Sh. Rakesh, UDC, CPRS, Jalandhar promoted to the post of Asstt. w.e.f. 11.9.2017
2. Sh. Mohinder Singh, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 08.9.2017
3. Sh. Narender Paul, LDC, CPRI, Shimla promoted to the post of UDC w.e.f. 08.9.2017
4. Smt. Sneha Lata, LDC, CPRIRS, Modipuram to the post of UDC w.e.f. 11.9.2017
5. Smt. Seema Verma, LDC, CPRIRS, Modipuram to the post of UDC w.e.f. 15.9.2017
6. Sh. Jai Ram Thakur, Asstt, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 13.10.2017 (A.N)
7. Smt. Meena Verma, Asstt, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 13.10.2017 (A.N)
8. Smt. IC Dharma Paul, Asstt, CPRS, Muthorai promoted to the post of Asstt. Admn. Officer w.e.f. 13.10.2017 (A.N)
9. Smt. Poonam Sood, Asstt, CPRI, Shimla promoted to the post of Asstt. Admn. Officer w.e.f. 13.10.2017 (A.N)
10. Smt. Babli Bhawant, Asstt, CPRS, Kufri promoted to the post of Asstt. Admn. Officer w.e.f. 29.12.2017
11. Sh. Sandeep Verma, UDC, CPRI, Shimla promoted to the post of Asstt. w.e.f. 28.11.2017

12. Sh. Santosh Kumar, CPRI, RS, Modipuram promoted to the post of Asstt. w.e.f 28.11.2017 (AN)
13. Sh. Daljit Singh, CPRS, Jalandhar promoted to the post of UDC w.e.f.23.10.2017 (AN)
14. Sh. Gokal Ram, CPRI, Shimla promoted to the post of UDC w.e.f.23.10.2017
15. Sh. Ashok Kumar, CPRI, RS, Modipuram to the post of UDC w.e.f 24.10.2017
16. Sh. Raghubir Singh, CPRI, Shimla to the post of UDC w.e.f. 28.11.2017

Retirements

1. Sh. Krishan Lal, AAO, CPRS, Gwalior on 05.4.2017 on VRS.
2. Sh AD Sharma AO, ICAR-CPRI, Shimla on 30.4.2017
3. Sh. PC Sharma, AAO, ICAR-CPRI, Shimla on 30.4.2017 Skilled Support Staff

Skilled Support Staff

Grant of MACP benefit

1. Shri Tapan Burman, SSS, CPRS, Patna, granted 3rd MACP w.e.f. 10.03.2017
2. Shri Roshan Lal, SSS, CPRI, Shimla, granted 3rd MACP w.e.f. 17.11.2017
3. Shri Kanhiya Prasad, SSS, CPRI, Shimla, granted 3rd MACP w.e.f. 27.11.2017
4. Shri Bir Bahadur, SSS, CPRI, Shimla, granted 3rd MACP w.e.f. 27.11.2017
5. Shri Sita Ram, SSS, CPRS, Kufri, granted 1st MACP w.e.f. 19.07.2017
6. Shri Madan Lal, SSS, CPRS, Kufri, granted 1st MACP w.e.f. 19.07.2017
7. Shri Jia Lal, SSS, CPRS, Kufri, granted 1st MACP w.e.f. 19.07.2017
8. Shri Roop Singh, SSS, CPRS, Kufri, granted 1st MACP w.e.f. 19.07.2017
9. Shri Hira Singh, SSS, CPRI, Shimla, granted 1st MACP w.e.f. 20.07.2017
10. Shri Mani Ram, SSS, CPRI RS, Modipuram , granted 1st MACP w.e.f. 21.07.2017
11. Shri Raj Pal, SSS, CPRI RS, Modipuram , granted 1st MACP w.e.f. 22.07.2017
12. Shri Parsu Ram, SSS, CPRS, Gwalior, granted 1st MACP w.e.f. 24.07.2017
13. Shri Bharat Singh, SSS, CPRS, Gwalior, granted 1st MACP w.e.f. 24.07.2017

14. Shri Punjab Singh, SSS, CPRS, Gwalior, granted 1st MACP w.e.f. 24.07.2017
15. Shri Ram Prakash, SSS, CPRS, Gwalior, granted 1st MACP w.e.f. 24.07.2017
16. Shri Manu Singh, SSS, CPRS, Gwalior, granted 1st MACP w.e.f. 24.07.2017
17. Shri J. Bhojan, SSS, CPRS, Muthorai, granted 1st MACP w.e.f. 25.07.2017
18. Smt. S.Pankjam, SSS, CPRS, Muthorai, granted 1st MACP w.e.f. 25.07.2017
19. Shri K.Ramasamy, SSS, CPRS, Muthorai, granted 1st MACP w.e.f. 25.07.2017
20. Shri Bishnu Rai, SSS, CPRS, Patna, granted 1st MACP w.e.f. 27.07.2017
21. Shri Ram Nath, SSS, CPRS, Jalandhar, granted 1st MACP w.e.f. 03.08.2017
22. Shri Jagnan Nath, SSS, CPRS, Jalandhar, granted 1st MACP w.e.f. 03.08.2017

New Appointment

1. Miss Kiran, Skilled Support Staff, CPRI, Shimla joined on 18.8.2017 (FN) on compassionate ground.

Retirements

1. Sh. Subhash, CPRS, Jalandhar on 30.6.2017.
2. Sh. Niril, CPRS, Jalandhar on 30.6.2017
3. Sh. Piar Chand, Skilled Support Staff, CPRI, Shimla retired on 31.10.2017(AN)
4. Sh. Ram Ekbal Rai, Skilled Support Staff, CPRS, Shilling retired on 31.12.2017 (AN).
5. Sh. Mangtey, SSS, CPRI RS Modipuram, retired on 31.01.2018
6. Sh. Ram Rattan, SSS, CPRS, Gwalior, retired on 31.01.2018
7. Sh. Khem Chand, SSS, CPRI, Shimla, retired on 28.02.2018
8. Sh. Ramji Lal, SSS, CPRS, Gwalior, retired on 28.02.2018
9. Ms. Niranjan Kaur, SSS, CPRS, Jalandhar, retired on 28.02.2018

Death:

1. Sh. Munna Singh, Skilled Support Staff, CPRS, Gwalior died on 18.9.2017.

Institute Budget for the year 2017-2018

Head	Allocation Govt. Grant	Allocation Internal Res. + Council Share	Total Allocation	NEH	TSP	Other than NEH/TSP	(Amount in Rupees) Expenditure Revenue Generation	Total Expenditure
<u>Grants in Aid - Capital Works</u>								
A.1 Land	0	0	0	0	0	0	11039144	11039144
B.1 Office Buildings	0	0	0	0	0	0	0	0
B.2 Residential Buildings	0	0	0	0	0	0	0	0
B.3 Other works	0	0	0	0	0	0	0	0
Total: Works	0	0	0	0	0	0	11039144	11039144
<u>Other Capital Expenditure</u>								
C. Equipments	600000	0	600000	0	0	603249	0	603249
D. Information Technology	200000	0	200000	0	0	194069	0	194069
E. Library Books and Journals	1000000	0	1000000	0	0	999840	0	999840
F. Vehicles and Vessels	0	0	0	0	0	0	0	0
G. Livestock	0	0	0	0	0	0	0	0
H. Furniture & fixtures	0	0	0	0	0	0	0	0
I. Others	0	0	0	0	0	0	0	0
Total: Other Capital Expenditure	1800000	0	1800000	0	0	1797158	0	1797158
Total Grants in Aid - Capital	1800000	0	1800000	0	0	1797158	11039144	12836302
<u>Grants in Aid - Salaries</u>								
<u>Establishment Expenses</u>								
A.1 Establishment Charges	328600000	0	328600000	0	0	328600056	0	328600056
A.2 Wages	400000	0	400000	0	0	399680	0	399680
A.3 Overtime Allowance	0	0	0	0	0	0	0	0
Total: Establishment Expenses	329000000	0	329000000	0	0	328999736	0	328999736
Total Grants in Aid - Salaries	329000000	0	329000000	0	0	328999736	0	328999736
<u>Grants in Aid - General</u>								
<u>Pension and Retirement Benefits</u>								
A. Pension & Other Retirement Benefits	226000000	0	226000000	0	0	225999436	0	225999436
Total: Pension and Retirement Benefits	226000000	0	226000000	0	0	225999436	0	225999436
<u>Travelling Allowances</u>								

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