

Annual Report 2020



ICAR-CENTRAL POTATO RESEARCH INSTITUTE
Shimla - 171 001, Himachal Pradesh

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ICAR-CPRI Annual Report-2020

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Editorial Board

Manoj Kumar, N.K. Pandey, Ravinder Kumar, V.K. Dua, Brajesh Singh, R.K. Singh, Vinay Bhardwaj, Sanjeev Sharma, J.K. Tiwari, Tanuja Buckseth, S.K. Luthra, Name Singh, Vinod Kumar, Sanjay Rawal & Anuj Bhatnagar.

Compilation and production

N.K. Pandey, Ravinder Kumar, DK Gupta & Rakesh Kumar

Photographs

DK Gupta

Published by

Dr. Manoj Kumar

Director (Acting)

ICAR-Central Potato Research Institute, Shimla-171 001 (Himachal Pradesh)

Email: directorcpri@gmail.com, director.cpri@icar.gov.in

Website: <http://cpri.icar.gov.in>

Phone: 0177-2625073

Fax: 0177-2624460

Designed and printed by

New Era Graphics

#Amrik Singh Building, Ground Floor,

Near IGNOU, Khalini, Shimla-171 002 (H.P.)

Ph.: 0177-2628276, 9218625002

Email: newera.sml@gmail.com

PREFACE

It is my great pleasure to present the Annual Report 2020 of ICAR-Central Potato Research Institute (CPRI), Shimla. Since inception of the institute in 1949, development of potato varieties and technologies has lead our country as the second largest producer of potato contributing to ~12% of global production. As per the first advance estimate for 2020-21 (DAC&FW), India the potato production is estimated to be 53.11 million tonnes from 2.25 million ha area with an average productivity of 23.60 t/ha. This significant growth became possible only after the development of technologies by the institute. This Annual Report presents an overview of research and development conducted at the institute during the year.

The enrichment of potato germplasm repository of the institute is a continuous process and presently it includes more than 4600 accessions. During 2020, a total of 49 accessions were imported from The Netherlands including 20 processing varieties for HZPC Mahindra and 29 processing varieties for Technico AgriSciences. New advanced stage hybrids/varieties namely HT/07-1329 was recommended for release in 38th Group Meeting of AICRP (Potato) held in 2020 via Zoom. New potato varieties namely Kufri Karan (late blight resistant), Kufri Chipsona-4 (Processing), Kufri Thar-1, Kufri Thar-2, Kufri Thar-3 (Drought tolerant), Kufri Manik (superior in mineral content), Kufri FryoM (French fry) and Kufri Sangam (table/processing) were notified in Oct., 2020 by Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, DAC, Government of India. 09 advanced stage hybrids namely MS/14-243 (Table), MSP/16-307, MSP/16-375 (nutritionally superior), J/12-10, J/12-54, J/12-146 (early bulking) MP/12-223 (processing), HT/12-834 (heat tolerant) and WS/09-609 (drought tolerant) were identified for introduction in AICRP for multi-location testing. Institute has developed diagnostic SSR marker to identify parents and progenies of multi-coloured fleshed potato (MP/4-816 x CP4242). In biotechnology, the global gene expression profiles indicated that the candidate genes probably play crucial roles in enhancing NUE in potato. In transcriptome analysis of mother plant and tissue culture-derived plant of Kufri Bahar, genome-wide DNA methylation pattern was analyzed at three cytosine contexts (CpG, CHG and CHH). A total of 81 genotypes (progenies and parents) were analysed by two well-characterized potato SSR markers (STU6SNRN and STI1KA), and developed a data matrix for genetic fidelity purpose and other applications. Institute has developed advance hybrids (NUE/15-8, NUE/15-14, NUE/23, and NUE/15-67) based on 20 traits of agronomic, physio-biochemical and NUE parameters. 28 promising transgenic lines of Kufri Girdhari expressing the CDF1.2 gene were characterized for early tuberisation under micro tuber production system. Apart from this, 22 different genes having major role in potato sprout development were identified for designing dsRNA. WOFOST crop growth model was used for impact assessment of climate change in MP. Considering the combined effect of temperature and CO₂ fertilization, the productivity of Kufri Badshah is likely to decline in 2030 (1.2%), 2050 (4%) and 2080 (6.9%) over the baseline under RCP 4.5. Similar trends were observed for Kufri Jyoti (1.6, 5.0 and 8.8%) and Kufri Pukhraj (9.7, 5.6 and 10.6%) for future climate scenarios of 2030, 2050 and 2080, respectively. In a study on GHG emissions from the potato fields, it was revealed that the cumulative emission of N₂O-N from different potato treatments varied from 0.34 to 2.04 kg ha⁻¹ and application of urea led to significant increase in N₂O emissions (11-86%) over the ammonium sulphate. Indo-Blightcast model findings revealed that the late blight favorable period is likely to be reduced in the studied districts Mansa, Ludhiana, Fategarh and Faridkot. A decision support system for SSNM was developed using QUEFTS Model for Punjab and Uttar Pradesh. A study on the combined application of superphosphate, rock phosphate and PSB in acid soils of Shillong showed that 30% of recommended P as starter dose is sufficient in acidic soils having high available P content. Under GAP, all treatment combinations, level of Pendimethalin, Chlorpyrifos, Imidacloprid and Mancozeb was below the Codex MRL. Thus, we can recommend their prescribed doses due to chemical residues under safe limits. Under mechanization project, a manually pulled and battery operated

spraying system was designed for safe and uniform application of pesticides/herbicides in field crops. Two new designs of women-friendly hand-tools were developed for quick transplanting of potato micro-plants, weeding, digging, earthing-up and scraping of soil. A solar drying unit has been developed for dehydration of potato chips/shreds/sticks. The CPRI-VEGFAST technology was also intended for kitchen gardening on the rooftops/yards/balconies especially in urban areas. A new design of minituber counting machine with counting capacity of 20,000 to 25,000 minitubers/hour was developed. Genetic diversity analysis of *Globodera pallida* population from Ooty (GpO) and Shimla (GpS) revealed that these two populations are not close to each other; Ooty (GpO:MW084957) population had more resemblance to European population whereas Shimla (GpS:MW084958) population was found close to Algeria, Scotland, UK and Portugal populations. A significant reduction was observed in PCN infestation from 51.25-62.85% in Fluensulfone 2% GR treatment as compared to untreated control. One step reverse transcriptase-recombinase polymerase amplification (RT-RPA) assays were developed for rapid detection of PVX and PVS from potato leaves and tubers (periderm). Batch certification of 7.47 lakh plants of potato and 2.00 lakh plants of apple was done under NCS-TCP, DBT Govt. of India. A combination of nine volatile oils was found highly effective for sprout suppression up to 250 days of storage at 10-12°C in large scale potato trials using five varieties. A method for quantification of individual anthocyanins was developed on HPLC. Two novel potato products viz. Potato Jalebi and Potato Fruit Cookies were developed and the technology of these products is ready for their commercialization. The final patent on “Composition exhibiting sprout inhibitory effect in potatoes” was filed in May 2020. During 2019-20, total production of 2869.98 tons nucleus and breeder seed was achieved from an area of 124.56 ha. A total 110 virus-free *in vitro* culture tubes of basic seed material of 21 varieties were also supplied to 10 different seed producing organizations in India. A survey was conducted in Haryana by interviewing 60 farmers of Kurukshetra district of Haryana. Kufri Pukhraj was found the most popular variety while Kufri Chipsona-3 and Corrolla red were also cultivated by farmers. A total of 236 FLDs were laid out in different potato growing areas of UP, MP, Bihar, Meghalaya, TN, Punjab. The institution also conducted 45 training programmes at the headquarters and its regional stations for the officials and farmers of the country. More than 20 exhibitions, fairs, celebration of important days, chat shows, kisan goshthees were also organized. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 08 live phone-in programmes on doordarshan and aakashwani. Under HRD Cell, 20 Scientists, 40 Technical officers and 10 Administrative officers were sent to participate in various training programmes and attended several seminars/ symposia/ workshops/ conferences etc.

I congratulate scientists and other staffs of the institute for carrying out outstanding research and development during the year. I extend my special thanks to the editorial team for making this report brief and timely publication. I would like to thank the QRT and RAC team for suggestions in refining our research. I am grateful to Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his support. I express my sincere thanks to DDG (HS), and ADG (HS-I) for providing necessary guidance.



(Manoj Kumar)
Director (Acting)

CONTENT

Introduction	1
Executive Summary	4
Research Programmes	10
Division of Crop Improvement & Seed Technology	12
• Management of potato genetic resources	12
• Breeding trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses	17
• Genetic enhancement of potato through molecular and genomic tools	35
• Development and production of nucleus and breeder seed of notified potato varieties through conventional and hi-tech systems.	44
Division of Crop production	55
• Impact, adaptation and management strategies for climate resilient potato production	55
• Nutrient and water management for improved productivity and sustainability of potato	61
• Technology development and refinement for potato and potato based cropping systems	70
Division of Plant Protection	85
• Biology, ecology and management of insects and nematode pests of potato	85
• Re-defining epidemiological parameters and management approaches for potato pathogens	96
Division of Crop Physiology, Biochemistry & Post-harvest Technology	111
• Post-harvest management and nutritional enhancement of potatoes	
Division of Social Sciences	121
• Transfer of potato technologies to stakeholders and assessment of their impacts	121
Library and Documentation Services	131
Publications	133
Institute Activities	145
Training and Capacity Building	151
Awards & Honours	154
Staff Position	156
Institute Budget	169



भारतीय
ICAR

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 five divisions namely, Division of Crop Improvement & Seed Technology Crop Production, Plant protection, 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 six regional stations located across the country viz. Modipuram (UP), 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 71 scientists, 133 technical staffs and 69 administrative staff & 82 Skilled Support Staff 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

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 five Divisions namely; Crop Improvement & Seed Technology; Plant Protection; Crop Production, Crop Physiology, Biochemistry & Post Harvest Technology and Social Sciences under 11 well defined research programmes. 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, NASE, NEC and UPCAR are also under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

STAFF & FINANCE

The institute has 472 sanctioned staff strength comprising of 87 scientific, 178 technical, 102 administrative and 105 supporting staff excluding RMP. The staff position as on 31.12.2020 was 355 including 71 scientific, 133 technical, 69 administrative and 82 supporting staff. In 2019-20, total allocation was ₹73,41,98,000/- and total expenditure was ₹73,16,45,765/-. The institute generated about ₹11 crore under Revolving Fund Scheme (RFS) by sale of breeder seed etc. During the year, one new Scientist joined the institute, 2 joined as inter-institutional transfer & one Scientist was promoted from Sr. Scientist to Principal Scientist. In technical category, 16 were promoted, 2 were transferred, 3 were retired and one resigned. Under administrative category, one was

joined, 5 were promoted, 2 were retired, 2 were transferred on selection basis, and 4 were granted financial up-gradation under MACP Scheme. In skilled supporting staff, 4 got grant of MACP benefit, 1 promoted, 9 retired and one transferred (Intra-Institutional).

FACILITIES

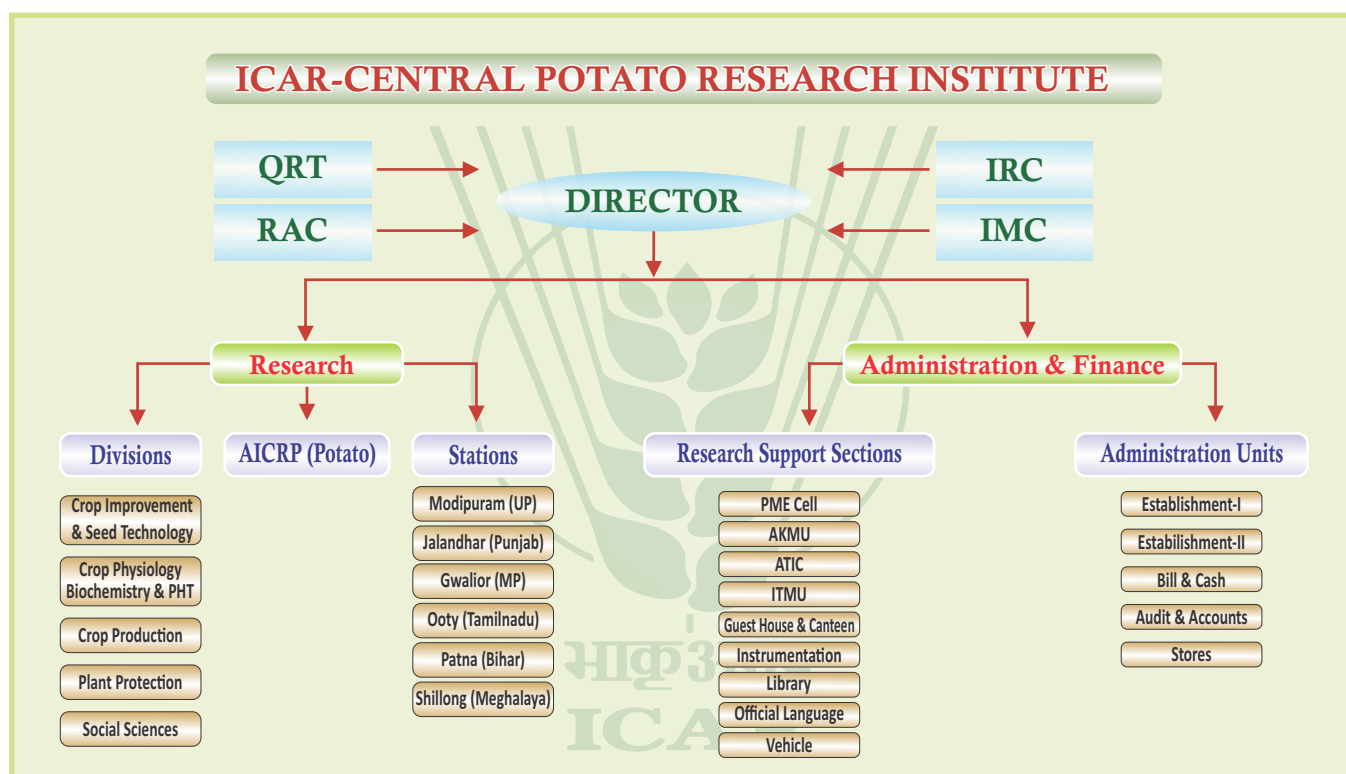
The institute created state-of-the-art laboratories for conducting basic and strategic research in the field of biotechnology, genetics and plant breeding, plant protection, soil science and agronomy, plant physiology, biochemistry, and post-harvest technology. The ICAR-CPRI is the first institute, among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

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

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 at ICAR-CPRI, Shimla, ICAR-CPRI, RS, Modipuram, ICAR-CPRI, RS, Patna and ICAR-CPRI, RS, Shillong for soil less disease free seed potato production. A BPD Unit has been established at ICAR-CPRI, RS, 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.



ICAR-CPRI, RS, Modipuram



ICAR-CPRI, RS, Patna



ICAR-CPRI, RS, Jalandhar



ICAR-CPRI, RS, Gwalior



ICAR-CPRI, RS, Ooty



ICAR-CPRI, RS, Shillong

EXECUTIVE SUMMARY

DIVISION OF CROP IMPROVEMENT & SEED TECHNOLOGY

“Management of potato genetic resources” is basic programme of the division which aims at collection, conservation, evaluation and documentation of germplasm. During the year, 49 accessions were imported from The Netherlands including 20 processing varieties for HZPC Mahindra and 29 processing varieties for Technico Agrisciences. Besides this, 14 potato land races were collected from different villages of Meghalaya state. The present germplasm collection at ICAR-CPRI consists of more than 4,600 accessions of cultivated, semi-cultivated and wild species from 30 countries. These are being conserved in field gene banks, in vitro repository and also as true seeds. A large number of accessions were evaluated for various biotic and abiotic stresses, keeping quality, processing attributes, quality attributes and also adaptability to various thermos-photoperiods and promising accessions were identified. Generated information has been maintained in electronic databases. Three elite genetic stocks were registered with the ICAR-NBPGR, New Delhi.

The hybridization programme resulted production of 5, 30, 789 true potato seeds from 358 crosses involving superior parents for yield, quality and resistance/tolerance to biotic and abiotic stresses. In all, 1, 96, 460 seedling were recovered from 5, 42, 278 true potato seeds of 271 crosses. In initial clonal generation, 26,219 clones are being evaluated. In advanced stage hybrids trials, 389 advanced clones are being assessed in 32 trials for yield, quality and resistance/tolerance to biotic and abiotic stresses. Investigated late blight resistance and keeping attributes of nutritionally superior advanced clones. Developed diagnostic SSR marker to identify parents and progenies of multi-coloured fleshed potato (MP/4-816 x CP4242). The finding suggests that STI0003 is a diagnostic marker to identify the advance clones with multi-coloured flesh tubers. Processing quality of genotypes during storage at 10-12°C with CIPC was done to identify the superior processing advanced clones. Based on consistently good performance over the years, 9 advanced stage hybrids namely MS/14-243 (Table), MSP/16-307,

MSP/16-375 (nutritionally superior), J/12-10, J/12-54, J/12-146 (early bulking) MP/12-223 (processing), HT/12-834 (heat tolerant) and WS/09-609 (drought tolerant) has been identified. Worked out optimum NPK requirement (kg/ha) of varieties/advanced clones namely, Kufri Neelkanth (240N, 60P, 120K), MS/9-2196 (240N, 60P, 160K), Kufri Sangam (240N, 40P, 160K), HT/7-113 (180N, 40P, 100K), WS/7-113 (180N, 40P, 100K). The response of Nitrogen was 240, 160, 240, 180 kg/ha for Kufri Thar-2, CP4393, MS/11-664 and WS/9-609, respectively. Crop geometry of 60x25cm and 66x20cm was found optimum for Kufri Neelkanth and Kufri Sangam. MS basal medium supplemented with NAA (2.5 µM), BA (4.2 µM) and GA₃ (1.37 µM), 32g l⁻¹ sucrose and 75 mM NaCl concentration was best for screening genotypes for salinity tolerance in potato. Twenty-seven diploid accessions of *Solanum tuberosum* were imported from USDA potato genebank including 12 accessions in TPS form and 15 accessions in-vitro form. Thirty-three clones of 12 accessions imported from USDA were evaluated for ploidy using flow cytometry and all were confirmed as diploids. Besides, among 38 in-vitro accessions, 28 accessions were confirmed as diploids. New improved advanced stage hybrids/varieties namely HT/07-1329 was recommended for release in 38th Group Meeting of AICRP (Potato) held during 28.09.2020 to 30.09.2020 via Zoom. New potato varieties namely Kufri Karan (late blight resistant), Kufri Chipsona-4 (Processing), Kufri Thar-1, Kufri Thar-2, Kufri Thar-3 (Drought tolerant), Kufri Manik (superior in mineral content), Kufri FryoM (French fry) and Kufri Sangam (table/processing) has been notified in October, 2020 by Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, Department of Agriculture and Co-operation, Government of India.

In Biotechnology programme, transcriptome analysis was performed to identify genes involved in high nitrogen use efficient potato cv. Kufri Gaurav grown under aeroponic conditions with precision phenotyping. As a result, identified genes under N stress that might be associated with enhancing

nitrogen use efficiency such as superoxide dismutase, GDSL esterase lipase, probable phosphatase 2C, high affinity nitrate transporters, sugar transporter, transcription factors so on. Comparative methylome and transcriptome dynamics was examined for tuber shape variation in a tissue culture-derived variant clone in potato cv. Kufri Bahar. This showed a few common genes in both particularly CpG and RNA-seq analyses such as 3-ketoacyl-CoA synthase 10, F-box family protein, early-responsive to dehydration 3 so on. Generated SSR fingerprints of interspecific potato somatic hybrids using SSR markers for genetic fidelity purpose. Developed nitrogen use efficient advanced hybrids *viz.*, NUE/15-8, NUE/15-14, NUE/23, and NUE/15-67 having higher yield and NUE traits for low N input agriculture. Phenotyped Kufri Girdhari transgenic lines expressing CDF1.2 gene for early tuberisation under long day environment and evaluated tuberisation performance of activation tagging Kufri Jyoti mutants under containment facility. Role of heat shock transcription factors (HSFs) in potato was deciphered and identified 15 genes in the potato genome. Further, standardized protocols for development of in vitro somaclonal variant by exposing callus cultures to Fe/Zn deficiency and revealed genes associated with iron stress response in potato. In silico analysis of starch branching enzyme was investigated. Twenty-four genes having major role in potato sprout development were identified for designing dsRNA based sprout suppressant in potato.

During 2019-20, total production of 2869.98 tons nucleus and breeder seed was achieved from an area of 124.56 ha. Out of which, 1932.49 tons production from 88.12 ha was through conventional and 937.49 tons from 36.44 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from conventional system was 67.33 and 32.67 through hi-tech system. A total 2029.41 tons of breeder seed was supplied to various government and private agencies. A total 110 virus-free *in vitro* culture tubes of basic seed material of 21 varieties were supplied to 10 different seed producing organizations in India and a revenue of Rs. 5,55,000/- has been generated. A total revenue of Rs. 8.6 crores have been generated by the disposal of breeder seed. Different varieties at different locations were considered to study the rate of production of cuttings (transplants). The first rounds of cuttings expand parent material in the first 4-6 weeks of production with the remaining

months dedicated to commercial production. Excellent results of ARC were recorded in Jalandhar and Modipuram with minimum 3-4 cuttings @ 6-8 tubers/cuttings. Results showed that the interaction effect between paclobutrazol concentration and treatment application time was significant on the number of mini-tubers, plant height and internodes distance traits. The maximum cost reduction (90 %) was observed when Isabgol alone was used as the gelling agent, followed by sago (88 %), sago + Isabgol (84 %), sago + agar (80 %), or Isabgol + agar (77 %). Similarly, the costs of water and carbon sources were reduced by 86% and 95%, respectively, by using low-cost substitutes. Significant differences in mini-tuber production, stolon number and length and root length were observed among stress treatments and cultivars. Low pH of nutrient solution at 3.5 @ 8 h with EC 2.0 dS m⁻¹ significantly increased most growth variables and exhibited faster tuberization, higher mini-tuber number and as well as significant increase in stolon number/plant and number of stolon branches/plant. The results revealed that the total number of tubers obtained per m² were significantly affected by intra-row spacing and were higher at closer spacing (30x10cm). The number of tubers followed a decreasing trend with increasing intra-row spacing.

DIVISION OF CROP PRODUCTION

WOFOST crop growth model was used for impact assessment of climate change in Madhya Pradesh. For the future climate scenarios while considering the combined effect of temperature and CO₂ fertilization, the productivity of Kufri Badshah is likely to decline in 2030 (1.2%), 2050 (4%) and 2080 (6.9%) over the baseline under RCP 4.5. Similar trends were observed for Kufri Jyoti (1.6, 5.0 and 8.8%) and Kufri Pukhraj (9.7, 5.6 and 10.6%) for future climate scenarios of 2030, 2050 and 2080, respectively. Simulation results for RCP 6.0 showed that when the combined effect of temperature and CO₂ fertilization is considered, the productivity of Kufri Badshah is likely to increase in 2030 (1.2%) but may decline in 2050 (0.2%) and 2080 (2.3%) over the baseline. Maximum increase in productivity, 46.4 to 47.5 t/ha (2.4%) in 2030 and decline in yield in 2050 (0.2%) and 2080 (4.1%) was noticed in Kufri Pukharaj. At Modipuram, sprinkler irrigation scheduled at 150% CPE produced significantly higher total tuber yield (43.3 t ha⁻¹) in comparison to 100% CPE which produced 40.4 t/ha. In another experiment, the mulching with paddy straw @ 5 t/ha gave significantly

higher tuber yield than the spray of chemical formulations (CFs) under drip and sprinkler irrigation. At Jalandhar, in Open Top Chamber (OTC) tuber yield of selected genotypes hybrids (HT/7-1105 and HT/7-1329) increased slightly with increased N (125% RDN) under all the conditions. Elevated CO₂ (600 ppm) positively affected tuber yield in all the genotypes at 100% RDN and excess N levels. In a study on GHG emissions from the potato fields, it was revealed that the cumulative emission of N₂O-N from different potato treatments varied from 0.34 to 2.04 kg ha⁻¹. Application of urea led to significant increase in N₂O emissions (11-86%) over the ammonium sulphate. GHG emission was significantly higher (18-54%) under band placed urea as compared to its broadcasting. N₂O emission was significantly highest for 270 kg ha⁻¹ band placed urea fertilizer.

Potential impact of climate change on potato late blight outbreak in Punjab was studied using Indo-Blightcast Model. The findings revealed that in general the late blight favorable period is likely to be reduced in all the studied districts except Mansa, Ludhiana, Fategarh and Faridkot where it is likely to remain as a threat in the future climate scenarios (2030 & 2050). At Modipuram, the effect of different dates of planting on late blight development was revealed that under highly susceptible group (Kufri Bahar & Kufri Sindhuri), highest AUDPC was recorded for 17th Nov planted Kufri Bahar followed by 2nd Nov planting, while in Kufri Sindhuri, highest AUDPC was recorded for 17th Oct planted crop followed by 17th November planting. These variations in AUDPC may be due to genetic make-up of the varieties and prevailing environmental conditions. A decision support system for SSNM was developed using QUEFTS Model for Punjab and Uttar Pradesh. Field experiments were carried out at Jalandhar and Modipuram to validate and calibrate QUEFTS model for NPK recommendation at Modipuram. QUEFTS model based NPK recommendations produced 25% higher yield at 75% NPK, 20% higher yield at 100% NPK and 17% higher potato yield at 125% NPK as compared to standard recommendation for the region. In order to generate judicious and precise fertilizer recommendations, the experiments were conducted at Jalandhar, Gwalior and Shillong using omission plot technique. At Jalandhar, N was the most yield limiting nutrient and its omission reduced potato yield to the tune of 57 %

followed by P (22 %) and K (19 %). At Gwalior, omission of N and P produced 26.5 t/ha, it reduced the yield by 15.5% followed by N omission (27.1 t/ha) which was ~13.5% lower than 100% RDF. At Shillong, N-omission significantly reduced the potato yield in all the treatments and it suggested that N is most limiting nutrient for potato production followed by P and K.

Experiment to determine starter dose of P fertilizer conducted at Jalandhar revealed that Kufri Jyoti produced highest tuber yield at 40% RDP, which was at par with 50 and 100% RDP or FYM alone. A study on the combined application of superphosphate, rock phosphate and PSB in acid soils of Shillong showed that SSP+ RP (25:75) @ 140 kg P₂O₅ ha⁻¹ along with PSB proved combination. Likewise, it was also suggested that 30% of recommended P as starter dose is sufficient in acidic soils having high available P content. Split and foliar application of potassium led to highest total tuber yield while using 50% RDK as basal + 25% RDK at earthing up + two foliar applications @ 1.2% K₂O at 25 and 50 DAP. For judicious P-management, the application of lime and PSB alongwith SSP is highly beneficial in low pH soils. At Modipuram, effect of varieties and irrigation was significant on total tuber yield and tuber numbers. Potato yields were in the order of Kufri Khyati>Kufri Pukhraj>Kufri Anand>Kufri Bahar>Kufri Garima>Kufri Sadabahar. The yield of all varieties was highest with drip irrigation at 2.5 IW:CPE. Likewise, Kufri Mohan through drip fertigation produced highest tuber yield at 125% recommended NK, which was statistically at par with 100% recommended NK. Pot experiment study was carried out to evaluate the rice husk ash (RHA) as a source of phosphorus and found that application of 10 and 20 g RHA significantly increased the plant height, above ground total biomass and phosphorus content in the above ground biomass over control. A low-cost technology package is underway using the organic and inorganic sources of nutrients and micro-irrigation methods so as to economize the water and N through agronomic manipulations in potato.

Under good agricultural practices (GAP), four chemicals applied at recommended levels were estimated in potato tubers in a field study conducted at Shimla. In all treatment combinations, level of Pendimethalin, Chlorpyrifos, Imidacloprid and Mancozeb was below the Codex MRL. Thus, we can recommend their prescribed doses due to chemical

residues under safe limits. For early potatoes for exports, the Western Uttar Pradesh has ample potential. Hence, a field experiment was initiated with five promising potato varieties and hybrids *viz.*, K. Chipsona-3, K. Sangam, K. Neelkanth, HT/07-1329 and WS/07-113. At 60 days, K. Neelkanth (30%) recorded maximum proportion of export grade tubers (>55 mm) followed by heat tolerant hybrid HT/07-1329 (23%) and K. Sangam (22%). K. Neelkanth (53%) also had highest proportion of exportable tuber yield followed by K. Sangam (46%) and HT/07-1329 (44%). At Gwalior for organic seed production, 100% FYM+ neem-cake exhibited better yield over inorganic treatments. The de-haulming at 90 days resulted in highest total tuber and bigger seed size. The copper based fungicides and neem-oil were found useful for management of late blight in organic farming of potato. Organic management of black scurf of potato (for major soil and tuber borne diseases of potato) with buttermilk + copper rod, waste decomposer and one fungal bio-agent (up to 70% DI) showed better efficacy than untreated control (95% DI). At Shimla, in a field experiment initiated during *Kharif*2020 consisting four cropping systems (potato-garden pea, potato-broccoli, potato-garlic, potato-*Matricaria*), it was indicated that application of 100% RDF + FYM @ 10 t/ ha + PSB + AM-fungi in potato was beneficial to harness ~10.7 % higher tuber yield over the 100% RDF across different cropping systems. At Gwalior, rice yield was highest with 100% RDF followed by decomposed crop residue + Azotobacter + PSB + Jeevamrit under rice-potato cropping system.

Under precision farming, a comparative analysis of drone based and conventional spray against late blight disease and potato vectors was done at Modipuram. A soilless seed potato production unit has also been developed for rapid seed multiplication. A formulation for enhanced tuber number and size was prepared which ready for filing patent by CPRI-ITMC. Under mechanization project, a manually pulled and battery operated spraying system was designed at Jalandhar for safe and uniform application of pesticides/herbicides in field crops. Two new designs of women-friendly hand-tools were developed for quick transplanting of potato micro-plants, weeding, digging, earthing-up and scraping of soil. A solar drying unit has been developed for dehydration of potato chips/shreds/sticks. It was observed that the temperature inside drying unit was

approximately 15-22°C higher as compared to ambient diurnal temperature. The CPRI-VEGFAST technology was also intended for kitchen gardening on the rooftops/yards/balconies especially in urban areas. A new design of minituber counting machine with counting capacity of 20,000 to 25,000 minitubers/hour was developed under this project.

DIVISION OF PLANT PROTECTION

Insect vectors (aphids, whiteflies, and leafhoppers), soil pests and mite were monitored at Gwalior, Jalandhar and Modipuram on potato and alternate host plants during 2019-20. *Myzus persicae* first appeared on the potato plants in the 1st week of November at Jalandhar and crossed critical limit in the 3rd week of January. *M. persicae* did not cross the critical level till last week of December at Modipuram. The flight activity of the aphids, monitored with yellow sticky traps indicated that the flight was highest during the last week of October to first week of November, and after the third week of February. The population of whitefly remained above economic threshold till the 2nd week of November and after that less than one whitefly per plant was recorded. The population of leaf hopper remained above ETL (1 hopper/leaf) throughout the crop growth in the early crop except last week before haulm cutting at Modipuram. The leaf miner was observed infesting the potato fields in the Nilgiris hills with 92-100% incidence (flies/maggots/mines) and the intensity of leaf damage was up to 100%. Studies on temperature dependent development of peach-potato aphid, *Myzus persicae* (Sulzer) on potato revealed that the aphid can survive from 4 to 31°C on the crops. The winged morphs have significantly higher thermal requirement as compared to the wingless morphs. The genome size of *Macrosiphum euphorbiae* (Thomas) was estimated as 0.53pg or 519.4 Mbp by flow cytometry. The somatic hybrid LES-29 showed least preference for whitefly egg laying whereas, Kufri Himalini recorded the highest egg laying. Results of screening of potato varieties against PTM revealed variation in the egg laying on the tested varieties. The landing rate of whiteflies was considerably reduced in the plots covered with straw or plastic mulch. The effect of plastic mulches was most significant against aphids followed by that of raw straw mulch. Spinosad (@ 0.75 ml/l spray) found effective in reducing aphid population and was on par with standard check Imidachloprid @ 0.5 ml/l. Abamectin benzoate @ 0.75 ml/l spraying found

efficient against Leaf hoppers population and whiteflies was significantly reduced in Spinosad @ 1 ml/l spray. Bio-control potential of *Steinernema cholashanense* (Nguyen) on larval and pupal stages of potato tuber moth, *Phthorimaea operculella* (Zeller) was evaluated. *S. cholashanense* is capable of infecting larval and pupal stages of *P. operculella* under laboratory conditions.

Drenching with dsRNA based formulations of pathogenicity genes responsible for locomotory (*flp32c*) and sensory function (*ams1*) resulted in enhanced infestation in case of *flp32c* silenced nematode but premature death of J₂s because of food reserves depletion due to increased locomotion. While, there was low infestation in case of *ams1* dsRNA treated roots which is responsible for locating the host. Genetic diversity analysis of *Globodera pallida* population from Ooty (GpO) and Shimla (GpS) revealed that these two populations are not close to each other; Ooty (GpO:MW084957) population had more resemblance to European population whereas Shimla (GpS:MW084958) population was found close to Algeria, Scotland, United Kingdom and Portugal populations. The efficacy of new nematicide, Nimitiz (Fluensulfone 2% GR) (@ 0.5gm/plant) was checked on PCN population under pot condition along with untreated control. There was a significant reduction in PCN infestation from 51.25-62.85% in Fluensulfone 2% GR treated pots as compared to untreated control. *Paecilomyces lilacinus* @ 20 kg/ha was found more effective in reducing the PCN populations (Rf-1.4) followed by carbofuran 3G @65 kg/ha (1.6) compared to untreated control. The body length of *S. cholashanense* in all the nematode growth stages (infective juveniles, males, and females) of the Indian isolate was found smaller than the original description of *S. cholashanense* from China.

Results of survey conducted for dry rot prevalence in cold stores of Punjab and western Uttar Pradesh revealed the incidence of disease in the range of 3-16% and the association of *Fusarium oxysporum*, *F. solani*, *F. sambucinum* and *F. verticilloids* in causing dry rots in the surveyed region. *F. sambucinum* was found most aggressive in causing dry rot in tubers. Isolates of *Alternaria* species collected across agro-ecologies have shown variation in colony character and spore size. Isolates of *Phytophthora infestans* were observed sensitive to new molecules (cymoxanil,

dimethomorph, fenamidone and oxathiapiprolin). Indo-Blightcast model predicted appearance of late blight accurately across agro-ecologies and accordingly agr-advisories were issued for its management. Besides, model for prediction of early blight was also validated for terai region of Uttarakhand (Pantnagar) and plateau region of Maharashtra (Pune). Application of dimethomorph @ 0.1 %, Fluopicolide 62.5+ propamocarb hydrochlorid 625 SC @ 0.3% and Cyazofamid @ 0.04% were found effective against late blight. Spray schedule of mancozeb 75% @ 0.2% (before the appearance of disease) followed by azoxystobin 11.5% + mancozeb 30% WP @ 0.25% (at onset of the disease) and one more spray of azoxystobin 11.5% + mancozeb 30% WP @ 0.25% (after 7 days of second spray) recorded lowest disease severity. Application of chlorine dioxide (0.03%) resulted in significant reduction in common scab severity as compared to control. In initial screening, three cultures namely “Badami”, “Champaran Lal” and “Assomia Alu” had shown some degree of resistance against *Ralstonia solanacearum* while clones of “Phulbani Local” were found susceptible this year.

Developed protocol to extract high-quality RNA from polysaccharide-rich tissues of potato tuber i.e. sprouts and periderm and utilized for RT-LAMP based detection of PSTVd directly from the tubers. Besides, one step reverse transcriptase-recombinase polymerase amplification (RT-RPA) assays were developed for rapid detection of *Potato virus X* and *Potato virus S* from potato leaves and tubers (periderm). Transgenic lines developed for ToLCNDV- potato (GTLC2-127 and KPLC2-53) and PVY (KPYS-13, KPYS-20) resistance were screened this year also and found resistant to respective viruses. Identified plant based anti-viral compounds from *Camellia sinensis*, *Bougainvillea*, *Mirabilis*, *Solanum chaocence*, *Ricinus* seed and *Biden pilosa* that activated plant defence response against PVY. Studies on the effect of Acquisition Access Period (AAP) and Inoculation Access Period (IAP) on transmission of ToLCNDV-potato by *Bemisia tabaci* (Asia II5) revealed that at least 30 minutes period for acquisition access and inoculation access are needed to transmit the virus. Batch certification of 7.47 lakh plants of potato and 2.00 lakh plants of apple was done under NCS-TCP by testing mother cultures and random samples of standing crops.

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

A combinations of nine volatile oils was found highly effective for sprout suppression up to 250 days of storage at 10-12°C in large scale potato trials using five varieties. A method for quantification of individual anthocyanins was developed on HPLC, which may give precise results of anthocyanins. An alternative method with savings on labour and sample was developed on YSI analyzer for sugars analysis. Identification, cloning and characterization of a new isoform of Zeaxanthin epoxidase gene from potato was done to target improvement in nutritional value of potatoes. Storage and Retrogradation experiments were done on potatoes, which showed enhancement in resistant starch and lowering of glycemic index and glycemic load in potatoes after storage up to 48 hours. Addition of guar gum at 0.5-1% decreased the total carbohydrate in boiled potatoes up to 32%, it also decreased the glycemic index from high to medium range in varieties like K. Chipsona-1 and K. Bahar. A modified procedure for production of cold water soluble potato starch was developed, which solubilizes almost 100% starch in cold water. The procedure for bio-ethanol production from potato peel waste was also developed with high efficiency of up to 84g/L of bio-ethanol. Two novel potato products viz. Potato Jalebi and Potato Fruit Cookies were developed and the technology documents have been submitted to

ITMU for their commercialization. The final patent on “Composition exhibiting sprout inhibitory effect in potatoes” was filed in May 2020.

DIVISION OF SOCIAL SCIENCES

The varietal replacement rate in Punjab was estimated by interviewing 90 farmers (45 each from Jalandhar and Moga districts). The weighted average age of improved varieties was found to be about 38 years. In Haryana, a survey was conducted by interviewing 60 farmers of Kurukshetra district of Haryana. Kufri Pukhraj was the most popular variety while Kufri Chipsona-3 and Corrolla red were also cultivated by farmers. The weighted average age of improved varieties was found to be about 21.5 years in Haryana. For popularization of technologies developed by the institute, more than 236 FLDs were laid out in different potato growing areas of UP, MP, Bihar, Meghalaya, TN, Punjab. The institution also conducted 45 training programmes at the headquarters and its regional stations for the officials and farmers of the country. More than 20 exhibitions, fairs, celebration of important days, chat shows, kisan goshthees were also organized. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 08 live phone-in programmes on doordarshan and aakashwani. Under HRD Cell, 20 Scientists, 40 Technical officers and 10 Administrative officers were sent to participate in various training programmes and several attend seminars/ symposia/ workshops/ conferences etc.



RESEARCH PROGRAMMES

Sr. No.	Research Programmes & Institute Code No.	Programme Leader and Associates
1.	Management of potato genetic resources HORTCPRISIL202000300142	PI: Dr. Vinod Kumar. Associates: Drs. Vinay Bhardwaj, Salej Sood, Jagesh K Tiwari, Dalamu, G Vanishree, Kumar Nishant Chourasia, VU Patil, Ashwani Kr. Sharma, Tanuja Buckseth, Raj Kumar, Ratna Preeti Kaur, SK Luthra, Babita Chaudhary, Pooja Mankar, Shambhu Kumar, EP Venkatasalem, Divya K Lekshmanan, Arvind Kumar Jaiswal, Name Singh, Bandana, Anuj Bhatnagar, Sanjeev Sharma, Baswaraj Raigond, Ravinder Kumar, Gaurav Verma, Clarissa Challam, Janani P., Priyank Hanuman Mhatre, Aarti Bairwa, Kailash Chandra Naga, Rahul Kumar Tiwari, Jagdev Sharma, Som Dutt, Pinky Raigond, Sarla Yadav, Shruti Gupta, Kameshwar Sen, Vineet Sharma, Munna Lal
2.	Breeding trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses HORTCPRISIL202000400143	PI: Dr. SK Luthra. Associates: Drs. Babita Chaudhary, Dalamu, Jagesh K Tiwari, G Vanishree, Pinky Raigond, Brajesh Singh, Jagdev Sharma, VK Dua, Arvind Kumar Jaiswal, Mehi Lal, Sanjay Rawal, Milan Kumar Lal, Raj Kumar, Ratna Preeti Kaur, Shambhu Kumar, Sarla Yadav, VK Gupta, Vinay Bhardwaj, Bandana, Salej Sood, Kumar Nishant Chourasia, Sanjeev Sharma, EP Venkatasalem, Priyank Mhatre, Clarissa Challam, Aarti Bairwa, Baswaraj Raigond, Sundaresha S., Ravinder Kumar, Gaurav Verma, Kailash Chandra Naga, Vinod Kumar, Ashwani K. Sharma, Raj Kumar Rana, Devendra Kumar, Name Singh, Som Dutt, Sugani Devi, Sushil Sudhakar Changan, Anuj Bhatnagar, Manoj Kumar, Prince Kumar, Hemant Kardile.
3.	Genetic enhancement of potato through molecular and genomic tools. HORTCPRISIL202000500144	PI: Dr. Jagesh K Tiwari. Associates: Drs. VU Patil, Sundaresha S, Som Dutt, Hemant Kardile, Vinay Bhardwaj, Salej Sood, G Vanishree, Kumar Nishant Chourasia, Shashi Rawat, Brajesh Singh, Pinky Raigond, Milan Kumar Lal, Shushil Sudhakar Changan, Dharmendra Kumar, Sanjeev Sharma, Baswaraj Raigond, Aarti Bairwa, Jagdev Sharma, VK Dua, Rajesh Kumar Singh, Tanuja Buckseth, Vinod Kumar, SK Luthra, Devendra Kumar, Manoj Kumar, Ratna Preeti Kaur, Ashwani K. Sharma, Dalamu, Priyank Mhatre, EP Venkatasalem, Clarissa Challam,
4.	Impact, adaptation and management strategies for climate resilient potato production HORTCPRICIL201600100139	PI: Dr. VK Dua. Associates: Drs. Shashi Rawat, Sanjay Rawal, SP Singh, Paresh Chaukhande, Sunayan Saha, Name Singh, Devendra Kumar, Vijay Paul, Prince Kumar, Jagdev Sharma, Anil Sharma, VK Gupta, Som Dutt, Hemant Kardile, Brajesh Nare, Sanjeev Sharma, Mehi Lal, Anuj Bhatnagar, Mohd. Abbas Shah, Subhash Katore, Subhash Chander, Rabindra Padariya, Preeti Singh, Subhash, Yogesh Gupta, Sushil Kumar,
5.	Nutrient and water management for improved productivity and sustainability of potato HORTCPRISIL202000200141	PI: Dr. Name Singh. Associates: Drs. Manoj Kumar, SP Singh, Prince Kumar, Sunayan Saha, RK Singh, Sunayan Saha, VK Dua, Jagdev Sharma, Shashi Rawat, Anil Sharma, Manoj Kumar Nanda, Brajesh Nare, Anil K Choudhary, Janani P., Divya K Lekshmanan, Dharmendra Kumar, Priyank Mhatre, EP Venkatasalam,

6.	Technology development and refinement for potato and potato based cropping system HORTCPRISIL202000100140	PI: Dr. Sanjay Rawal. Associates: Drs. Pooja Mankar, Sanjeev Sharma, SK Luthra, VK Gupta, Devendra Kumar, Mehi Lal, Subhash S., Pinky Raigond, SP Singh, Subhash Katare Murlidhar Sadawarti, Raj Kumar Rana, Anil Sharma, Anil K Choudhary, RK Singh, Janani P, VK Dua, Clarissa Challam, N Sailo, Anuj Bhatnagar, Vinay Sagar, Mohd. Abas Shah, Rahul Bakade, Paresh Chaukhande, Brajesh Nare, Sukhwinder Singh, Sugani Devi, Som Dutt, Ratna Preeti Kaur, Sunil Gulati, Prince Kumar, Kailash C Naga, Dharmendra Kumar,
7.	Biology, ecology and management of insects and nematodes pests of potato. HORTCPRISIL202000700146	PI: Dr. Anuj Bhatnagar. Associates: Drs. Subhash Katare, Mohd. Abas Shah, Kailash Naga, Subhash S., Aarti Bairwa, Priyank Mhatre, Baswaraj Raigond, Ravinder Kumar, Rajesh Kumar Singh, Jagesh Tiwari, Kapil Kumar Sharma, Sanjeev Sharma, Shashi Rawat, Rahul Bakade, Kamala Jayanthi, Jagdev Sharma, Gaurav Verma, N Sailo, Rahul Kumar Tiwari, EP Venkatasalam, Ashwani Dr. Sundaresha S., Tanuja Buckseth, Dalamu,
8.	Re-defining epidemiological parameters and management approaches for potato pathogens HORTCPRISIL202000600145	PI: Dr. Sanjeev Sharma. Associates: Vinay Sagar, Sundaresha S., Ravinder Kumar, Mehi Lal, Rahul Kumar Tiwari, Rahul Bakade, Mohammad Abbas Shah, Shashi Rawat, Jagdev Sharma, Vinay Bhardwaj, Baswaraj Raigond, Gaurav Verma, Kailash Naga, Subhash S, Murlidhar Sadawarti, Subhash Katare, Pinky Raigond, Tarvinder Kochhar, CM Bisht, Subhash Kumar,
9.	Post-harvest management and nutritional enhancement of potatoes HORTCPRISIL202000800147	PI: Dr. Brajesh Singh. Associates: Drs. Som Dutt, Pinky Raigond, Sushil Changan Sudhakar, Milan Kumar Lal, Dharmendra Kumar, Devendra Kumar, Bandana, Arvind K Jaiswal, N Sailo, SK Luthra, Ratna Preeti Kaur, Sundresha S., Hemant Kardile, Vinay Sagar, Baswaraj Raigond, Rahul Kumar Tiwari, Jagdev Sharma, Sanjay Rawal, Pynbianglang Kharumunid, Sukhwinder Singh, Brajesh Nare, Vineet Sharma, Yogesh Gupta, Shelly Chopra,
10.	Transfer of potato technologies to stakeholders and assessment of their impacts HORTCPRISIL202000900148	PI: Dr. NK Pandey. Associates: Drs. Pynbianglang Kharumnuid, RK Singh, Shashi Rawat, Ashok Chauhan, Arjun K. Sharma,
11.	Development and production of nucleus and breeder seed of notified potato varieties through conventional and hi-tech systems. HORTCPRISIL202001000149	PI: Dr. Rajesh Kumar Singh. Associates: Drs. Tanuja Buckseth, Ashwani Kr. Sharma, Manoj Kumar, Vinay Singh, Raj Kumar, Mohd. Abbas Shah, SP Singh, Subhash Katare, Murlidhar Sadawarti, Shambhu Kumar, RK Singh, N Sailo, EP Venkatasalem, Jagesh Tiwari, Sukhwinder Singh, Vinay Singh, Clarissa Challam, Pinky Raigond, Ratna Preeti Kaur, Sugani Devi, Sushil Sudhakar Changan, Anil K Choudhary, Dhruv Kumar, Sunayan Saha, Prince Kumar, RK Samadhiya, Parvesh Jassal, Sumita Sharma, Harveer Singh, KP Singh, Satinder Kumar, Jasveer Singh, Pushpender Kumar, Akhilesh Kumar, Arun Kumar Singh, YP Singh, Sanjay Sharma, Sidharth Saroha



DIVISION OF CROP IMPROVEMENT & SEED TECHNOLOGY

PROGRAMME: MANAGEMENT OF POTATO GENETIC RESOURCES

Genetic resources of a crop are the basic raw material required for its genetic improvement. The main activities of this interdisciplinary programme are to import the germplasm, conserve the available collection safely, evaluate the collection for important biotic and abiotic stresses, and document the information in an easily retrievable form for use by the researchers.

Collection

A total of 49 accessions were imported from The Netherlands including 20 processing varieties for HZPC Mahindra and 29 processing varieties for Technico Agrisciences. During the year 54 accessions free from quarantined pests were added to germplasm repository. Besides this, 14 potato land races were collected from different villages of Meghalaya state. Presently, more than 4600 accessions of cultivated and wild potato species, obtained from 30 countries are conserved at the institute.

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	58	60		60	
Advanced hybrids	86	50	-	96	
Indigenous varieties	51	107	-	107	
Indigenous samples	97	42		97	
Exotic	1837	2700	-	2950	30
b) Andigena	701	77	-	762	5
c) Wild/ semi -cultivated sps.	119 (40 species)	130 (29 species)	294 (70 species)	540 (125 species)	5
Total germplasm				4612	

Conservation

Field conservation: One thousand five hundred and ninety Tuberosum accessions, 701 Andigena accessions and 63 indigenous samples were maintained in the fields at Jalandhar. Nearly 1335 Tuberosum accessions and 110 indigenous samples were maintained in the fields at Kufri. Besides this, 159 Tuberosum accessions were also maintained at Modipuram. In wild species, 347 clones of 119 accessions representing 40 Solanum species were multiplied for maintenance breeding whereas, 294 accessions of 70 species were maintained in TPS form. In total, 540 accessions (in tuber / TPS/ *in vitro* form) of 125 species were conserved at CPRI, Shimla.

***In vitro* conservation:** Nearly 2700 Tuberosum

accessions and 130 accessions of 29 wild species were maintained in *in-vitro* form. Minutubers of 182 accessions from *in vitro* repository were produced and added to the germplasm collection maintained under field conditions at Kufri/ Modipuram. Mericlones of different hybrids and varieties were excised and tested for their freedom from all viruses. During this year, 4 varieties, namely Kufri Sahyadri, Phulwa Splashed, Kufri Sangam and Badami were made free from all viruses.

Evaluation

Adaptability:

Temperate long days

Kufri: In single row trial, 88 accessions were evaluated

along with Kufri Jyoti, Kufri Himalini and Kufri Girdhari as controls. Six accessions namely CP2085, CP3631, CP4499, CP4502, CP4510 and CP4523 out-yielded the best control Kufri Himalini (251g/plant). Among these 4 accessions namely CP2085, CP3631, CP4499 and CP4510 were promising to late blight also.

Sub-tropic short days:

Jalandhar: One hundred (100) Tuberosum accessions were evaluated under spring planting conditions. The yield of germplasm accessions ranged from 30 to 280 g/plant, while best control variety was Kufri Jyoti (200 g/plant). The other control Kufri Pukhraj yielded 190g/plant. Promising accessions were: CP3318 (280 g/plant) and CP2148 (250g/plant).

Modipuram: Under early planting, 134 Tuberosum genotypes, including germplasm lines, advance hybrids and control varieties were evaluated under heat stress conditions in a replicated trial at 75 DAP. Genotypes namely MF 1, Kufri Lima, MS/14-0243, MS/15-758 and CP 4491 were identified based on at par performance with heat tolerant variety Kufri Surya (207g/plant). These genotypes fulfilled the criteria of $\geq 77\%$ germination, $\geq 174/216$ gram marketable/ total yield per plant, $\leq 15\%$ mite burn and $\leq 13\%$ hopper burn.

Under normal planting, sixty-one genotypes, including germplasm lines, advanced stage hybrids and control varieties were evaluated in a replicated trial at 90 DAP. Promising genotypes namely CP3273, CP3368, CP3470, CP4143, CP4149, Kufri Arun, Kufri Neelkanth, Kufri Bahar, Kufri Lima, Kufri Sindhuri, SKL2019 and Kufri Lalit were identified based on genotypes fulfilling the criteria of $\geq 87\%$ germination, $\geq 496/515$ gram marketable/ total tuber yield/plant and $\geq 18\%$ tuber dry matter.

Reaction to late blight: Eighty-eight tuberosum accessions including controls Kufri Jyoti, Kufri Girdhari, and Kufri Himalini were screened for foliar blight resistance under natural open epiphytotic conditions at Kufri. Based on late blight incidence recorded three times at interval of seven days between two subsequent readings, 17 accessions viz., CP2167, CP2336, CP2354, CP2370, CP3203, CP3258, CP3547, CP3664, CP4428, CP4429, CP4430, CP4498, CP4499, CP4501, CP4510, CP4520 and CP4521 were highly resistant (AUDPC < 250) while only 4 accessions namely CP1424, CP1449, CP1588 and CP4228 were resistant (AUDPC 251-350). Seventeen accessions were moderately resistant (AUDPC 351-650) and remaining 47 genotypes were

either susceptible (AUDPC 651-1200) or highly susceptible (AUDPC > 1200).

By detaching leaf method, 51 germplasm accessions were tested for foliage resistance to late blight. Nineteen accessions (CP Nos. 1085, 1143, 1163, 1197, 1235, 1239, 1310, 1315, 1316, 1317, 1318, 1324, 1325, 1340, 1344, 1357, 1338, 1363 and 1371) were highly resistant, whereas 22 accessions were resistant. Remaining accessions were either moderately resistant or susceptible. Out of 51 accessions tested for tuber resistance by tuber slice method, six accessions (CP Nos. 1057, 1160, 1162, 1310, 1328 and 1344) were highly resistant and seven accessions namely CP Nos. 1143, 1207, 1235, 1330, 1339, 1375 and 1379 were resistant. Remaining accessions were either moderately resistant or susceptible.

Viruses: Fifty-one germplasm accessions were screened for resistance through DAS-ELISA against PVX and PVY. Thirty-five accessions namely CP Nos. 1012, 1057, 1061, 1123, 1137, 1159, 1162, 1163, 1181, 1187, 1207, 1215, 1238, 1239, 1304, 1310, 1314, 1317, 1318, 1324, 1325, 1326, 1328, 1329, 1330, 1339, 1340, 1344, 1357, 1358, 1363, 1365, 1375, 1377 and 1435 had combined resistance to PVX and PVY while 41 and 40 accessions showed resistance to PVX and PVY, respectively.

A total of 23 *in vitro* accessions found positive for PSTVd during previous years were tested for its confirmation through RT-PCR analysis. All of them were found infected to PSTVd. The infected accessions are being cleaned through long term conservation.

Leaf hopper and mites: Out of 78 accessions, 28 accessions (CP Nos. 1932, 3319, 3322, 3341, 3383, 3450, 3452, 3470, 3495, 3499, 4149, 4238, K. Sindhuri, K. Ganga, K. Lima, K. Surya, K. Pukhraj, K. Garima, FL-2215, Santana, Nafida, Sassy, Crisps4all, Farida, Lady Rosetta, Columba and Dolly) had hopper burn below 1%. No mite damage was observed in all the lines.

Cyst nematodes: Seventy-one tuberosum accessions were screened for potato cyst nematode (*Globodera rostochiensis* and *G. Pallida*) resistance through root ball technique under glasshouse condition at Kufri. Based on the cyst count at 55 days after planting, 8 accessions were highly resistant to both PCN species & these will be confirmed during next cropping season.

Keeping quality: Ninety-nine accessions were evaluated for keeping quality at room temperature

(14-38°C, 44-75% RH) in comparison to three control cultivars namely, Kufri Dewa, Kufri Ashoka and Kufri Pukhraj. Periodical observations on weight loss, sprouting and rotting in tubers were recorded at 30 day interval up to 90 days of storage (DOS). Firmness was recorded on a scale of 1-5 with score 5 assigned to most firm as freshly harvested/cold stored potatoes. Accessions were rated in different categories on the basis of storage performance viz., weight loss, rotting, total loss and physical appearance of tubers after 90 DOS.

Out of the 99 accessions only 2 accessions (CP 1578 & CP 2176) were found as best keeper having less than 10% total storage losses, whereas 24 accessions (CP Nos.1137, 1378, 1441, 1445, 1468, 1538, 1556, 1559, 1571, 1589, 1632, 1757, 2023, 2058, 2102, 2124, 2149, 3084, 3112, 3116, 3326, 3370, 3451, 3497) as good keeper with storage losses in the range of 10.00 to 15.00%.

Chipping and physico-chemical constituents: At Jalandhar, 99 Tuberosum accessions were evaluated for processing quality parameters viz. chip colour, dry matter and reducing sugar and sucrose contents. Based on chip colour (acceptable score up to 3 on 1-10 scale of increasing dark colour), dry matter (>21%) and reducing sugar (<100 mg/100g fresh tuber wt.), four accessions (CPNos.1608, 2060, 3502 and 3503) were found highly suitable for chipping.

Seventy-five accessions were also evaluated for vitamin

C content which varied widely between 14.89 to 43.21 (mg/100 g fr.wt) with minimum and maximum values registered by CP 2298 and CP2333, respectively. Ten top most accessions for vitamin C content (mg/100g fr.wt.) were: CP2333 (43.21), CP2365 (41.26), CP2394 (39.74), CP2355 (39.52), CP2418 (38.67), CP 2302 (36.18), CP2422 (38.06), CP2379 (35.65), CP2350 (35.63) and CP2399 (35.38).

Micro-nutrient Content: Thirty-five accessions were evaluated for iron and zinc content. Iron content varied from 22.7 ppm (CP 1604) to 36.3 ppm (CP 1592) whereas the range for Zn content was from 13.4 ppm (CP 1641) to 22.1 (CP 1578). The topmost five accessions for Zn content (ppm) were: CP 1578 (22.1), CP 1596 (21.8), CP 1566 (21.1), CP 1613 (20.9) & CP 1552 (20.7) and for Fe content (ppm) were: CP 1592 (36.3), CP 1578 (35.3), CP 1622 (32.6), CP 1652 (32.4) and CP 1564 (31.6).

Protein Content: Total soluble protein content of 18 accessions of potato was estimated. Five tubers (freshly harvested) of each accession were washed thoroughly and peeled. Subsequently, potato tubers of each accession were cut separately in small pieces and mixed. Samples were drawn from the mixed pieces. Pieces were further cut into smaller pieces, weighed and stored at -80°C for further use. Soluble protein contents were measured using Bradford method. Three replicates of each sample were used for protein

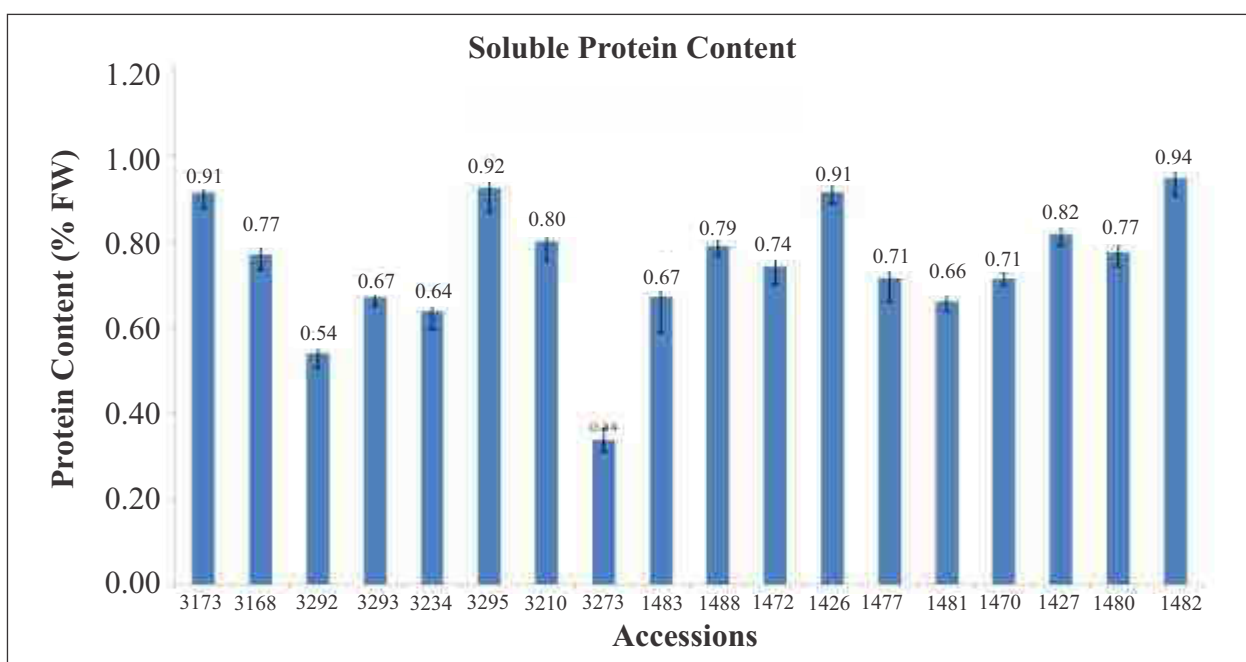


Fig.1: Total soluble protein content of 18 accessions of potato

estimation.

The estimated soluble protein content of the 18 accessions is presented Fig.1. The protein contents were found in the range of 0.34 % (accession CP 3273) to 0.94 % (accession 1482) on fresh weight (FW) basis. Of the 18 accessions, 6 accessions were found to have more than 0.8% soluble protein (FW basis). These were: CP 1426 (0.91%), CP 1427 (0.82%), CP 1482 (0.94%), CP 3173 (0.91%), CP 3210 (0.80%) and CP 3295 (0.92%).

Water use efficiency: Twenty-six accessions were evaluated at 3 moisture regimes i.e. 0.20-0.25, 0.40-0.45 and 0.60-0.65 bars/atm soil moisture tension at 15 cm soil depth for higher yield and water use efficiency. Three accessions namely CP3359, CP3464 and CP3599 gave an equal yield as produced by control variety yields Kufri Bahar at all irrigation levels. But, tuber yield of these accessions were less than the control variety Kufri Pukhraj.

Foliage maturity: Out of 75 Tuberosum accessions screened for foliage maturity at Patna, 12 accessions namely CP Nos.3495, 3515, 3540, 3542, 3579, 3580, 3594, 3605, 3614, 3622, 3627 and 3644 were found early maturing having >80% foliage maturity at 75 DAP.

Wild Species:

Late blight resistance test of wild species: Three years of late blight resistance evaluation of fifty clones belonging to 22 accessions of 8 species resulted in the identification of one highly resistant clone [SS2846-

05 (*S. berthaultii*)] and five resistant clones (SS2837-11, SS3013-02, SS3114-02, SS2895-02, SS2895-01) of four species namely *S. acaule*, *S. kurtizinum*, *S. verrucosum*, *S. brevicaulle*.

Besides, 287 clones belonging to 118 accessions of 43 species were screened for late blight resistance using detached leaf assay under lab conditions. Five clones of four species, namely *S. demissum* (SS1847-07, SS3114-0), *S. chaconese* (2936-02), *S. brevicaulle* (2895-01) and *S. vernei* (3102-0) were found to be highly resistant, 75 clones of 23 species were resistant and 67 clones of 27 species were moderately resistant to late blight.

Under controlled chamber conditions, eleven diploid wild potato species were tested after challenge inoculation of *Phytophthora infestans*, and all were found highly resistant (HR) to late blight. These were: *Solanum berthaultii* (BER57), *Solanum cardiophyllum* (CPH62), *Solanum iopetalum* (IOP59), *Solanum jamesii* (JAM07), *Solanum lesteri* (LES29), *Solanum microdontum* (MCD24), *Solanum polyadenium* (PLD47), *Solanum pinnatisectum* (PNT43), *Solanum stoloniferum* (STO61), *Solanum trifidum* (TRF22) and *Solanum verrucosum* (VER58), whereas control Kufri Bahar was highly susceptible.

Registration of wild species potato clones: Following three diploid wild species potato clones developed by the clonal selection method were registered with the ICAR-NBPGR, New Delhi. These are important genetic materials for somatic hybridization and parental line in the diploid breeding programme.

BER57 (INGR20072;

solanum berthaultii,

Accession no. PI 265857)

Traits: Highly resistant to late blight disease and diploid wild species with wider genetic base



Phenotypes of potato clone BER57



Phenotype of potato clone PLD47

PLD47 ((INGR20073,
Solanum polyadenium,
Accession no. CGN17747)

Traits: Highly resistant to late blight disease and diploid wild species with wider genetic base

JAM07 (INGR20074,
Solanum jamesii,
Accession no. PI 498407)

Traits: Highly resistant to late blight disease and diploid wild species with wider genetic base.



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.



PROGRAMME: BREEDING TRAIT SPECIFIC VARIETIES FOR PRODUCTIVITY, QUALITY AND RESISTANCE TO BIOTIC AND ABIOTIC STRESSES

Research activity 1: Breeding nutritionally superior potatoes varieties

(SK Luthra, Babita Chaudhry, Dalamu, Jagesh Kumar Tiwari, G. Vanishree, Pinky Raigond, Brajesh Singh, Jagdev Sharma, VK Dua, Bandana, Arvind Kumar Jaiswal, Sanjay Rawal, Mehi Lal & Milan Kumar Lal).

Hybridization: A total of 1, 14, 000 hybrid TPS were generated in summer season at Kufri from 17 diverse crosses involving 12 parental lines.

Seedling stage: A total of 23,840 seedlings were raised in the field from sowing of 95,274 true potato seeds of 43 crosses.

Initial clonal stages: In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 1,449 clones are being assessed along with controls at 90 days.

Advanced stage trials: Sixty six (66) advanced clones are being assessed in replicated trial at 75 and 90 days.

Amylose rich advanced clones: Among the 18 advanced clones investigated during last three years, seven clones namely MSA/16-126, MSA/16-140, MSA/16-144, MSA/16-159A, MSA/16-159C, MSA/16-333 and MSA/16-353B and with high amylose or amylopectin content has been promoted for trials. The high total tuber yield was recorded in MSA/16-144 (47 t/ha), followed by MSA/16-126 (42 t/ha), MSA/16-159A, MSA/16-333, MSA/16-353B (39 t/ha), MSA/16-140 (38 t/ha) and MSA/16-

159C (33 t/ha) as compared to Kufri Bahar and Kufri Chipsona-3 (42 t/ha). The high amyloses content was recorded in MSA/16-144 (36%), MSA/16-126, MSA/16-353B (34%), MSA/16-140, MSA/16-333 (32%) and low in MSA/16-159C (8%).

Identification of diagnostic SSR marker (STI0003) for multi-coloured fleshed potato:

Developed diagnostic SSR marker to identify parents and progenies of multi-coloured fleshed potato. One hundred eight (108) progenies (MSP/17-136 to MSP/17-243) of cross between parents (MP/4-816 x CP4242) were analysed by SSR markers. Only one marker STI0003 (PIC: 0.84) was identified highly polymorphic and clearly distinguished the progenies and parents. Allelic profile of STI0003 showed total eight alleles (118, 122, 125, 130, 139, 145, 149 and 152 bp), of which prominent alleles in parents were (MP/4-816: 118, 130 and 149 bp, and CP 4242: 130, 149 and 152 bp), while progenies contained 2 to 7 alleles (e.g. MSP/17-13: 130 and 149 bp). The finding suggests that STI0003 is a diagnostic marker to identify the advance clones with multi-coloured flesh tubers. The tubers phenotypes of the 108 progenies indicated wide variation for tuber skin and flesh colour as compared to parents MP/4-816 (light yellow ovoid tubers with shallow eyes and light yellow flesh) and CP4242 (purple oblong tubers with shallow eyes and purple flesh (Fig. 1 and 2).



Fig. 1: Tuber phenotype of parents and selected progenies

Processing attributes at Modipuram: Processing attributes investigated in 21 advanced clones/varieties revealed tuber dry matter content range from 16-24% and maximum in Lady Rossetta (24%) followed by K Chipsona-3 (22%), Atlantic, MSP/16-216, MSH/17-16 (20%) and MSP/17-89 (19%). Glucose content ranged from 2 to 202

mg/100g FTW and minimum in Atlantic (4), Lady Rossetta (6), K. Chipsona-3 (9), MSP/16-272 (29), MSP/16-216 (47), MSP/17-89 (52 mg/100g FTW). Chip colour score ranged from 2 to 9 and minimum in Atlantic, K. Chipsona-3 (2), Lady Rossetta (3), MSP/16-272 (4), MSP/17-89, MSP/17-147, MSP/17-212 (5).

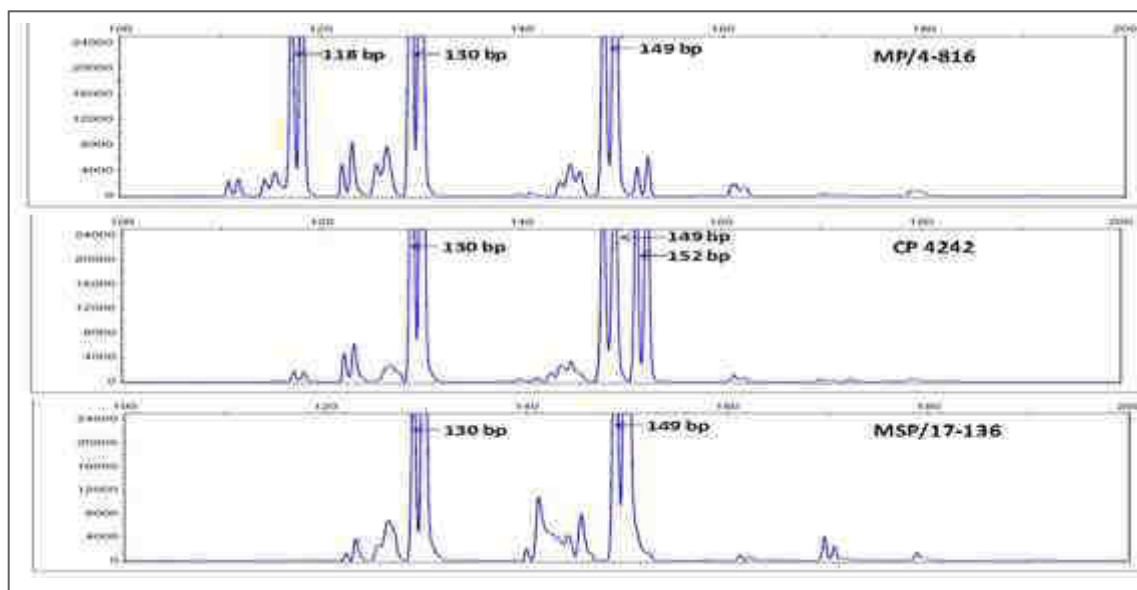


Fig. 2: SSR profiling of parents and progeny using STI0003 marker

Biochemical analysis at Shimla

Carbohydrates' content: Starch content ranged from 50 to 86% (dry weight basis) in 40 potato clones and maximum starch content was observed in advance hybrid MSP/18-19 (86%) followed MSP/16-300 (85%), MS/17-643 (85%) and MSH/18-06 (85%). Amylose content varied from 15 to 36%, and it was reported to be the maximum in MS/17-162 (36%) followed by K. Frysona (35%), MS/17-198 (35%) and MSP/18-68 (33%). Reducing sugars ranged from 103 to 318 mg/100g FW and reducing sugars equal to or less than 150mg/100g FW was reported in MSP/16-216 (103 mg/100g FW), K. Frysona (110), K. Chipsona-3 (119) and MSP/16-307 (151). Sucrose content ranged from 20 to 83 mg/100g FW and low content was reported in MSP/17-212 (20 mg/100g FW), K. Frysona (21), MSP/16-216 (29) and MSP/16-307 (29).

Antioxidants' content: Total phenols were estimated from lyophilized potato flesh in 40 advanced clones/varieties and ranged from 13 to 218 mg/100g FTW. Potato clones MSP/18-68 (218 mg/100g FTW), MSP/16-375 (163), MS/17-162 (127) and MS/17-975 (106) contained high concentration of total polyphenols. Anthocyanins (malvidin+pelargonidin) were estimated from lyophilized potato flesh and concentrations ranged from 0.1 to 110 mg/100g FTW. High concentration of anthocyanins was reported in purple fleshed potatoes such as MSP/16-375 (110 mg/100g),

MSP/16-307 (72), MS/17-648 (59), MSP/16-300 (45) and MSP/17-212 (44). Total carotenoids varied from 32 to 417 µg/100g FW. High concentration of carotenoids was reported from yellow fleshed potatoes such as MSP/16-272 (417 µg/100g FW), MSP/18-19 (405 µg/100g FW), Kufri Neelkanth (332 µg/100g FW), MSP/17-212 (287 µg/100g FW) and MSP/17-147 (258 µg/100g FW).

Flavouring compounds: Flavouring compounds, particularly adenosine monophosphate and guanosine monophosphate (AMP+GMP) ranged from 1.13 to 5.57 µg/g FW in boiled tubers. Clones MSP/16-375 (5.57 µg/g FW), MSP/16-307 (5.09), MSP/16-216 (5.04), MSP/16-300 (4.93) and MSP/17-212 (4.85) contained high concentration of flavouring compounds. Glutamate ranged from 16 to 48 mg/100g FW and high glutamate content was reported in Kufri Lalit (48 mg/100g FW), MSP/16-272 (47), Kufri Pukhraj (46), MSP/16-216 (44), MP/16-525 (43) and MS/17-629 (40) and MS/17-643 (40). Among these, MSP/16-216 contained high concentration of AMP+GMP and glutamate. Glutamine content varied from 43-230 mg/100g FW and was high in MS/17-629 (230 mg/100g FW), MSP/18-68 (208), MSP/16-216 (190), MSP/18-16 (183) and MSP/16-375 (180).

Zinc content: Among the 40 genotypes, zinc content in varieties ranged from 16.7 mg/kg in Kufri Sinduri to 24.6 mg/kg in Kufri Pukhraj, whereas in advanced clones it ranged from 13.2 mg/kg in MSP/16/375 to

27.3 mg/kg in MSP/18-68. Advanced clones MS/17-848 (25.4 mg/kg), MSP-17-7 (25.8 mg/kg), MSP/15-60 (26.1 mg/kg) and MSP/18-68 (27.3 mg/kg) contained higher zinc than control varieties.

Biochemical analysis at Jalandhar: Among 40 advanced clones the visual flesh colour of the 9 clones was deep purple; 10 clones purple to red and 21 clones, dark yellow to creamy-white coloured. This colour was retained after dehydration and frying also (Fig 3). The dry matter content of 6 clones (MS/17-848, MSP/16-307, MSP/16-375, MSP/16-300,

MS/17-162 and MP/16-525) was less than 18%. Dry matter content of 10 clones was more than 20 %. Highest dry matter content was found in MSP/16-216 (24.9%) which was comparable to the dry matter of Lady Rosetta (25.3%) and Atlantic (24.4%) whereas, lowest dry matter was found in MSP/16-307 (16%). Dehydrated chip fry colour score (Fig.3) of only 4 clones MSP/18-16, MSP/16-216, MSP/18-19 and MSP/17-147 was within acceptable range with the reducing sugar content of 95.3, 94.0, 99.2 and 110.6 mg/100 g fresh wt, respectively.

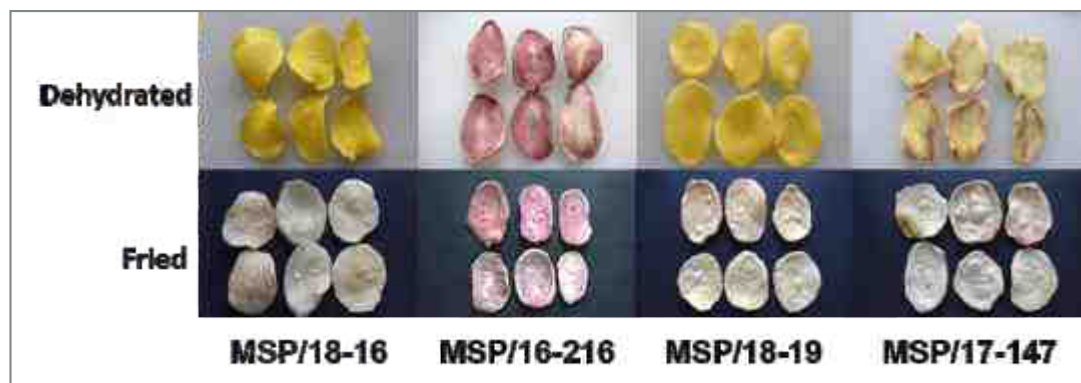


Fig.3: Dehydrated chip fry colour of promising clones

Introduction of promising advanced clones in AICRP: Based on consistence performance in trials at Modipuram, three advanced clones MS/14-243, MSP/16-307 and MSP/16-375 (Fig.4) has been introduced in AICRP for multi-location testing.

MS/14-243 (CP2160 x K.Garima): The advanced clone with total tuber yield of 36 t/ha (75 days) and 48 t/ha (90 days) showed superiority of 8% and 13% over Kufri Bahar (34 and 42 t/ha). It produces attractive white-cream, ovoid tubers with shallow-medium eyes and white-cream flesh. It possesses 20% tuber dry matter at 90 days, very good keeping quality and slight resistance (AUDPC: 660) to late blight as compared to Kufri Bahar (AUDPC:1060).

MSP/16-307 (MS/8-1148 x CP4242): The advanced clone with total tuber yield of 51 t/ha (90 days) showed superiority of 21% and 11% over Kufri Bahar (42 t/ha) and Kufri Lalit/Kufri Neelkanth (46

t/ha). It produces attractive dark purple ovoid tubers with shallow eyes, purple flesh and floury/mealy texture. It possesses 17% tuber dry matter, very good keeping quality and slight resistance (AUDPC: 778) to late blight as compared to Kufri Bahar (AUDPC: 872). The advanced clones possess high anthocyanins, ascorbic acid and flavouring compounds.

MSP/16-375 (MS/8-1148 x CP4242): The advance clone with total tuber yield of 46 t/ha (90 days) showed superiority of 9% over Kufri Bahar (42 t/ha). It produces attractive dark purple ovoid tubers with shallow eyes, purple flesh and floury/mealy texture. It possesses 18% tuber dry matter, very good keeping quality and slight resistance (AUDPC: 656) to late blight as compared to Kufri Bahar (AUDPC: 872). The advanced clones possess high anthocyanins, ascorbic acid and flavouring compounds.



Fig.4: Tubers of advanced clones introduced in AICRP: MS/14-243, MSP/16-307 and MSP16-375

Notification of drought tolerant potato variety: New drought tolerant variety Kufri Thar-2 has been notified in October, 2020 by Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, Department of Agriculture and Co-operation, Government of India, New Delhi for cultivation in agro-climate zone *viz.*, Middle Gangetic Plains Region (Zone 4, Uttar Pradesh), Upper Gangetic Plains Region (Zone 5, Uttar Pradesh), Trans-Ganga Plains Region (Zone 6, Haryana), Eastern Plateau and Hills (Zone 7, Chhattisgarh) and Western Dry Region (Zone 14, Rajasthan). Its plants are medium and vigorous with resistance to late blight. It is a water use efficient variety with high drought tolerance index and lower water requirement. The variety produces attractive, light yellow, ovoid tubers (7-8) with shallow eyes and light yellow flesh (Fig. 5), possess 20-21% tuber dry matter and very good keeping quality. It has ability to produce up to 30 t/ha under less water (<20%) availability and 35 t/ha under normal irrigation regime.

Keeping quality studies: Fifty eight (58) advanced clones/varieties were assessed under ambient temperatures starting during March-May, 2020 [temperature: minimum-23°C (17-28), maximum-25°C (19-30), relative humidity: minimum-61% (35-88), maximum-82% (59-99)]. In table potato segment, advanced clones namely MS/11-664, MS/14-505, MS/15-1001, MS/15-1422, MS/15-1505, MP/14-908, MP/15-318, MS/16-1157 showed excellent keeping quality by virtue of low total weight loss and better tuber appearance as compared to leading varieties Kufri Bahar (7.39% total weight loss and 4.33 tuber appearance). Besides MS/11-664, MS/15-1422, MS/15-1505, MP/14-908, and MS/16-1157 possessed longer tuber dormancy >10 weeks than Kufri Bahar (6 weeks). In nutrient rich potatoes segment, advanced clones namely MSP/15-60, MSP/16-216, MSP/16-216, MSP/16-272, MSP/16-300, MSP/16-307, MSP/16-375 showed excellent keeping quality by virtue of low total weight loss and better tuber appearance as compared to leading varieties Kufri Bahar (10.47% total weight loss and 3.75 tuber appearance).

Sharing of breeding material: Advanced clones/varieties were shared for assessment of



Fig. 5: Morphological characteristics of Kufri Thar-2: Leaf, flowers, sprout and tuber

adaptability (6), processing (6), nitrogen use efficiency (56), organic farming and export (84), late blight screening (76). Beside, 165,540 TPS of 50 crosses were sent to 5 AICRP centers (Bhubaneswar, Deesa, Dholi, Raipur and Srinagar) for seedling raising and further selection as per institute breeding protocol for promotion of region specific breeding.

Optimizing agro-technology for variety Kufri Neelkanth: Kufri Neelkanth responded up to 240 kg nitrogen (32.1 & 35.2 t/ha), 60 kg phosphorous (37.1 & 39.7 t/ha) and 120 kg potassium (35.1 & 38.4 t/ha) per hectare for marketable and total tuber yield, respectively with tuber dry matter content of 19.% at 90 days. The spacing of 60 X 25 cm was optimum for higher marketable (39.4 t/ha), total (44.0 t/ha) and net tuber yield (40.6 t/ha) with 20% less seed (3.33 t/ha) as compared to conventional spacing of 60 X 20 cm with seed tubers of 50g.

Optimizing agro-technology for advanced clones: Nitrogen dose of 240 kg/ha seems optimum for cv. Kufri Thar-2 as it attained marketable and total tuber yield of 30.7 and 32.6 t/ha, respectively with 20 % tuber dry matter. Advanced clone CP4393 at 160 kg N/ha had marketable and total tuber yield of 34.7 and 36.9 t/ha, respectively. Similarly, dose of 240 kg N/ha was better for MS/11-664 as it observed comparable marketable (47.8 t/ha) and total (50.9 t/ha) tuber yield to higher N levels at 90 days.

Advanced clone MS/09-2196 responded at 240

kg/ha nitrogen (marketable-38.1 t/ha and total tuber yield-42.7 t/ha), 60 kg/ha phosphorous (marketable 38.0 t/ha, total tuber yield- 42.5 t/ha and 160 kg K₂O (marketable-37.7 t/ha and total tuber yield 42.2 t/ha) with tuber dry matter content between 16-17%.

Late blight reaction at Kufri: Forty (40) advanced clones and varieties were screened for late blight resistance under natural epiphytotic field condition and based on late blight data recorded thrice and AUDPC calculation, advanced clones MSP/18-13, MSH/18-01, MSA/16-126 and MSA/16-140 were highly resistant (AUDPC<250), MSP/17-7, MSA/16-144, MSA/16-159A, MSA/16-159C, MSA/16-333 and MSA/16-353B were moderately resistant (AUDPC 351-650) and remaining accessions were either susceptible or highly susceptible.

Evaluation for late blight resistance at Modipuram: Seventy one (71) advanced clones/varieties are being assessed for late blight screening under field and lab condition.

Weightage scale development: Plant breeder frequently needs to compare the performance of new line/genotype with the prevailing popular variety before initiating their multi location trials. The popular approach for this evaluation/comparison is assigning weights to important attributes/parameters as per their relative order of importance (Weightage Score card) and then summing all the individual attributes score for final comparison of the varieties. One of the main constraints herein is determination of individual trait weights in accordance with their relative importance in total plant performance which is random in nature.

To overcome this, rank and weight approach was evaluated for comparison. Four popular weightage approaches viz., rank order centroid weight and rank sum weight method, reciprocal/ inverse weight

methods and equal weight method were studied. The weightage score by rank order centroid method and rank sum weight method were found satisfactory. However, manual ranking is the limitation of this method. Correlation and standard deviation approach help to determine the weights of attributes as per their relative importance. To assess the feasibility of this method, data was collected from published literature for 12 yield contributing traits in potato and the initial findings revealed that shelf-life, disease incidence, pest incidence, average tuber weight and marketable yield are the traits in their descending order of importance. This finding needs further refinement with field data observations.

Research activity 2: Breeding early bulking agile potato varieties suitable for intensive cropping systems (*Raj Kumar & Ratna Preeti Kaur*).

Hybridization: A total of 49633 seeds of 36 crosses were obtained.

Seedling stage: A total of 39442 F₁ seedlings obtained from 79784 true potato seeds of 45 crosses were transplanted in field.

Initial clonal stages: In all 4841 clones belonging to F₁C₁ (3046 clones), F₁C₂ (1471 clones) and F₁C₃ (324 clones) are being evaluated along with controls Kufri Pukhraj and Kufri Khyati.

Replicated yield trials: In all 70 advanced clones are being evaluated in three preliminary yield trial (52) and three confirmatory yield trials (20) along with controls Kufri Pukhraj and Kufri Khyati.

Introduction of hybrids in AICRP: Three early hybrids viz., J/12-10, J/12-54 and J/12-146 (Fig.6) has been identified for introduction AICRP Potato based on their 3 year performance for yield and associated characters.



Fig.6: Tubers of advanced clones introduced in AICRP: J/12-10, J/12-54 and J/12-146

Research activity 3: Breeding improved red skinned varieties for eastern plains

(Shambhu Kumar & Sarala Yadav).

Hybridization and seedling stage: A total of 32,474 true potato seeds of 25 successful crosses attempted at Patna were sown in the nursery beds and consequently 19,920 seedlings were transplanted in the main field.

Initial clonal stages: In all 1025 clones belonging to F_1C_1 (784 clones), F_1C_2 (175 clones) and F_1C_3 (66 clones) are being evaluated along with controls at 75 days.

Preliminary yield trial: Seventeen advanced clones are being evaluated in replicated trials along with eight controls at 75 days.

Confirmatory Yield Trials: Thirteen advanced clones (9 red and 4 white skinned) are being evaluated in two trials (replicated) along with eight controls at 75 and 90 days crop duration.

Notification of nutritionally rich medium maturing potato variety Kufri Manik: Medium maturing high yielding (30-35 t/ha), advanced clone PS/06-88 (Kufri Manik) has been notified in October, 2020 by Central Sub-Committee on Crop Standards Notification and Release of Varieties for Horticultural Crops, Ministry of Agriculture, Department of Agriculture and Co-operation, Government of India, New Delhi for cultivation in eastern plains. It produces attractive deep red, avoid uniform tuber with medium deep eyes and white creamy flesh (Fig.7). It is rich in micronutrient and antioxidants. The deep red skin colour is retained/persist even after six months of cold storage. It possesses moderate resistance to late blight and better keeping quality. Tubers have high anthocyanin pigment (0.68 μ /g, F.W.), carotenoids (33.0 μ /g



Fig.7: Plant with tubers of Kufri Manik

F.W.), micronutrients (Zn 20.70 ppm, Fe 41.08 ppm, Cu 6.40 ppm, Ca 422.30 ppm and Mg 0.95 ppm on dry wt basis) waxy texture with good flavour & taste. The flesh stay firm throughout the cooking process and held their shape. It proved most suitable for cultivation in Eastern plains of India. This variety can also be successfully grown in central plains. The variety produces 30-35 t/ha at 90 days harvest and is better than Kufri Lalima and K. Lalit.

Research activity 4: Breeding for processing varieties

(VK Gupta, Vinay Bhardwaj, Bandana, Arvind Jaiswal, Sanjay Rawal, Salej Sood & Mehi Lal).

Hybridization: A total of 131573 TPS of 87 crosses were produced at Kufri and Modipuram.

Seedlings stage: A total of 109766 TPS of 52 crosses were sown in nursery bed and 26761 seedlings were transplanted.

Initial clonal stages: In all 1446 clones belonging to F_1C_1 (1140 clones), F_1C_2 (283 clones) and F_1C_3 (23 clones) are being evaluated for tuber and processing traits.

Replicated yield trials in main season at Modipuram: In all 28 advanced clones are being evaluated in a preliminary yield trial (13) and a confirmatory yield trials (15) along with seven controls at 75, 90 and 110 DAP for total tuber yield, processing grade yield, chip colour and dry matter.

Evaluation in early planting at Modipuram: Eight advanced clones along with seven control varieties were evaluated at 75 DAP and MP/13-1045 (20 t/ha) and MP/13-662 (16 t/ha) were found to be superior with regard to yield but on over all basis MP/13-662 and MP/14-171 were found to have yield as well as acceptable quality traits than to their respective controls.

Evaluation of advanced clones under CIPC storage at Burdwan (West Bengal): At initial testing (harvest), all the 6 advanced clones were found acceptable except MP/13-1045, however in final testing (after 6 months of storage under CIPC) most of the genotypes had acceptable glucose and sucrose levels but MP/12-126 recorded lowest TPOD (12%) followed by MP/13-1045 (22%).

Evaluation trial on new French fry variety Kufri FryoM in Gujarat: In trial conducted with four different doses of Nitrogen i.e. 150, 200, 250 and 300

kg/ha, Kufri FryoM performed well.

Its total tuber yield was at par compared to the other 13 varieties, whereas Kufri Frysona recorded the highest yield. Application of 250 kg nitrogen/ha showed good fry colour for K. Frysona and K. FryoM compared to check varieties. K FryoM has oblong to long tuber shape but girth is very thin. The preferred range for frozen processing potato tubers is 50-80%, especially for QSR French fry products. In this trial, tuber size of Kufri FryoM was lower than Santana and Innovator but higher than Kufri Frysona. The SG values for Kufri FryoM showed perfect for French fries processing. Kufri FryoM and Kufri Frysona both reported low defects compared to Santana and Innovator. First fry colour test was done after 4 month of storage (7th July, 2020); second fry colour test was done after 6 month of storage (7th October, 2020) and last fry colour test done after 9 month of storage (23rd November, 2020). One year trial result showed that K. Frysona and K. FryoM can be stored for long term storage. K. Frysona showed very less number of sugar ends as compared other varieties and K. FryoM however was at par with the K. Frysona.

CPRI-ITC trials in South India (Kharif): In multi-location trials conducted on 24 processing and heat tolerant genotypes at four locations, viz., Lingadahalli-Chikmagalur (Karnataka), Kamalapur-Dharwad (Karnataka), Odeyarapalya-Chamarajnagar (Karnataka), and Igglur-Thalavadi, (Tamilnadu) in Kharif 2020. The location wise quality accepted genotypes are MP/9-45, MP/10-172, MP/14-1029, HT/7-1329 (Chamrajnagar); MP/10-172, MP/15-750, K Surya (Chikmagalur); MP/11-142 (Thalavadi) and MP/12-105, MP/13-662, MP/9-28, HT/7-1329 (Dharwad). Some of the genotypes recorded solid content of 20.0 and above in MP/10-172 (24%) in Chikballapur, MP/13-662 (23%) in Dharwad, K Surya (21%) in Chikmagalur and MP/14-1029 (20%) in Chamrajnagar. Advanced clones namely

MP/9-45, MP/10-172, MP/13-662, MP/9-28, MP/11-142 & Kufri Surya performed better during last two years trials in rabi and kharif.

Evaluation trial at Burdwan (West Bengal): Ten advanced clones and seven control varieties has been planted.

CPRI- ITC trial in South & Eastern India (Rabi): Multi-location trials involving processing and heat tolerant genotypes are being conducted at three locations, Viz., Karnatka (25 genotypes at Hiriyalachenahalli- Chikaballapur District), West Bengal (24 genotypes at Kotulpur – Bankura District) and Telangana (21 genotypes at Zaheerabad District) in rabi season.

CPRI- ITC Technico joint potato breeding programme for development of early maturing processing varieties: A total of 452 single plant clones of promising crosses imported from James Hutton Institute has been planted in F_1C_1 stage at Ludhiana, Punjab.

Supply of breeding material under material transfer agreement: Advanced clones has been supplied to ITC (11 advanced processing clones and 6 control varieties), Simplot, JRS India Foods (7 advanced French fry clones), McCain's (7 advanced French clones/varieties) and APART, CIP, Assam (38 advanced clones/varieties)

Storage behaviour of advanced clones at Modipuram: Seventeen advanced clones were evaluated for storage behaviour under ambient temperatures and less total weight loss (%) was noted in Kufri FryoM, Atlantic (9-10%), MP/13-1045, K Frysona, MP/14-1003, MP/14-171, (12-13%), MP/13-602, MP/13-662, MP/13-169 (14%) after 75 days of storage.

Identification of advanced clone in AICRP: Advanced clone MP/12-223 (CP4051 x MP/99-322) has been identified based on four year for processing into chips for AICRP trails. It produced



Fig. 8: Leaf, Flower, sprouts, tubers of MP/12-223

16 % higher mean processing (38 t/ha) and 10% higher total (43 t/ha) tuber yields than Kufri Chipsona-1 however; it remains at par with Kufri Chipsona-3. It produces attractive white cream, ovoid-tubers with shallow eyes and cream flesh (Fig.8). The hybrids possess 22% dry matter and acceptable fry colour score (3.3).

Notification of new potato varieties

Kufri FryoM, French fry variety: Advanced clone MP/4-578 has been notified by CVRC in its meeting held during October 2020 for cultivation in North Western and Central plains. It is a medium maturing

(90-100 days) variety with good keeping quality suitable for French Fries. It produces attractive, white-cream, oblong shaped tubers with shallow eyes and white flesh (Fig.9). Tubers don't show deformities like cracking or hollow heart. The variety produces high tuber yield (30-35 t/ha) at 90 days and possesses tuber dry matter 20-21%. It possesses field resistance to late blight. The variety produces higher processing grade tubers (>80% tubers), thereby would help farmers in realizing better returns. Long dormancy and months to tide over glut situations in the market. Cooked/boiled potato has acceptable aroma and mealy texture.



Fig. 9: Leaf, sprout, flowers and tubers of Kufri FryoM

Kufri Sangam a dual purpose variety: Advanced clone MP/6-39 has been notified by CVRC in its meeting held during October 2020. Variety has white-cream skin tubers, white flesh, ovoid shape and shallow eyes (Fig.10). It is medium maturing (90-100 days) with yield potential is 35-40 t/ha. It has moderately resistance to late blight and excellent storability. It has very good taste, aroma, mealy texture, excellent tuber appearance and no tuber cracking, tuber dry matter (20%), reducing sugars are <150mg/100 g of fresh weight, suitable for table

purposes and processing to chips & French fries. Hybrid performed well in central plains for both table & processing purposes and therefore, recommended for release in these agro-climate zone viz., Gujarat plains and Hills region (Zone 13), Central Plateau and Hills region (Zone 08) and Eastern plateau and Hills region (Zone 07), while for table purposes this hybrid recommended for northern plains- Trans-Gangetic plains region (Zone 06) and Upper Gangetic plains region (Zone 05).



Fig.10: Flower, sprouts, tubers and French fries of dual purpose variety Kufri Sangam

Kufri Chipsona-4 a chipping variety: Advanced hybrid MP/01-916 has been notified by CVRC in its meeting held during October 2020. Variety has white-cream, round tubers with shallow eyes and white flesh (Fig.11). It has dormancy period >45 days and total weight loss-11%, moderately resistant to late blight. Kufri Chipsona-4 possess high dry matter, low reducing sugars, low phenols and suitable for

processing to chips. Hybrid performed well in Karnataka, West Bengal, MP & Gujarat states for processing potatoes to chips and therefore, recommended for release in Southern plateau and hills region (Zone 10), Lower Gangetic plains region (Zone 03), Central plateau and hills region (Zone 08) and Gujarat plains and hills (Zone 13).



Fig.11: Leaf, sprout and tubers of Kufri Chipsona-4

Biochemical analysis of advanced processing clones:

In initial clonal stages, a total of 50 clones (F_1C_2 Stage) and 32 clones (F_1C_3 Stage) were analysed for chip colour and dry matter and eight clones of F_1C_2 seven clones of F_1C_3 Stage were found suitable owing to their acceptable dry matter and chip/fry color.

Preliminary yield trial: A total of 14 advanced clones were analyzed for processing quality at 75 and 90 days of maturity and MP/15-667, MP/15-699 and MP/15-651 were found suitable on the basis of chip colour, dry matter glucose and sucrose contents.

Confirmatory yield trial: A total of 14 advanced clones were tested for processing quality from 75, 90 and 110 days, and MP/14-169, MP/14-635, MP/14-332 and MP/14-1003 at 110 DAP were performed well on the basis of chip colour, dry matter glucose and sucrose contents.

Final yield trial: A total of 14 advanced clones were tested for processing quality from 75, 90 and 110 days harvest and MP/12-223, MP/13-602, MP/13-662, MP/13-669 and MP/13-1045 found suitable on the basis of chip colour, dry matter and glucose content at 110 days. However, hybrids viz., MP/13-669 and MP/13-1045 showed acceptability for processing at 90 DAP also.

Processing quality of genotypes during storage at 10-12°C with CIPC at Jalandhar: Among the 15 genotypes investigated at 180 days of storage, all genotypes recorded more than 20% dry matter except MP/12-1045 (20%). Highest dry matter was found in MP/13-662 (25%) which was higher than control cultivars Atlantic and Lady Rosetta. It was found that during 180 days of storage only MP/13-662 (2.92) and MP/12-1045 (3.04) recorded chip colour score within acceptable range, which was comparable to control cultivars Atlantic (2.56) and Lady Rosetta (2.60). Except MP/4-578, throughout the 180 days of storage all hybrids recorded fries' colour within acceptable range. Fries colour of MP/12-105 and MP/12-126 was lowest and at par to control cultivar Atlantic. It was found that from processing perspective, among all hybrid's MP/12-1045 and MP/13-662 performed best and found suitable for

chips as well as French fries.

Optimizing agro-technology for newly released variety Kufri Sangam: Kufri Sangam responded at 240 kg Nitroegn (marketable-33.5 t/ha and total tuber yield-37.2 t/ha) 40 kg P_2O_5 /ha was (marketable-30.7 t/ha and total tuber yield-33.5 t/ha), 160 kg K_2O /ha (marketable-30.4 t/ha and total tuber yield-34.1 t/ha with tuber dry matter 19-20%). Crop geometry of 66 X 20 cm was found better as it recorded marketable (36.2 t/ha), total (39.5 t/ha) and net (35.4 t/ha) tuber yield comparable to closer or wider crop geometry.

Late blight screening: Fifteen advanced clones along with three control varieties are being assessed for late blight screening in field as well as in the lab condition.

Research activity 5: Breeding for biotic stresses (late blight, viruses & cyst nematodes)

(Vinay Bhardwaj, Salej Sood, Dalamu, Kumar Nishant Chourasia, G. Vanishree, Sanjeev Sharma, EP Venkatasalam, Priyank Hanuman Mhatre, Clarissa Challam, Mehi Lal, Babita Chaudhary, Aarti Bairwa, R Baswaraj, S. Sundaresha, Ravinder Kumar, Gaurav Verma, Kailash Chandra Naga, Vinod Kumar, Ashwani Sharma, Raj Kumar Rana & VK Dua).

Hybridization: At Kufri/Shimla, among the 125 crosses attempted, 1, 22, 904 TPS were extracted from 690 berries of 75 successful crosses. At Ooty, about 5508 TPS were produced from 17 crosses.

Seedling raising and screening for late blight resistance:

A total of 5300 seedlings of 12 crosses recovered from 20000 TPS were screened under controlled conditions against complex races of *Phytophthora infestans* at Shimla. A total of 997 resistant seedlings were obtained, which were, transplanted in the earthen pots in the glass-house and poly-house. The highest number of resistant seedlings (%) were obtained in the cross CP2370×Santana (29%) followed by the crosses CP4045×JEX/A-122 (27%), CP4052×K. Jawahar (24%), SM/10-174×K Mohan (21%) and SM/09-100×CP4242 (21%). At harvest 323 clones were obtained from these resistant seedlings. At Ooty, 80500 TPS of 14 cross were sown and 1676 seedlings were transplanted in poly house for screening against late blight under natural conditions. On maturity, 215 F_1C_1 selections were made.

Initial clonal evaluations: In the initial stages (F_1C_2 to F_1C_4), 141 genotypes were evaluated under natural field conditions at Kufri for their disease resistance

and adaptability and at harvest 112 clones were selected. At Ooty, 1597 clones were evaluated in rows/single hill along with four control varieties and 37 clones were selected. At Shillong, in the initial clonal generations (F_1C_1 to F_1C_3), 1622 clones were evaluated and 271 promising clones were selected based on late blight incidence and tuber characteristics.

Evaluation of medium maturing late blight resistant hybrids in advanced clones at Kufri: In F_1C_5 , among the 5 advanced clones evaluated, SM/10-247 showed 17.2% yield superiority over best control Kufri Karan, and two other hybrids viz., SM/10-12 and SM/10-246 were statistically at par to best control. In F_1C_6 , among the six advanced clones evaluated, SM/10-101 showed 16.9% yield gain over the best control Kufri Himalini. Two other hybrids namely SM/09-13 and SM/10-121 were also selected based on statistically at par yield performance to best control. In F_1C_7 , among the 8 advanced clones evaluated, SM/11-120 showed yield advantage of 10.24%, while, SM/10-103 and SM/09-163 showed 5% yield advantage over best control, Kufri Himalini.

Advanced clone trials at Ooty: Thirty one advanced clones were evaluated in replicated trials along with six control varieties and 3 advanced clones were selected on the basis of agronomic traits and resistance to cyst nematodes and late blight. In another trial, three advanced clones were assessed in replicated trial along with five control varieties and OS/07-63 and OS/06-66 along with Kufri Karan recorded maximum yield (11.96, 9.94 and 9.52 t/ha respectively). The hybrids were found moderately resistant to late blight and showed resistance to golden cyst nematode.

Advanced clone trials at Shillong: In confirmatory yield trial, among the three advanced clones evaluated, SS/11-295 yielded 21% higher total yield over control Kufri Himalini at 120 days harvest. The hybrid produces yellow round tubers with shallow

eyes and pale yellow flesh colour having 19% tuber dry matter, good keeping quality and medium resistance to late blight.

Evaluation of advanced hybrids for tolerance to PCN: Among the 35 advanced clones and 7 susceptible cultivars screened against *Globodera rostochiensis* & *G. pallida* under controlled conditions in pots at Kufri, SM/11-120 was found highly resistant against both the species of PCN. All other hybrids were susceptible to highly susceptible. During last three years, the advanced clone SM/11-120 did not observe even a single cyst of PCN in root balls and consistently showed highly resistant reaction to both the species of PCN (Fig.12).

Screening of advanced hybrids against whitefly (*Bemisia tabaci*): Host plant resistance has been the main component of Integrated Pest Management strategies but has not explored extensively in potato for managing the sucking pests of potato specially whitefly. Advanced clones viz., SM/10-174, SM/10-253, SM/13-163 and SM/13-150 and two varieties were screened against the whitefly under choice assay. The potato plants were randomly arranged along with the border of the insect proof cage and approximately five thousand whiteflies were released in the middle of the cage to give equal opportunity to access the plants. Then three compound leaves were sampled from top, middle and bottom of plants after 6 days of post inoculation. The numbers of eggs were counted on the all the compound leaves under the stereo zoom microscope and the average number of eggs calculated by dividing with the total area measured. There was a significant difference in the whitefly eggs among the potato hybrids ($F= 8.5582$, $df=4$, $p<0.0001$). The highest eggs were observed on Kufri Himalini (Fig.13) which was on par with SM/10-253, SM/13-163, SM/13-150 and Kufri Girdhari. The SM/10-174 was recorded as least preferred hybrid for egg laying.



Fig.12: Screening for PCN resistance a) No cysts on the roots of SM/11-120 b) Cysts of both species present in the roots of Kufri Jyoti

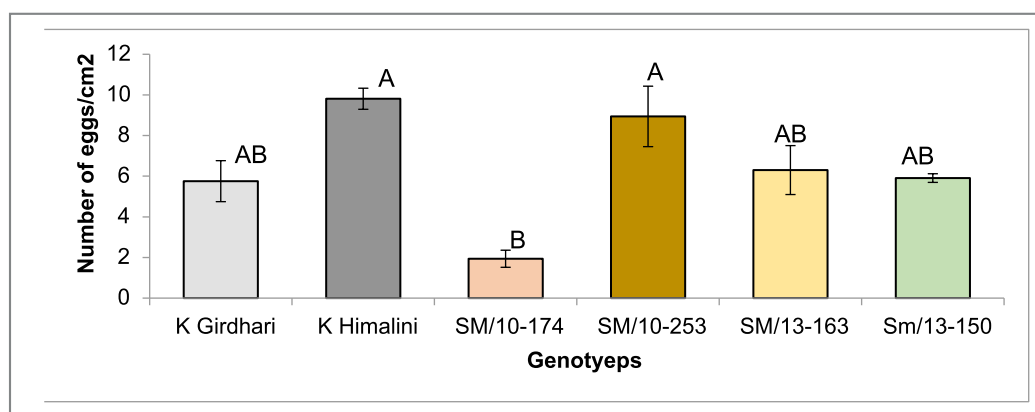


Fig. 13: Potato hybrids screened against whitefly. The graph represents number of eggs (mean ± SE) and accessions with at least one common letters each column is not significantly different at $P < 0.05$ (Tukey–Honest Significant Difference)

Molecular Breeding: Hybridization was done so as to combine multiple resistance genes in a common genotypic background mainly for late blight ($R1$, $R2$ and $R3$), PVY (Ry_{adg} , Ry_{sto}) and potato cyst nematodes ($H1$, HC_QRL and $Gro1-4$) resistance using molecular assisted selection. A total of 16,720 hybrid TPS were extracted from 8 successful crosses.

Research activity 6: Development of varieties with resilience to abiotic factors

(Devendra Kumar, VK Gupta, Sanjay Rawal, Name Singh, Brajesh Singh, Som Dutt, Babita Chaudhary, Kumar Nishant Chourasia, Sugani Devi, Sushil Sudhakar Changan, Milan Kumar, Pinky Raigond & Anuj Bhatnagar)

Breeding for heat tolerance

Hybridization: A total 94 crosses were attempted at Kufri and out of 52 successful crosses, 50,000 TPS were extracted.

Seedling stage: In all 20,580 seedlings were transplanted in the field from the 50,000 TPS of 71 crosses used for seedling raising.

Initial clonal stages: In all 623 clones belonging to F_1C_1 (458 clones of 32 families), F_1C_2 stage (143 clones of 32 families) and F_1C_3 stage (22 clones of 14 families) has been planted for multiplication/selection at 90 days.

Advanced stage trials in early crop at Modipuram: Among the 10 advanced clones evaluated at 75 DAP, advanced clones namely HT/12-116, (19 t/ha), HT/15-240 (18 t/ha), HT/12-830 (14 t/ha) were found to be promising as compared to Kufri Surya (18 t/ha) in final yield trial. In addition, among the 23 advanced clones (F_1C_4 stage selected at CTCRI) evaluated at 75 DAP, 10 advanced clones were

selected and high total tuber yield was obtained in HTMK/17-6 (22 t/ha), HTMK/17-12 (21 t/ha), HTMK/17-13, HTMK/17-9 (20 t/ha), HTMK/17-8 (19 t/ha) and HTMK/17-23 (17 t/ha) as compared to Kufri Surya (17 t/ha) in final yield trial.

Screening for mite and hopperburn in early planting:

A total 35 genotypes including two control varieties were screened in two experiments for response to mite, leafhopper and PALCV. The infestation of mite and hopperburn was recorded in the scale of 0-5, Where 0 is no symptoms, 1 is severe (>80%), 2 is 61-80 %, 3 is 41-60 %, 4 is 21-40 % and 5 is low (1-20 %) infestation. The results at 75 days reflected that mite burn symptoms were in the range of 0-60 %, hopperburn ranged from 0-40 % and virus incidence ranged from 1-20 %. High miteburn (scale 1) was recorded in HT/12-830, HT/14-95, HT/12-116, HT/12-834 and Kufri Lauvkar and they were badly affected by miteburn. Genotypes viz., Kufri Surya, HT/16-240, HT/14-109, HT/12-43, and HT/15-240 had no symptoms of miteburn. Kufri Surya did not show any symptoms of leafhopper damage and HT/12-830, HT/12-834 and HT/15-240 recorded high damage due to leaf hopper (scale 1). Severe to high virus incidences (1-2 scale) were recorded in HT/15-240, HT/16-240, HT/12-830, HT/16-113, HT/10-1554 and Kufri Surya. However, moderate (4-5 scale) virus incidence were recorded in HT/14-109 and HT/12-43.

Optimizing agro-technology of recently released advanced heat tolerant clone HT/07-1329:

The advanced clone under early planting responded significantly to 180 kg N/ha (marketable-16.2 t/ha and total tuber yield-18.7 t/ha), 40 kg P_2O_5 /ha (marketable-16.9 t/ha and total tuber yield-19.6 t/ha) and 100 kg K_2O /ha (marketable-16.1 t/ha and total

tuber yield 18.8 t/ha) with tuber dry matter content of 20% at 75 days.

Advanced stage trial at Pune and Bhubaneswar: At Pune 23 advanced clones were evaluated under kharif planting season at 90 DAP and high total tuber yield was obtained in HTMK/17-17 (20 t/ha), HTMK/17-5, HTMK/17-7 (19 t/ha), HTMK/17-21 and HTMK/17-23 (18 t/ha). At Bhubaneswar 33 advanced clones has been planted in rabi season crop.

Storage behaviour of advanced clones at Modipuram: Twelve advanced clones were evaluated for storage behaviour under ambient temperatures. Kufri Surya, Kufri Bahar, HT/12-830 and HT/12-

834 were noted for superior storability owing to low storage losses (9-14%) after 75 days of storage.

Introduction of advanced clone in AICRP: Based on four year trials in early planted crop at Modipuram, and two year trials at Pune, advanced clone HT/12-834 (K Chipsona-1x K Khyati) has been identified for entry into AICRP. It produced 8% and 19% higher total tuber yield at Modipuram and Pune, respectively than K. Surya. It produces white-cream, round oval tubers with shallow eyes and cream flesh (Fig.14). It has 17% tuber dry matter, long dormancy and very good keeping quality under country store conditions.



Fig.14: Leaf, Flowers, sprouts and Tubers of HT/12-834

Release of new variety: Advanced clone HT/07-1329 (2372 X CP-1748) has been recommended for release as heat tolerant variety in the 38th Group meeting of AICRP (Potato). It produces white-cream ovoid tubers with shallow eyes and cream flesh (Fig.15). It has early-medium maturing (85-90 days) and yield potential is 30-35 t/ha. It has excellent storability under ambient conditions (9% total weight losses at 75 days of storage) as against 11% in Kufri Surya and 16% in Kufri Bahar. It possesses excellent tuber

appearance, no tuber cracking, tuber dry matter (19%), very good taste and mealy-floury texture. It performed well in of UP, Haryana, Punjab, Uttarakhand, MP, Gujarat and Odisha, Maharashtra and also in West Godavari District of Andhra Pradesh; therefore, it has been recommended for early season planting in Indian plains and main season planting in plateau regions including West Godavari District of Andhra Pradesh.



Fig.15: Leaf, Flowers, Sprouts and Tubers of HT/7-1329

Identification and cloning of genes associated with tuberization under abiotic stresses: The work on high temperature and drought responses in potato plants led to the identification “Sugar Partitioning Affecting protein (SPA)” gene. Complete Open Reading Frame (ORF) of *SPA* gene composed of 480 nucleotides has been cloned (Fig 16). Deduced protein from the cloned SPA gene was found to

contain 159 amino acids (Fig 17). Molecular weight and theoretical isoelectric point of the deduced protein was estimated to be 17.23 kDa and 8.09, respectively. The cloned gene has been assigned accession number is MT996235 by NCBI GenBank. Conserved domain analysis revealed the presence of DnaJ domain in the protein deduced from the cloned *SPA* gene (Fig. 17). DnaJ proteins are highly

conserved and play crucial roles in protein translation, folding, unfolding, translocation, and degradation. They act primarily by stimulating the ATPase activity of Hsp70s, an important chaperonin family. This central domain contains four repeats of a CxxCxGxG motif and binds to two Zinc ions. Comparative expression analysis of the cloned *SPA* gene revealed the differential levels of expression in response to temperature in different varieties at tissue levels. In leaf tissue of K. Surya plants kept at higher temperature, the expression of SPA was found to be higher by 53.8 % as compared to those at normal temperature (Control). In case of leaf tissues of K. Chandramukhi and K. Pukhraj plants kept at higher temperature, increase in the expression of SPA was found to be 18.9 % and 7.8 %, respectively, than those kept at normal temperature. In case of K. Jyoti

leaf the expression was found to be decreasing by 13.7 % in response to higher temperature

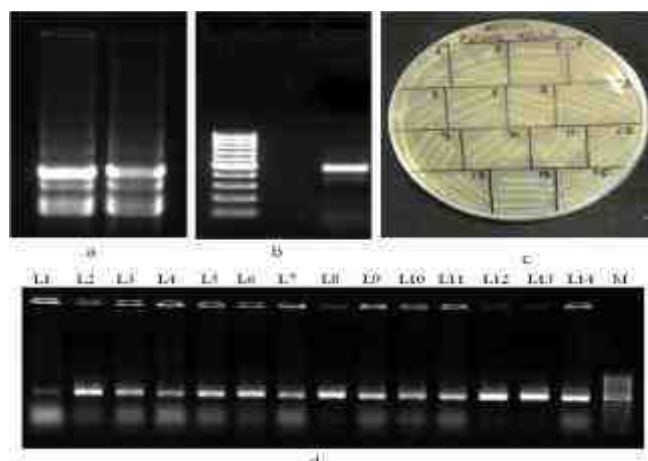


Fig.16: Cloning of Sugar Partitioning Affecting (SPA) protein gene from potato. (a) RNA isolated from potato leaf, (b) PCR amplified SPA gene, (c) transformed colonies and (d) colony PCR

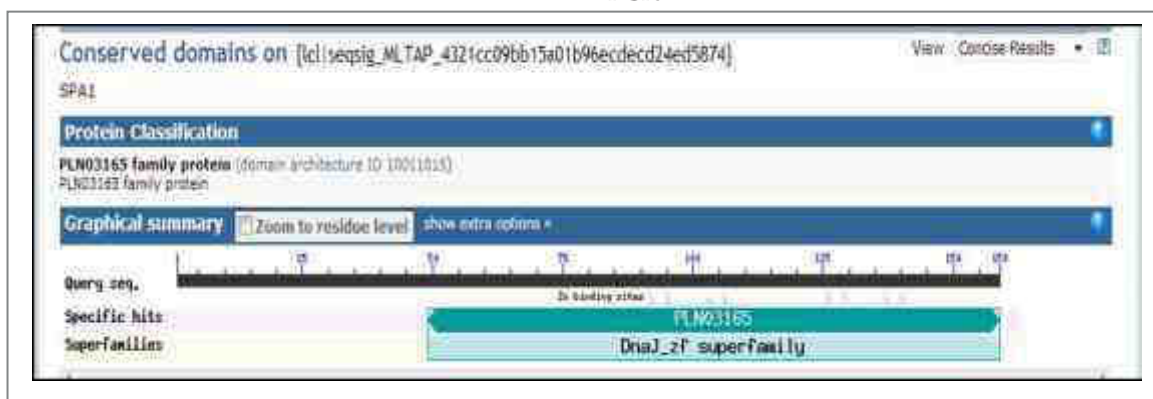


Fig. 17: Conserved domain analysis of SPA protein

Breeding for drought tolerance

Parent selection: The 20 germplasm accessions are CP1404, CP1406, CP1420, CP1424, CP1584, CP1662, CP1665, CP1757, CP2161, CP2186, CP2268, CP2278, CP2302, CP2363, CP3084, CP3085, CP3088, CP3091, CP3149 and CP3644 has been identified with drought tolerance traits and will be screened by analyzing various physio-chemical parameters (RWC, MSI, ABA, proline etc.).

Seedling stage: In all 6626 seedlings were recovered and transplanted from 53000 TPS of 7 crosses and about 79 % (5208) are survived up to earthing up.

Initial evaluation under water stress: A total of 36 clones comprising F_1C_3 (4 Nos), and F_1C_4 (32 Nos) were exposed to water stress executed through delayed irrigation and quantified through water meter along with controls K. Bahar and K. Pukhraj, K. Thar-1 and K. Thar-3 at 90 days.

Final Yield Trial: A total of 6 advanced clones are

being assessed in replicated split plot design under water stress and well-watered control along with K. Thar-1 and K. Thar-3. Irrigations are regulated to be in equal quantity of water, using digital water meter. Besides, intermittent rains the field phenotypic traits viz. leaf vigour (SPAD value), stay-green trait and other associated traits viz. total yield tuber dry matter under stress, etc were recorded

Introduction of advanced clone in AICRP: Based on superiority in traits associated with drought tolerance viz. deeper roots (higher root pulling force), stay-green trait, total yield, tuber dry matter under stress, attractive tuber traits, advanced clone WS/09-609 has been introduced in AICRP for mufti-location trials. Based on four years trials, it produced 36.8 t/ha as compared to K Bahar (32 t/ha) under water-stress, while it tuber yield was 39.5 t than K Bahar (37.6 t) under well-watered conditions. It produces white-cream, round-ovoid tubers with shallow eyes and cream flesh (Fig.18). It produces defect free higher

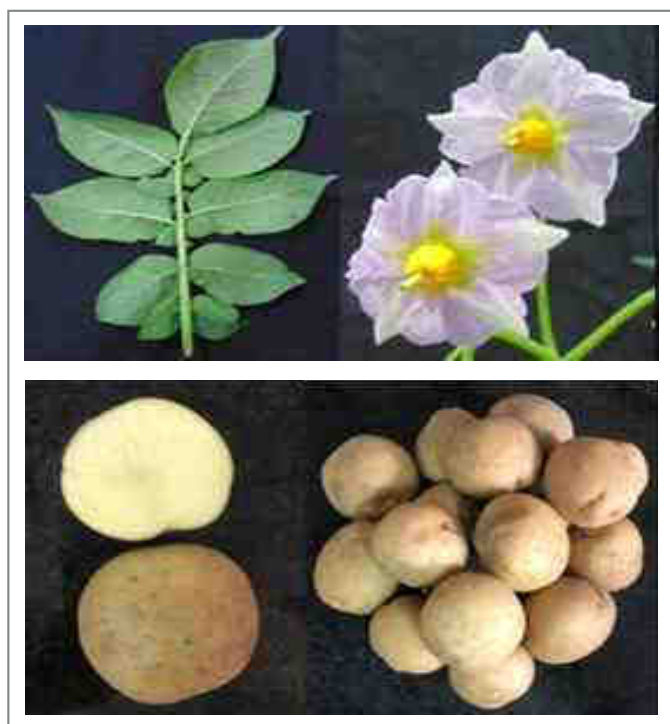


Fig.18: Leaf, flowers and Tubers of WS/09-609

tuber yield than K. Bahar and K. Thar-3 (15 % and 8%, respectively) under water stress with >19% tuber dry matter having moderate resistance to late blight. It

has long dormancy with very good keeping quality, maintains acceptable chip quality up to the month of May under on farm storage. Organoleptic tests showed very good appearance, much flavored, very good in taste without bitterness and waxy texture.

Notification and release of drought tolerant variety:

KufriThar-1 (WS/05-146) has been notified as new water use efficient variety in East coast plains and Hills region (Zone 11) and Middle Gangetic plains region (Zone 04). It produces white-cream, round-ovoid tubers with shallow-medium deep eyes and cream flesh (Fig.19). It has medium maturity (90-100 days) with 30-35 t/ha yield under less water (20% availability). It is suitable for table purposes and adjudged to be good in taste, with typical potato flavor, acceptable texture, very good tuber appearance, dry matter (19%) and no tuber cracking. It is water use efficient as it recorded very low Drought Susceptibility Index (DSI) and yield reduction (YR) under deficit irrigation regime bestowed with very good storability at par with popular variety Kufri Bahar.

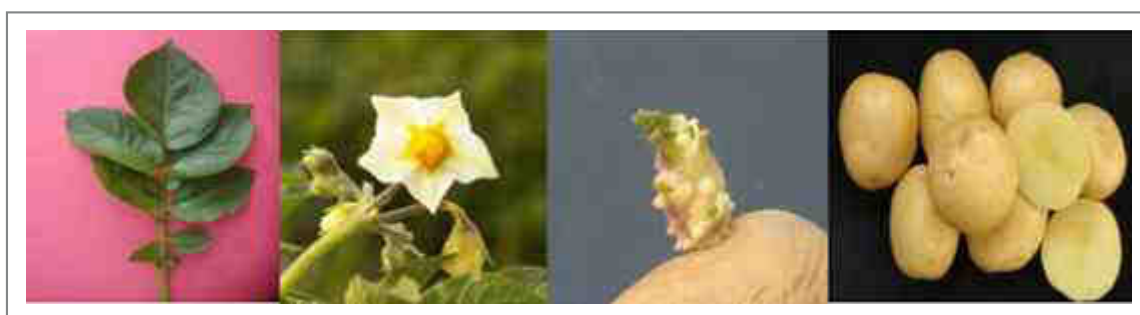


Fig.19: Leaf, Flower, Sprout and Tubers of Kufri Thar-1

Evaluation of water stress advanced clones for higher yield & water use efficiency: Four advanced clones namely WS/13-1-135, WS/13-1-192, WS/12-9-110, WS/2011-367 along with K. Bahar and K. Pukhraj were evaluated at three soil moisture regimes viz. 0.20-0.25, 0.40-0.45 & 0.60-0.65 bars/atm soil moisture tension at 15 cm soil depth for higher yield and water use efficiency. Results revealed that all advanced clones produced higher yield and found high water use efficient than control (K. Bahar & K. Pukhraj) except WS/2011-367.

Optimizing agro-technology for advance water stress tolerant clone WS/07-113 in main season: WS/07-113 responded at 180 N kg/ha (marketable-31.6 t/ha and total tuber yield-35.9 t/ha), 40 kg/ha

P_2O_5 (marketable-27.6 t/ha and total tuber yield of 31.2 t/ha), 100 kg K_2O /ha (marketable-30.2 t/ha and total tuber yield 32.0 t/ha) with tuber dry matter range between 17-18%. WS/09-609 responded to nitrogen dose of 180 kg/ha (marketable-42.5 and total tuber yield-45.2 t/ha) with tuber dry matter of 20% at 90 days.

Effect of deficit water on root parameters: Nine genotype has been planted in plastic pots filled with sand, soil and vermi-compost. Half of pots of each genotype were given water stress by complete stop of irrigation after 50 DAP. Besides, seven advanced clones has been planted in field along with two controls, K. Gaurav and K. Surya to identify the promising genotype.

Influence of biostimulants on biochemical attributes of drought stressed potato plants:

The influence of biostimulants viz. seaweed extract (SWE) (*Ascophyllum nodosum*) and chitosan (CHT) separately and in combination on biochemical attributes (particularly related to plant defense response) of drought stressed (D) in K. Surya, K. Pukhraj and K. Badshah was studied in pot grown plants. Stress was induced by withholding the water from 40th to 50th day of planting (DOP). Seaweed extract (0.4%), chitosan (0.1%) and their combination (0.4% Seaweed extract & 0.1% Chitosan) were applied to plants through foliar application on 30 and 45 DOP and biochemical estimations were carried out after 3 days of application. Results are reported on average of three varieties. The total soluble sugars were the maximum in drought stressed plants (649 mg/100g FW). The content of sugars decreased to some extent in drought stressed plants treated with seaweed extract (555 mg/100g FW), chitosan (571 mg/100g FW) and their

combination (604 mg/100g FW) and decrease was 15%, 12% and 7%, respectively, compared to drought stressed untreated plants (Fig.20.1). However the low sugar content was reported in unstressed potato plants treated with chitosan (314 mg/100g FW), seaweed extract (362 mg/100g FW) and their combination (378 mg/100g FW). Total soluble protein was the maximum in drought stressed potato plants treated with seaweed extract (1.51%), followed by chitosan (1.48%) and lower in combination of seaweed and chitosan (1.39%) (Fig 20.2). The seaweed application increased the protein content of stressed plants to 20%, chitosan to 18% and combination of biostimulants increased protein to 10% compared to stressed untreated plants. Application of biostimulants on unstressed plants also showed similar trend as that in stressed plants. The content was the minimum in combination of biostimulants and comparatively higher in seaweed treated plants.

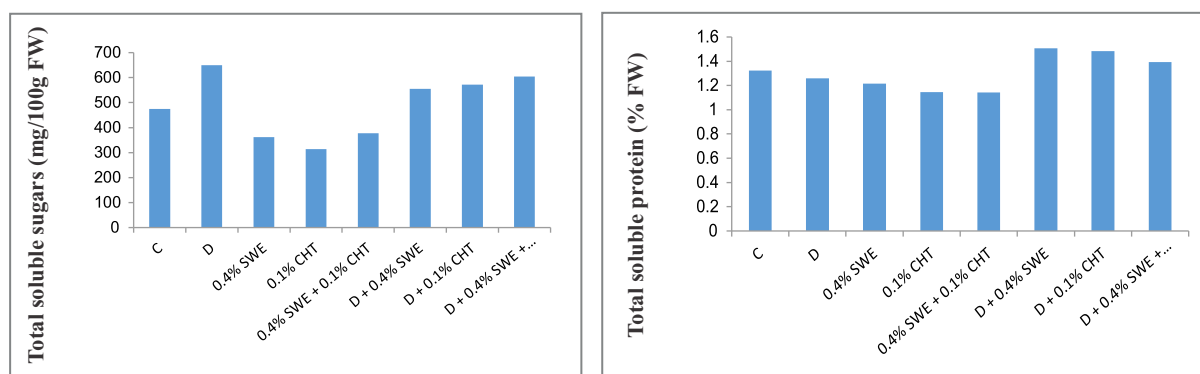


Fig. 20.1& 20.2: Effect of biostimulants on total soluble sugars and total soluble protein in drought stressed potato plants (C-Control, D-Drought, SWE-seaweed extract, CHT-Chitosan)

Total phenols were reported in high concentration in drought stressed plants (21 mg/g FW). Among the biostimulant treated stressed plants, phenol concentration was high in chitosan treated plants (15 mg/g FW). Except for drought stressed untreated plants, rest of treatment showed non-significant effect of biostimulant application (Fig.21). Chlorogenic acid was reported in maximum concentration in seaweed treated stressed plants (3.51 mg/g FW), followed by chitosan treated stressed plants (3.49 mg/g FW) and comparatively lower in stressed plants treated with combination of biostimulants (3.33 mg/g FW) (Figure 2). Drought stressed untreated plants contained lowest concentration of chlorogenic acid

(2.67 mg/g FW). Application of seaweed extract, chitosan and their combination increased the chlorogenic acid to 17%, 16% and 11% compared to stressed untreated plants. Anthocyanin showed reverse trend in treated stressed plants. The content was maximum in stressed plants treated with combination of biostimulants (3.23 mg/100ml FW), followed by stressed untreated plants (2.93 mg/100ml FW), chitosan treated stressed plants (2.80 mg/100ml FW) and seaweed treated stressed plants (2.77 mg/100ml FW) (Fig. 21). Anthocyanin content was least in chitosan treated unstressed plants (1.60 mg/100ml FW).

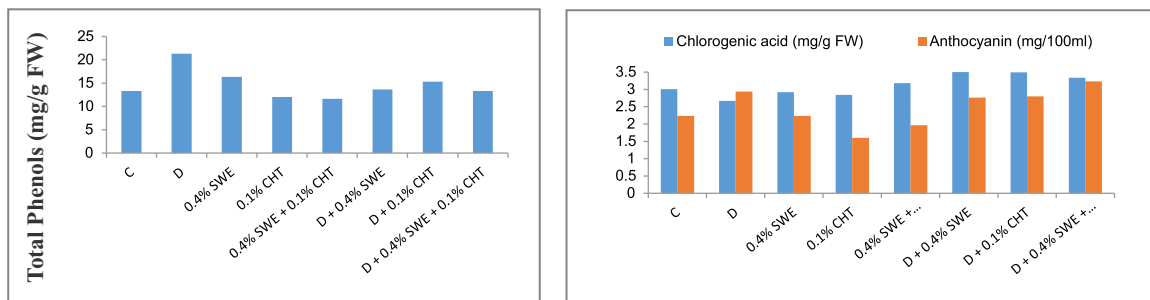


Fig. 21: Effect of biostimulants on totals phenols, chlorogenic acid and anthocyanin content of drought stressed potato plants

Effect of biostimulants was most prominent on proline content (Fig.22). Proline content was least in unstressed plants and was the maximum in drought stressed plants (50 $\mu\text{g}/100\text{g FW}$). Application of biostimulants reduced the proline content to some extent that indicated these biostimulants plays an important role in amelioration of drought stress. The proline content was comparatively more in seaweed treated stressed plants (48 $\mu\text{g}/100\text{g FW}$), lower in chitosan treated stressed plants (46 $\mu\text{g}/100\text{g FW}$). The

combination of seaweed and chitosan reduced the content to maximum extent among stressed plants and content in these plants was 43 $\mu\text{g}/100\text{g FW}$. The combination of biostimulants reduced the content of proline to 14% as compared to untreated stressed plants. Application of biostimulants showed non-significant effect on peroxidase activity. Peroxidase activity was the minimum in control plants (2.9 $\mu\text{moles}/\text{min}/\text{g FW}$) and varied non-significantly among stressed plants (Fig 22).

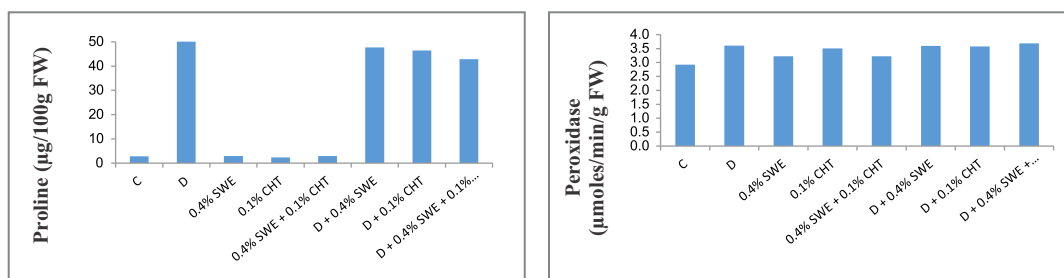


Fig. 22: Effect of biostimulants on proline content & peroxidase activity in drought stressed potato plants

Breeding for salt tolerance

Hybridization: A total 16 crosses were attempted using potential salt tolerant parents and 4686 TPS were extracted.

Seedling stage: 4686 TPS of 16 crosses were used to raise the seedlings. In all 1024 seedlings were transplanted in the field out of which 577 (about 56 %) are survived.

Multiplication of tubers from *in-vitro* conservation: Thirty salt responsive accessions were sub-cultured, maintained and propagated through *in-vitro* and multiplied in tuber form.



Fig. 23: Root length and growth at different NaCl concentration



Fig. 24: Kufri Himsona and Kufri Lima at different salt concentration

Method for *in-vitro* screening of salinity tolerance:

For inducing salinity different concentrations of NaCl (10mM, 20 mM, 25mM, 40 mM, 60mM, 75mM, 80mM, 100mM, 150mM and 250mM) were added to modified MS media and the pH was adjusted to 5.7 ± 1 . The modified MS media was sterilized at 105kPa in steam autoclave for 15 mins. The nodal cutting of 10 genotypes were surface sterilized in 0.1% mercuric chloride solution for 1-2 mins followed by washing in

double distilled water and these cuttings were placed in test tubes containing 10 ml of modified MS media having different concentrations of NaCl (10 levels) in three replications. These cultures were maintained at $25 \pm 2^\circ\text{C}$ with 16/8 h light/dark cycle for 5 weeks. After 5 weeks, growth parameters and morphological characters were recorded and it was confirmed that MS basal medium supplemented with NAA (2.5 μM), BA (4.2 μM) and GA₃ (1.37 μM), 32g l⁻¹ sucrose and 75 mM NaCl concentration was best for screening genotypes for salinity tolerance in potato since, growth of root as other parameters was significantly hindered as compared to control (Fig.23).

In-vitro screening for salinity tolerance: Ten potato varieties were screened for salinity under *in-vitro* conditions at four level of salinity stress *viz.*, 25, 75, 150 and 250 mM NaCl concentration. None of the varieties except one survived and in all senescence, wilting and drying of explant occurred at 250 mM NaCl concentration. Kufri Surya showed a partial rooting at this concentration whereas, delayed senescence was observed in Kufri Jyoti but there was no rooting initiation after 5 weeks. At 150mM concentration most varieties showed partial rooting initiation except K. Ganga, K. Garima and K. Lima. All the varieties showed rooting after 5 weeks at 75 mM concentration. Based on 50% reduction in growth parameters K. Himsona was found to be tolerant (Fig. 24).

Activity 7: Development of nitrogen use efficient varieties (Raj Kumar, Manoj Kumar & Prince Kumar)

Hybridization: A total of 20,011 seeds of 33 crosses were obtained

Raising of seedlings: A total of 51,231 seedlings obtained from 1,06,330 seeds, were transplanted in field.

Initial clonal stages: In all 13,439 clones belonging to F₁C₁ (12360 clones), F₁C₂ (731 clones) and F₁C₃ (348 clones) are being evaluated along with controls Kufri Pukhraj and Kufri Garuav.

Replicated yield trials: In all 91 advanced clones are being evaluated in four preliminary yield trial (66) and three confirmatory yield trials (25) in main planting.

Evaluation for nitrogen use efficiency: Nine (9)

advanced clones are being evaluated at 90 days in replicated yield trial with different doses of N under normal planting condition for evaluation of nitrogen use efficiency.

Activity 8.: Diploid F₁ hybrid breeding in potato (Salej Sood, Vinay Bhardwaj, Hemant Kardile, Kumar Nishant Chourasia, Rajkumar Rana, Brajesh Singh, Sanjeev Sharma & Babita Chaudhary).

Diploid germplasm augmentation: Twenty-seven diploid accessions of *Solanum tuberosum* were imported from USDA potato genebank including 12 accessions in TPS form and rest 15 accessions in-vitro cultures. From TPS of 12 diploid accessions 123 diploid clones were harvested in tuber form. The number of tubers ranged from 1 to 17.

In-vitro diploid accessions conversion into tubers in aeroponics: In-vitro tissue culture raised plants of 28 diploid accessions were planted in aeroponics a total of 7552 mini-tubers were produced from 26 accessions for further multiplication in field (Fig. 25). Two accessions, CP3810 and CP4724 did not produce tubers.

Ploidy analysis: Thirty-three clones of 12 accessions imported from USDA were evaluated for ploidy using flow cytometry and all were confirmed as diploids. Besides, among 38 in-vitro accessions, 28 accessions were confirmed as diploids.



Fig. 25: Multiplication of new diploid accessions in aeroponics

TPS to tuber conversion for evaluation under inbreeding: Four hundred and sixty-four (464) seedlings of two diploid populations *viz.*, DMxM18 (3316 TPS) and DMxM6 (4450 TPS) in S₁ and S₂ generation were planted at, Modipuram in the net-house for conversion into tuber form and selection. The population DMxM18 resulted in 13 and 5 families, while 5 and 22 families were selected from DMxM6 population in S₁ and S₂ generation, respectively (Fig. 26).



Fig. 26: Selfed berries of S₁ and S₂ generation diploid population and (a) Diploid S₂ generation families in net-house b) Weak S₂ generation diploid plant

Inbred development programme: Tissue culture raised plants of 12 diploid accessions were selfed to generate 2540 S₁ TPS. Similarly, TPS of three diploids populations (CP3736xCP4539, CP4591xCP4592, DMxM18) were planted and individual plants were selfed to generate 1150 S₁ TPS. In S₁ generation, seed tubers of 18 selected families at Modipuram and TPS of thirty families of three diploid populations (DMxM18, DMxM6 and USW4xM6) were planted and individual plants were selfed to generate 6050 S₂ TPS. In the next generation (S₂ generation), tubers of selected 27 families of two populations at Modipuram and TPS of six families of two populations

(DMxM18, DMxM6) were grown to generate 2050 S₃ TPS through inbreeding. Many plants in S₂ generation did not flower, some produced small flowers, which dropped at the bud stage itself. Some plants produced pale yellow foliage and were very weak. Only few plants flowered and could be selfed for generation advancement.

Sli gene transfer for self-compatibility: Two self-compatibility gene (*Sli*) donor lines were crossed as male parent with 17 new self-incompatible diploid potato clones and 550 TPS were generated as S₀ generation lines.



PROGRAMME: GENETIC ENHANCEMENT OF POTATO THROUGH MOLECULAR AND GENOMIC TOOLS

Transcriptome profiling for high nitrogen use efficiency in potato

Nitrogen (N) is an important nutrient for plant growth. However, its excess application leads to environmental damage. Hence, improving nitrogen use efficiency (NUE) of plant is one of the plausible options to solve the problems. Aim of this study was to identify candidate genes involved in enhancing NUE in potato cv. Kufri Gaurav (N use efficient). Plants were grown in aeroponic with two contrasting N regimes (low N: 0.75 mM, and high N: 7.5 mM) (Fig. 1). Higher NUE in Kufri Gaurav was observed in low N based on the parameters like NUE, NUpE (N uptake efficiency), NUtE (N utilization efficiency) and AgNUE (agronomic NUE). Further, global gene expression profiles in root, leaf and stolon tissues were analyzed by RNA-sequencing using Ion Proton™ System. Quality data (Q20) of 2.04 to 2.73 Gb per sample were mapped with the potato genome. Statistically significant ($P < 0.05$) differentially expressed genes (DEGs) were identified such as 176 (up-regulated) and 30 (down-regulated) in leaves, 39 (up-regulated) and 105 (down-regulated) in roots, and 81 (up-regulated) and 694 (down-regulated) in stolons (Fig. 2). Some highly up-regulated genes in leaves were superoxide dismutase [Cu-Zn] chloroplastic (5.46 log₂ FC), GDSL esterase lipase At5g33370-like (4.81) etc.; whereas highly down-regulated genes in leaves were superoxide dismutase [Fe] chloroplastic (-5.28), VQ motif-containing 10-like (-4.34) etc. In roots, of total 302 up-regulated and 382 down-regulated DEGs, statistically significant DEGs were 39 (up-regulated) and 105 (down-regulated). A few highly up-regulated genes were probable phosphatase 2C 72 (5.85), urea-proton symporter DUR3 (3.73), high affinity nitrate transporter-like (3.17) etc.; whereas down-regulated genes in roots were NRT1 PTR FAMILY-like (-4.48), SPX domain-containing 4 (-3.62) etc. In stolons, of total 397 up-regulated and 1910 down-regulated DEG, statistically significant DEGs were 81 (up-regulated) and 694 (down-regulated). A few up-regulated genes were kunitz-type inhibitor C (6.62), tropinone reductase I (4.45) etc.; whereas

down-regulated genes were tetra-peptide repeat homeobox 1-like isoform X1 (-6.93), ferric reduction oxidase 4-like (-6.14) etc. Venn diagram analysis showed some common genes in the tissues (Fig. 3). In up-regulated genes category, only superoxide dismutase [Cu-Zn] chloroplastic was common in leaf and root, whereas four genes (probable phosphatase 2C 72, urea-proton symporter DUR3, bidirectional sugar transporter SWEET10-like and high affinity nitrate transporter-like) were common in root and stolon. Among down-regulated genes, two genes (SPX domain-containing and vetispiradiene synthase) were common in leaf and root, two genes (superoxide dismutase [Fe] chloroplastic and probable elastin-binding) in leaf, root and stolon, and seven genes in root and stolon. The gene ontology (GO) terms like metabolic process, cellular process and catalytic activity were predominant. Our RT-qPCR analysis confirmed the gene expression profiles of RNA-seq. Overall, we identified candidate genes associated with improving NUE such as superoxide dismutase, GDSL esterase lipase, probable phosphatase 2C, high affinity nitrate transporters, sugar transporter, proline rich proteins, transcription factors (VQ motif, SPX domain, bHLH) etc. Our findings suggest that these candidate genes probably play crucial roles in enhancing NUE in potato.

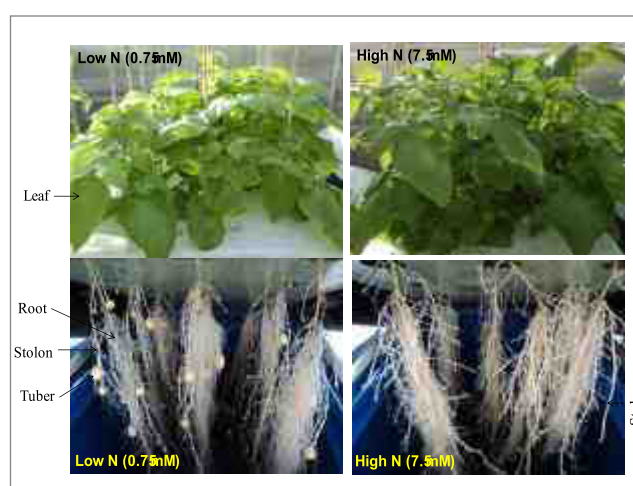


Fig. 1: Phenotypes of a potato cv. Kufri Gaurav under aeroponic with low N (0.75 mM) and high N (7.5 mM, control)

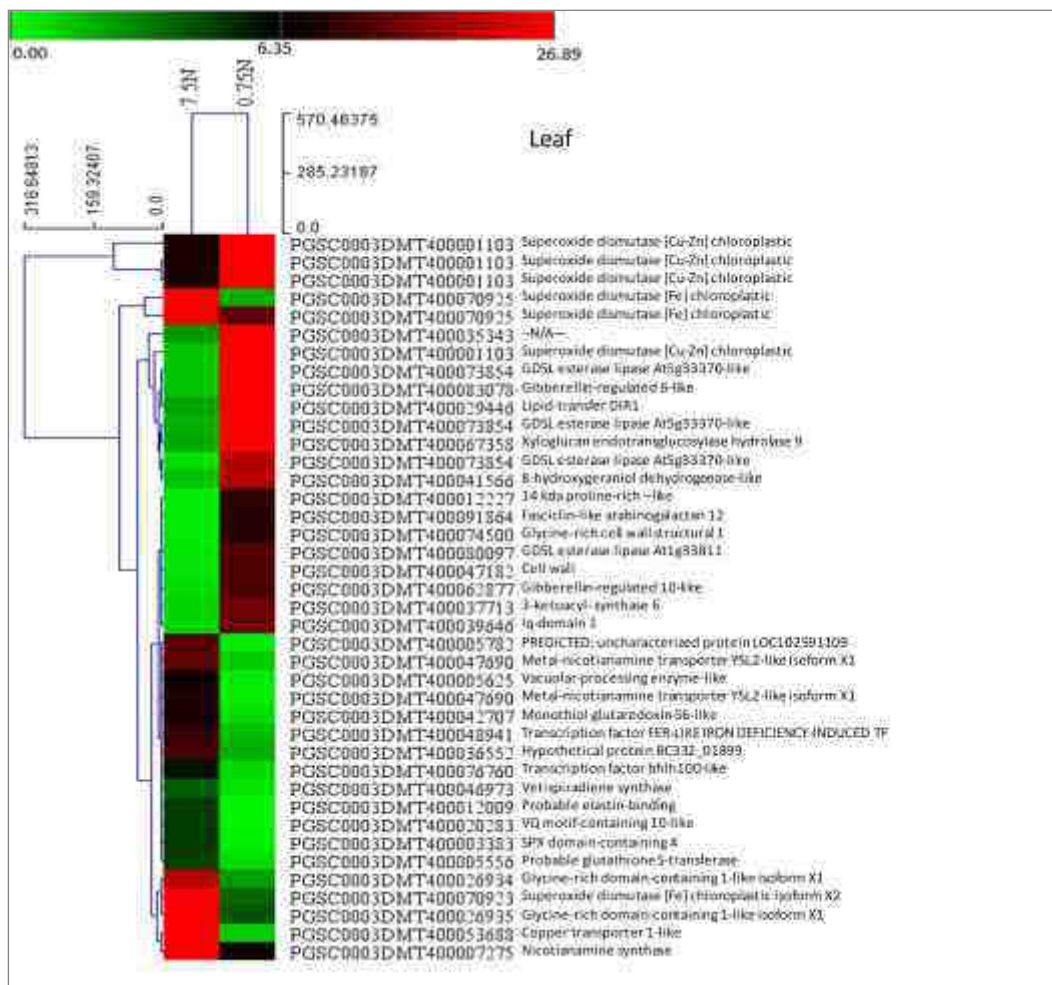


Fig. 2: Heat map of top 20 differentially expressed genes (DEG) ($P \leq 0.05$) in leaf tissues of potato cv. Kufri Gaurav grown in aeroponic with low N (0.75 mM) and high N (7.5 mM, control)

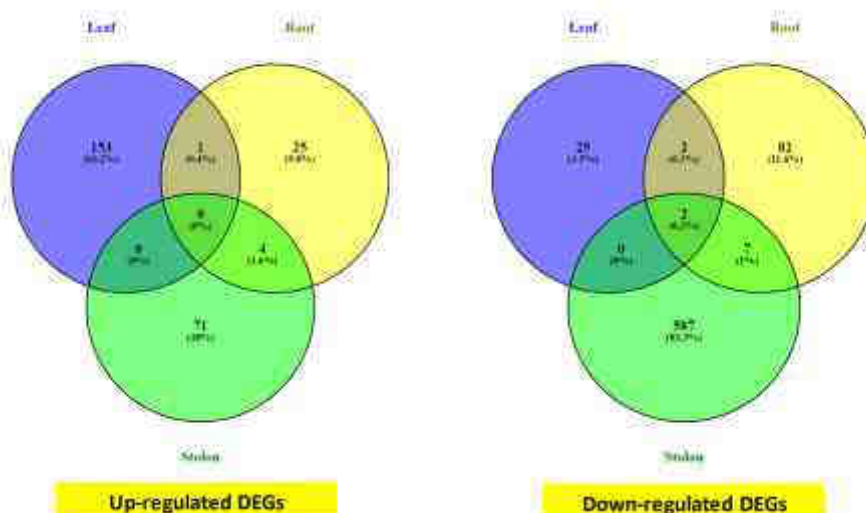


Fig. 3: Venn diagram analysis shows common DEG (up-regulated and down-regulated) in potato leaf, root and stolon tissues of cv. Kufri Gaurav grown in aeroponic with low N (0.75 mM) and high N (7.5 mM, control)

Comparative analysis of methylome and transcriptome data for tuber shape variation in tissue culture-derived variant of potato cv. Kufri Bahar

Bahar: Mother plant (M1, round) and tissue culture-derived plant (M2, elongated) of Kufri Bahar was used for methylome and transcriptome analyses. Genome-wide DNA methylation pattern was analyzed at three cytosine contexts (CpG, CHG and CHH). Of total cytosines analyzed, per cent of methylated cytosines was more in M1 (37.89%) than M2 (37.41%), where CHH was the highest than CHG and CpG. DMRs analysis revealed 4572 (CpG), 9320 (CHG) and 2453 (CHH) methylated regions in M2 (versus M1, control). Maximum DMRs were observed on chromosome #5 (2520) followed by chromosome #1 (1509). Downstream region showed maximum DMRs (1958) followed by upstream (1484), exon (1424), intron (1089), promoter 1kb (393), and proximal promoter (184), and unannotated (7630). A number of hyper-methylated and hypo-methylated genes were observed in potato such as integrase core domain containing protein, pentatricopeptide repeat-containing protein, gag-pol protein, cytochrome P450, zinc finger protein, ATP binding protein, F-

box family protein, transcription factor and so on. In CpG context, the most common DNA methylation in plants, genes having high methylation difference (75-100%) were like ankyrin repeat-containing protein, glutaredoxin, F-Box protein, inositol-1,4,5-triphosphate-5-phosphatase, transcription factor (WRKY5/MYBR/C3HL/AP2), UDP-glucosyltransferase and endo-1,4-glucanase (Fig. 4). Venn diagram analysis showed a considerable number of common genes in methylome and transcriptome analyses. Importantly, 29 genes were common in CpG and DEGs (RNA-seq) analysis such as 3-ketoacyl-CoA synthase 10, F-box family protein, early-responsive to dehydration 3, chlorophyll a-b binding protein 8 chloroplastic, SAUR family protein, cytochrome P450 77A2, transcription factor, endo-1,4-beta-glucanase etc. Whereas, 30 genes were common in CHG and DEGs such as FAD binding domain containing protein, glycine-rich cell wall structural protein 1.8, UDP-glucosyltransferase, F-box protein, glycosyltransferase family GT8 protein, transcription factor RF2a, cytochrome P450 etc., whereas five genes were common in CHH and DEGs such as proline-rich protein and chlorophyll a/b binding protein type I (Fig. 5).

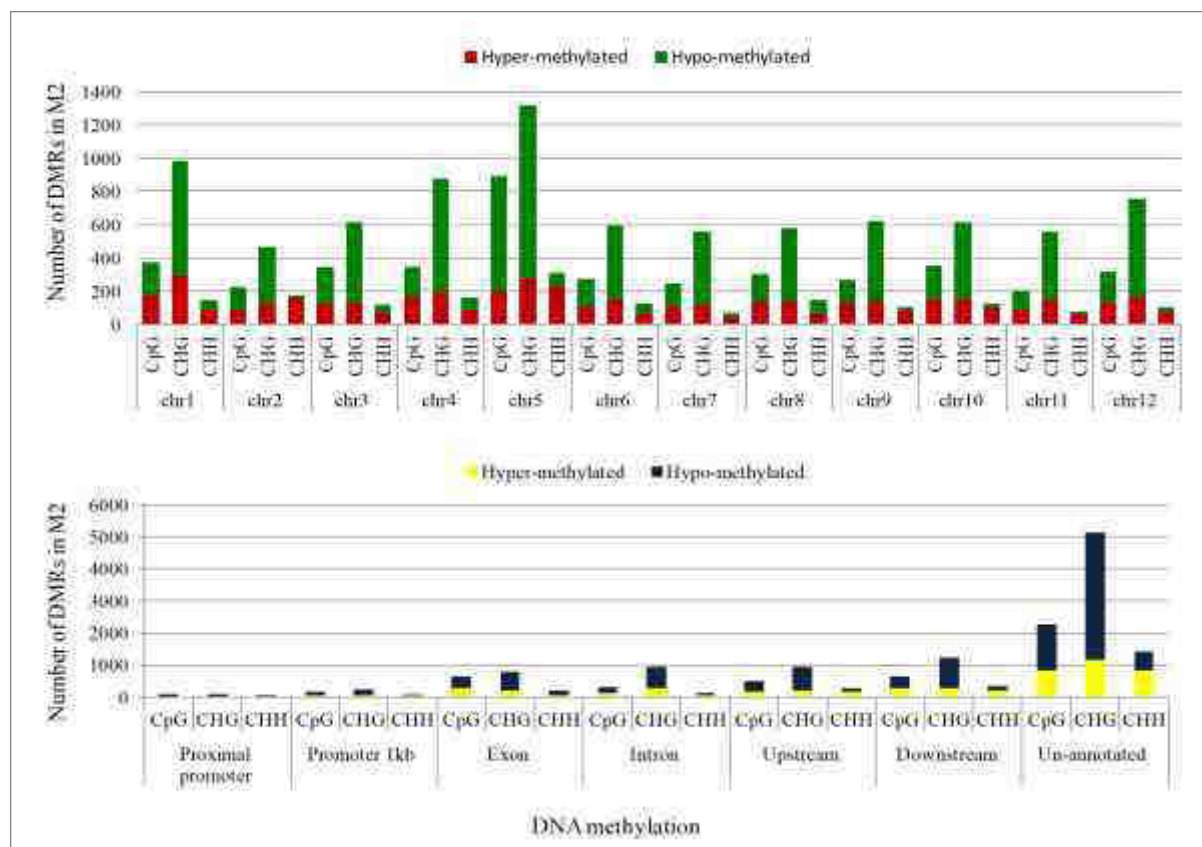


Fig. 4: Chromosome and gene region wise distribution of differential methylation regions (DMRs)

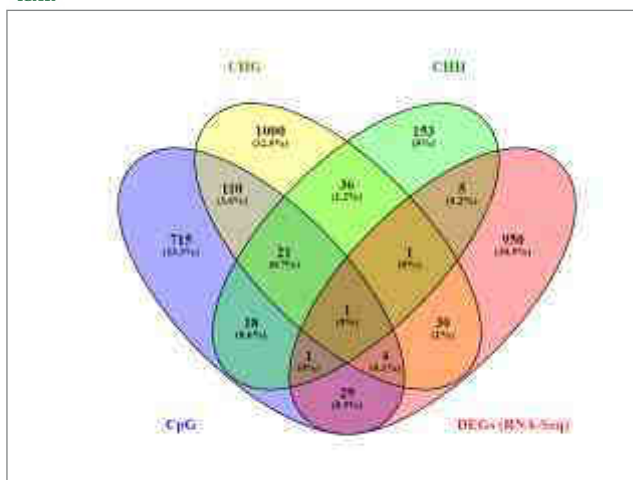


Fig. 5: Venn diagram depicting the number of common and exclusive genes in DNA methylation contexts and differentially expressed genes

Development of SSR fingerprints of interspecific potato somatic hybrids: Interspecific potato somatic hybrid progenies, developed earlier by crossing somatic hybrids with Indian potato varieties, were used for DNA fingerprints by SSR markers. A total of 81 genotypes (progenies and parents) were analysed

by two well-characterized potato SSR markers (STU6SNRN and STIICA), and developed a data matrix for genetic fidelity purpose and other applications. High polymorphism was observed in STIICA (PIC: 0.98) than STU6SNRN (PIC: 0.95), and also higher number of alleles was observed in STIICA (22) than STU6SNRN (7). In STU6SNRN, alleles size 179, 182, 190 and 200 bp were predominant; whereas in STIICA, alleles size 195, 201, 221, 235, 242 and 245 were observed frequently in more than 50 per cent of the genotypes. Diversity analysis showed a clear distinction among the genotypes based on the Jaccard dissimilarity coefficient by the Neighbour-joining tree method using the DARwin software. Our study suggests that SSR fingerprints would be of practical utility to strengthen genetic fidelity of these somatic hybrids. Further, SSR fingerprints would also be valuable resources in resolving issues related to identification of true-to-type clone during field evaluation in multiple environments (Fig. 6 & 7).



Fig. 6: Tubers phenotype of advanced stage potato somatic hybrids. i) MSH/17-16: Yellow ovoid tubers, shallow eyes and yellow flesh; ii) MSH/14-7: Yellow ovoid tubers, shallow eyes and yellow flesh; iii) MSH/14-112: White ovoid tubers, shallow eyes and white flesh

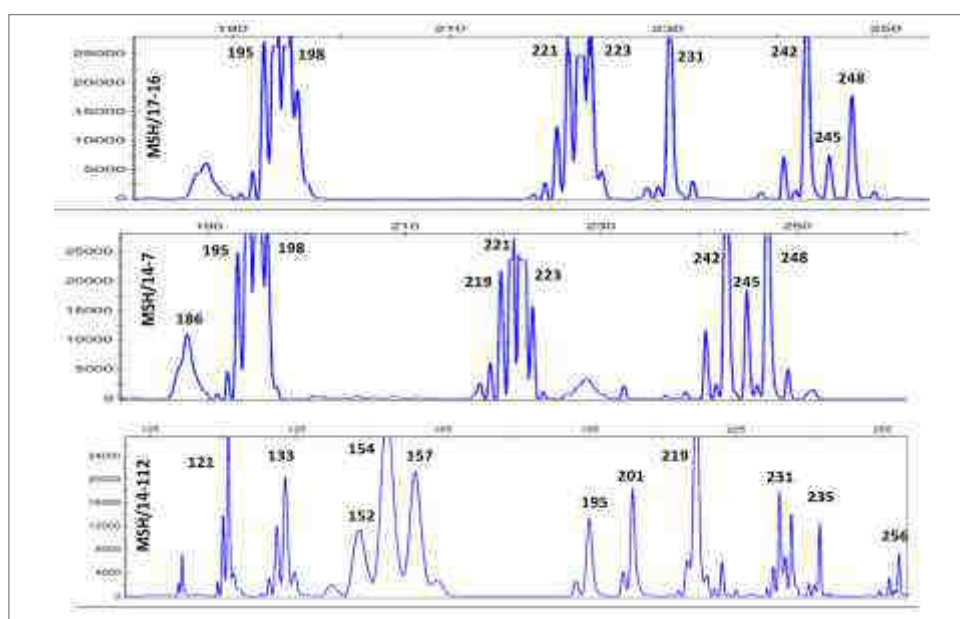


Fig. 7: SSR (STIICA marker) allelic profile of advanced stage clones of interspecific potato somatic hybrids (MSH/17-16, MSH/14-7 & MSH/14-112). Value on peaks indicates SSR allele size (bp)

Development of nitrogen use efficient hybrids of potato: Global agriculture faces problems of environmental pollution due to excess application of nitrogen (N) fertilizers in potato. Hence, aim of this study was to develop potato hybrids with high nitrogen use efficiency (NUE) for sustainable crop production. We generated here a bi-parental population of 116 progenies by crossing two contrasting varieties *viz.*, Kufri Jyoti (N inefficient) and Kufri Gaurav (N efficient). After five years (2015-20) of tuber multiplication and field trials under limited N (50 kg N/ha) input, we developed advance hybrids based on 20 traits of agronomic, physio-biochemical and NUE parameters. Significant variations were observed in the progenies for most traits such as plant height, total leaf area, shoot dry weight and tuber traits (number, yield and dry matter). Further, plant total N content, NUE variables (NUE, NUpE, NUtE, HI and NHI) and physio-biochemical properties also differed significantly. The principal component analysis (PCA) and agglomerative hierarchical clustering (AHC) distinguished variation, and observed significant and positive correlations for tuber traits and NUE variables in the genotypes. Finally, we demonstrate here four advance hybrids (NUE/15-8, NUE/15-14, NUE/23, and NUE/15-67) with high

yield and NUE combined with other desirable traits. Further, our study implies that tuber yield and NUE parameters are the key criteria for selection of N use efficient genotypes under limited N input. These potato hybrids have potential for low N input agriculture (Fig. 8).

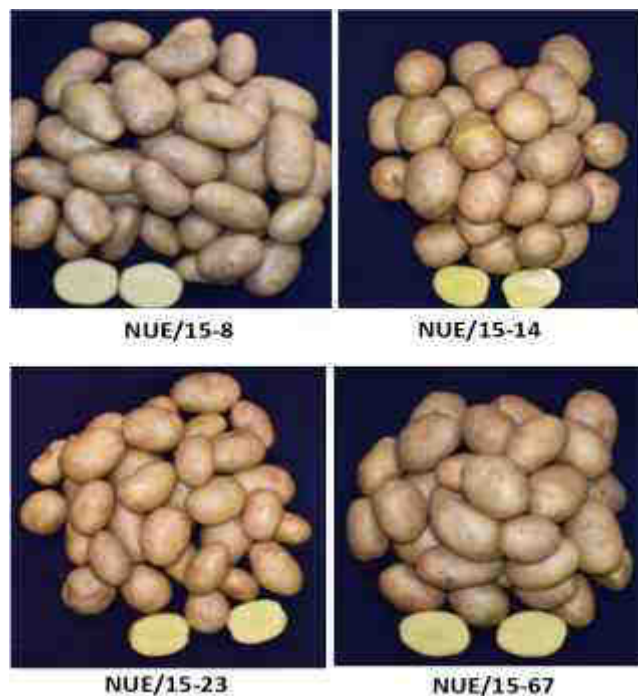


Fig. 8: Advance stage NUE potato hybrids (NUE/15-8, NUE/15-14, NUE/15-23 and NUE/15-67)

Phenotyping of Kufri Girdhari transgenic lines expressing CDF1.2 gene for early tuberisation under long day environment

In our earlier experiments, developed transgenic Kufri Girdhari expressing the *CDF1.2* gene, and molecular characterization like PCR and phenotyping for early tuberisation under controlled micro tuber production system, selected 28 promising lines out of 58 lines. In the second clonal generation, at Shimla conditions, positive lines were analyzed phenotypically for maturity and early tuberization, in which 25 of the lines were tuberising 13 days early and senescence phenotype in comparison to the non-transgenic Kufri Girdhari. In the third clonal generation, 6 lines of second clonal generation subjected to long day conditions (Shimla growing seasons) phenotype and observed significant

early (10 days) and more number of tubers and size in Kufri Girdhari transgenic lines compare to control Kufri Girdhari cultivar (Fig. 9).



Fig. 9: 10 days early and more tuberisation phenotypes in transgenic Kufri Girdhari lines compare to control under long day condition at Shimla

Tuberisation performance of Activation tagging Kufri Jyoti mutants under containment facility: In an earlier experiments, employed activation tagging approach to generate gain of function mutants in cultivated potato cultivars. Generated 17 activation tagged lines of potato cv. K. Jyoti and 15 K. Chipsona-1 lines out of 1000 putative transformants from each cultivars. After successful 3 clonal generations, characterize the mutants by using PCR with primers of *Bar* and *Hpt* genes. Positive activation tagged lines showed lateral multiple shoot outgrowth compared to control plants, as we

depicted in earlier studies. These lines were subjected to phenotyping for tuberisation performance under containment facilities. Some lines grown profusely and branched phenotype and more number of tubers (around 30 tubers per plant). Mutant lines showed abnormal, oblong shaped tubers (Fig. 10). There is need to understand the branched phenotypes, multiple tuberisation phenomenon and abnormal shape of tubers using thorough molecular characterization and this could may reveal the functionality of the genes and pathway underlying in these Kufri Jyoti mutants.



Fig. 10: Tuberisation performance of Activation tagging lines of Kufri Jyoti

Deciphering role of Heat Shock Transcription Factors (HSFs) in potato: In plants, HSFs are the terminal components of a signal transduction chain mediating the expression of genes responsive to various abiotic stresses. Fifteen HSF genes of potato were identified in the potato genome. Three HSF genes were found to be present on chromosome 2 and 8, 2 on chromosome 4 and 10, 1 on chromosome 6, 7, 9 11 and 12 and no gene were found on chromosome 1, 3 and 5. The predicted potato HSF gene structure indicated the maximum number of exons present to be 2 in potato HSFs.; however, exonic and intronic abundance did not show much variation in the HSF gene structure, except that HSF gene PGSC0003DMG402008167 had no intron. The length of genes ranges from 0.826 kbp to 6.315

kbp (Fig 11). *In silico* analysis was performed for the deduced protein sequences of the 43 HSF proteins obtained from NCBI and 15 sequences from PGSC. The length of HSF proteins was found to range from 55 to 536 amino acids with lowest molecular weight 12.20 kDa and highest of 60.25 kDa, respectively. Theoretical pI ranges from 4.71 to 9.58. Using gene specific and degenerate primer based approaches five genes viz. HP1, HP2, HP4, HP9 and HP10 were amplified, cloned and sequences from potato genome. The cloned sequences were submitted to NCBI GenBank. The assigned accession number to these cloned genes; HP1, HP2, HP4, HP9 and HP10 are MW001209, MW001210, MW001211, MW001212 and MW001213, respectively.



Fig. 11: Structures of HSF genes of potato

RNA-Seq analysis revealed genes associated with iron stress response in potato: Despite the fact that iron (Fe) is the fourth most abundant element in the earth's crust, iron is sparingly soluble under aerobic conditions, especially under alkaline conditions and calcareous soils, which accounts to 30% of the world's cultivated soils. To explore the molecular regulation mechanisms underlying potato in response to iron stress, transcriptome analysis of two contrasting potato genotypes CP-4069 (tolerant) and CP-3443 (susceptible) was performed. A total of 2,383 differentially expressed genes (DEGs) were identified by comparing the eight samples, of which 182 (7.64%) were novel and 16 (0.67 %) were isoforms. The highest number of DEGs (660) were identified between the control and the treatment of CP-4069 in

the root tissue (CP-4069 R⁺ vs CP-4069 R) and the lowest number of DEGs (134) were in comparison of the roots and leaf tissue of CP-3443 under the stress condition (CP-3443 R⁻ vs CP-3443 S). In response to low iron, the tolerant genotype CP-4069 showed more number of DEGs when compared to the susceptible CP-3443 in roots (660 vs 350) and similarly in the shoots (478 vs 244). Overall, the number of up-regulated genes under low iron conditions was higher except for the shoot of CP-3443 where number of down-regulated genes is higher as compared to up-regulated genes. In comparison between genotypes, DEGs were more in the roots than the shoots. In addition, overlapped differentially expressed genes between CP-4069 and CP-3443 under the control and the low iron

conditions were analyzed. In comparison Fe homeostasis-related genes were identified, which were specifically expressed in the roots, the shoots and common genes were 364, 212 and 16, respectively. Gene ontology (GO) and KEGG pathway analysis

were also performed in order to functionally categorize the differentially expressed genes and compare the metabolic pathways between CP-4069 and CP-3443 genotypes under the iron deficient condition in the roots and the shoots (Fig. 12).

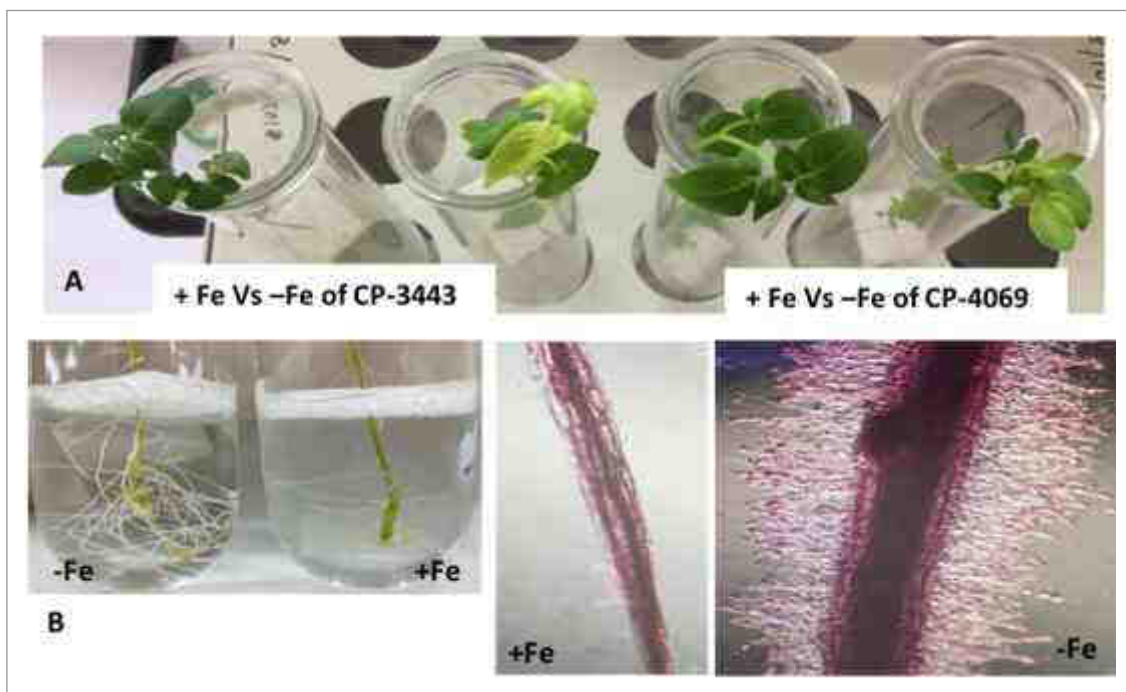


Fig. 12: Potato plants subjected to sufficient and Fe deficient Fe supply conditions (a) interveinal chlorosis of apical leaves (b) profuse lateral roots and root hairs formation in the deficient plants

Development of protocols for *in vitro* somaclonal variant by exposing callus cultures to Fe/Zn deficiency: *In vitro* selection of plants capable of growing in nutrient-deficient environments using plant tissue culture techniques is a cost-effective and alternative tool to avert micronutrient deficiency problems. Multiplication of potato cv. K. Megha and K. Chipsona-3 were attempted through somatic embryogenesis. The influences of medium (modified Murashige and Skoog medium (mMS) and Schenk and Hildebrandt (SH)) and growth hormones supplements in the induction of SE derived potato plants were studied. An increasing trend in callusing percentage with increasing levels of 2,4-D was found both in SH and mMS medium. Of the two different culture media and different 2,4-D levels (0.5, 1.0, 1.5, 2.0, 2.5 mg/l) tested, mMS medium with 2,4-D level of 1.5 mg/l was found to be more effective for callus induction with highest frequency of 99.66 % in

K. Chipsona-3 followed by 98.33 % in K. Megha after 4-6 wk of culture. Well developed calli were transfer into embryogenic induction medium GA3 (14.4 μ M) + BA (10.0 μ M) or GA3 (14.4 μ M) + zeatin (4.6 μ M) or BA (10.0 μ M) + zeatin (4.6 μ M - 22.8 μ M) were tested. Of the different levels of combination, mMS medium with zeatin (22.8 μ M) and BA (10.0 μ M) found to be more effective for somatic EC induction with a frequency of 91.66 % in K. Chipsona-3. The percentage of EC at different levels of growth hormones was significantly different among the genotypes and media. This technique using potato callus cultures will be employed in the screening and selection of valuable agronomic traits in plants such as Fe, Zn etc. *In vitro* selection can complement existing approaches and conventional field selection methods of acquiring Fe/Zn-deficiency resistant plants (Fig. 13).



Fig. 13: Embryogenic Calli (EC) obtained from different potato genotypes

In silico analysis of starch branching enzyme: Potato tuber mainly contains starch. Starch is the complex form of carbohydrate and is a polymer of glucose molecules. Starch is comprised of amylose and amylopectin chain of molecules. Amylose is a linear chain of glucose monomers linked by α -(1,4) glycosidic bonds, whereas amylopectin is predominant and is composed of linear chain linked

by α -(1,4) glycosidic bonds as well as branched-chain α -(1,6) glycosidic bonds. In our experiment, we studied starch branching enzyme 2.2 *in silico* with various software (<https://predictprotein.org/>; <https://www.rcsb.org/> and <https://swissmodel.expasy.org/>) and predicted the protein model for this enzyme (Fig. 14).

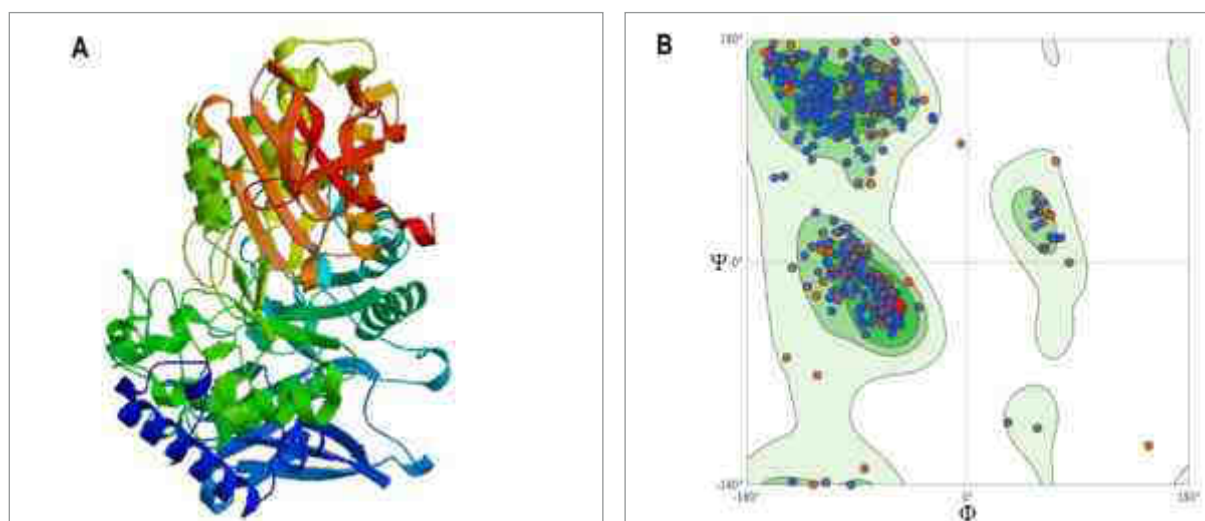


Fig. 14: (A): Three dimensional model of starch branching enzyme (SBE I) from the sequence analysed in <https://swissmodel.expasy.org>; (B): Ramachandran plot and distribution of amino acid in the enzyme complex

Development of dsRNA based potato sprout suppressant:

Twenty two different genes having major role in potato sprout development have been identified for designing dsRNA. The 22 genes identified include Histone H4, dUTPase, Histone H3, Alpha amylase, Cyclin B1, Cyclin B2, Cyclin A and B, Cyclin D1, Cyclin D2, Alternative oxidase, Alternative oxidase 2, Cytochrome c oxidase, Cytokinin receptor 1, Elongation Factor 1 alpha, Elongation factor Tu, GA1 Receptor GID1, Ribosomal protein L18 and Ribosomal protein S12. The effective siRNA regions from these target genes were identified using various bioinformatics tools viz. siDirect 2.0, Noble foundation psiRNA target finder tool etc. Two siRNA constructs, construct were designed using the identified sequences and cloned

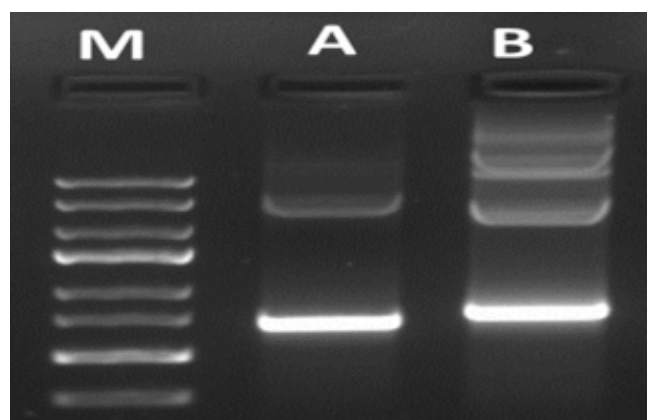


Fig. 15: Cloning of siRNA construct A and B into T7 expression vector

constructs (A and B) into T7 expression vector (Fig. 15).

PROGRAMME: DEVELOPMENT AND PRODUCTION OF NUCLEUS AND BREEDER SEED OF NOTIFIED POTATO VARIETIES THROUGH CONVENTIONAL AND HI-TECH SYSTEMS

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 different stations located in different regions of the country. The nucleus and breeder seed production and supply status of breeder seed during the 2019-20 is given below:

Project 1: Production of nucleus and breeder seed of important notified varieties of potato

Seed Production

A. Plains

A total production of 28699.84 qtls nucleus and breeder seed was achieved from an area of 124.56 ha. Out of which, 19324.92 qtls production from 88.12 ha was through conventional and 9374.92 qtls from 36.44 ha through hi-tech seed production systems respectively. The percentage of nucleus and breeder seed from conventional system was 67.33 and 32.67 through hi-tech system.

1. Conventional Seed Production System: A total no. of 19424 indexed tubers of different commercial potato varieties were tested at regional stations in the plains & in Stage-I crop 18208 hills were tested (Table 1).

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

Name of Station	Indexed Tubers		Field ELISA	
Plains	No of tubers tested	Healthy tubers No (%)	No of tubers/ hills tested	Healthy tubers/ Hills No (%)
Modipuram	5000	4856 (97.12)	4856	4712 (97.03)
Jalandhar	6184	6108 (98.77)	6108	5500 (90.04)
Gwalior	6452	5904 (91.51)	6044	5608 (92.79)
Patna	1788	1712 (95.75)	1200	1182 (98.50)

2. Station/stage wise area and production of different potato varieties is given in table 2.

Stage-I: A total production of 183.68 qtls. was achieved from an area of 2.57 ha (Table-2) with average production of 118.0, 33.84, 51.50 and 100 qtls./ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-II: A total production of 873.76 qtls. was achieved from an area of 5.80 ha (Table-2) with average production of 143.23, 124.39, 177.40 and 150.0 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-III: A total production of 3459.68 qtls. was achieved from an area of 16.38 ha (Table-2) with average production of 252.44, 226.90, 140.67 and 213.46 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage-IV: A total production of 14807.8 qtls. was achieved from an area of 64.37 ha (Table-2) with

average production of 293.22, 161.90, 186.20 and 205.19 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

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

(i) **Generation-1:** A total production of 1475.83 qtls. was achieved in G-I from an area of 6.041 ha with average production of 259.18, 232.29, 90.08 and 323.64 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

(ii) **Generation-2:** A total production of 7899.29 qtls. was achieved in G-2 from an area of 36.44 ha with average production of 311.71, 230.19, 105.96 and 213.25 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

Table -2: Station & variety wise area and production (qtls) in Conventional system 2020 (Plains)

Variety	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
I. Modipuram										
K. Anand	0.045	4.65	0.14	20.00	0.30	89.50	1.00	268.50	1.485	382.65
K. Bahar	0.480	59.65	1.60	187.50	3.50	953.00	6.75	2201.00	12.33	3401.15
K.Chipsona-1	0.071	6.95	0.35	56.50	1.00	200.00	4.50	1440.00	5.921	1703.45
K.Chipsona-3	0.040	4.65	0.15	22.50	0.25	78.00	1.20	355.00	1.64	460.15
K.Chipsona-4	-	-	-	-	-	-	0.70	183.00	0.70	183.00
K. Frysona	0.035	4.10	0.14	20.00	0.30	76.50	1.10	389.50	1.575	490.10
K. Khyati	0.055	6.30	0.18	35.00	0.60	149.50	3.70	870.00	4.535	1060.80
K. Pukhraj	0.044	5.60	0.20	37.50	0.25	71.50	2.25	610.00	2.744	724.60
K. Surya	0.055	6.75	0.14	20.50	0.30	87.00	1.70	453.50	2.195	567.75
K.Mohan	0.075	7.55	0.20	44.50	1.25	274.00	3.00	948.00	4.525	1274.05
K. Garima	-	-	-	-	0.45	91.00	1.90	433.00	2.35	524.00
Total	0.90	106.20	3.10	444.00	8.20	2070.00	27.80	8151.50	40.00	10771.70
II. Jalandhar										
K. Jyoti	0.45	15.02	0.58	62.50	1.12	277.92	8.91	1390.00	11.06	1745.44
K. Pukhraj	0.253	7.61	0.12	22.85	0.35	86.00	0.50	120.00	1.223	236.46
K. Badshah	0.033	1.07	0.027	3.35	0.05	12.00	-	-	0.11	16.42
K. Khyati	0.03	1.17	0.029	4.99	0.083	21.76	0.15	34.50	0.292	62.42
K. Surya	0.0028	0.33	-	-	-	-	0.012	2.40	0.0148	2.73
K. Himalini	0.025	1.62	0.025	2.63	0.08	19.50	0.026	7.00	0.156	30.75
K.Chipsona-1	0.03	1.06	0.029	4.44	0.035	7.00	-	-	0.094	12.50
Total	0.8238	27.88	0.81	100.76	1.718	424.18	9.598	1553.90	12.9498	2106.72
III. Gwalior										
KCM	0.10	4.75	0.21	34.50	0.76	112.50	2.80	352.00	3.87	503.75
K. Jyoti	0.13	5.98	0.29	49.50	1.09	187.00	5.57	1143.00	7.08	1385.48
K. Sindhuri	0.09	4.07	0.25	49.00	0.70	50.00	1.91	266.50	2.95	369.57
K. Lauvkar	0.09	4.36	0.17	25.50	0.50	38.00	1.28	213.00	2.04	280.86
K.Chipsona-I	0.11	5.67	0.30	47.50	1.22	229.00	6.65	1399.00	8.28	1681.17
K. Chipsona-3	0.08	3.18	0.19	32.50	0.71	120.00	1.96	475.00	2.94	630.68
K. Surya	0.09	5.65	0.25	56.00	0.70	62.50	2.56	383.90	3.60	508.05
K. Pukhraj	0.04	3.94	-	-	-	-	-	-	0.04	3.94
Total	0.73	37.60	1.66	294.50	5.68	799	22.73	4232.40	30.80	5363.50
IV Patna										
K. Arun	-	-	-	-	-	-	0.05	11.50	0.05	11.50
K. Himalini	0.012	1.00	0.01	2.00	-	-	-	-	0.022	3.00
K. Jyoti	0.027	1.50	0.025	7.50	0.15	34.50	1.00	165.50	1.202	209.00
K. Khyati	0.027	3.00	0.105	14.50	0.30	87.50	1.54	368.00	1.972	473.00
K. Keshar	0.012	1.50	0.005	1.00	-	-	-	-	0.017	2.50
K. Kanchan	0.006	0.50	-	-	-	-	-	-	0.006	0.50
K. Lailt	0.015	1.50	0.045	4.00	0.15	21.50	0.15	29.00	0.36	560.00
K. Pukhraj	0.009	2.00	0.03	3.00	0.15	18.00	0.30	70.50	0.489	93.50
K. Sindhuri	0.012	1.00	0.01	2.50	0.03	5.00	1.20	225.50	1.252	234.00
Total	0.12	12.00	0.23	34.50	0.78	166.50	4.24	870.00	5.37	1083.00
Plains' Total	2.5738	183.68	5.80	873.76	16.378	3459.68	64.368	14807.80	89.1198	19324.92

Table 3: Station & variety wise area and production (Qts.) in Hi-Tech system 2020 (Plains)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
I. Modipuram						
K. Chipsona-1	1.39	280.00	1.60	521.00	2.99	801.00
K. Chipsona-3	0.18	51.00	0.60	185.50	0.78	236.50
K. Chipsona-4	-	-	1.00	259.50	1.00	259.50
K. Frysona	0.08	29.50	0.10	36.00	0.18	65.50
K. Garima	0.10	33.00	0.60	130.00	0.70	163.00
K. Khyati	0.60	174.00	4.30	1171.00	4.90	1345.00
K. Mohan	0.80	220.00	6.60	2343.50	7.40	2563.50
K. Pukhraj	0.12	46.50	0.20	50.00	0.32	96.50
K. Surya	0.07	24.00	0.50	135.00	0.57	159.00
K. Sukhyati	0.09	31.00	-	-	0.09	31.00
Total	3.43	889.00	15.50	4831.50	18.93	5720.50
II Jalandhar						
KCM	0.20	41.90	2.66	569.90	2.86	611.80
K. Jyoti	0.156	38.15	0.25	53.64	0.406	91.79
K. Badshah	0.022	5.80	0.48	127.55	0.502	133.35
K. Pukhraj	0.753	182.50	0.75	180.90	1.503	363.40
K. Chipsona-1	-	-	0.40	97.50	0.40	97.50
K. Chipsona-3	-	-	0.25	51.85	0.25	51.85
K. Khyati	0.062	18.00	0.22	44.53	0.282	62.53
K. Himalini	0.346	68.84	1.98	498.15	2.326	566.99
K. Surya	-	-	0.30	56.55	0.30	56.55
K. Gaurav	0.032	9.50	1.11	25 3.02	1.142	262.52
Total	1.571	364.69	8.40	1933.59	9.971	2298.28
III Gwalior						
K. Chandramukhi	-	-	0.32	33.50	0.32	33.50
K. Lauvkar	0.17	15.76	0.60	75.00	0.77	90.76

K. Chipsona-1	0.03	1.75	0.33	38.50	0.36	40.25
K. Mohan	0.04	4.10	1.10	102.00	1.14	106.10
K. Surya	0.08	6.09	-	-	0.08	6.09
K. Pukhraj	0.07	4.72	-	-	0.07	4.72
K. Khyati	0.10	11.72	-	-	0.10	11.72
Total	0.49	44.14	2.35	249	2.84	293.14
IV Patna						
K. Ashoka	-	-	0.15	38.00	0.15	38.00
K. Chip-1	-	-	1.60	359.50	1.60	359.50
K. Chip-3	0.02	1.50	0.05	10.50	0.07	12.00
K. Himalini	0.15	48.50	1.20	255.50	1.35	304.00
K. Jyoti	0.02	5.00	-	-	0.02	5.00
K. Khyati	0.30	90.50	0.25	55.00	0.55	145.50
K. Lauvkar	-	-	0.05	5.50	0.05	5.50
K. Mohan	0.04	28.50	0.25	74.50	0.29	103.00
K. Pukhraj	0.02	4.00	-	-	0.02	4.00
K. Sindhuri	-	-	0.30	42.00	0.30	42.00
K. Surya	-	-	0.30	44.50	0.30	44.50
Total	0.55	178.00	4.15	885.00	4.70	1063.00
Plains Total	6.041	1475.83	30.40	7899.09	36.441	9374.92

3. Total supply of breeder seed

During 2020, total 20294.16 qtls breeder seed was supplied to various government and private agencies, from plains Table-4 (A & B).

B. Hills (2020)

Multiplication of basic material & maintenance of mother stock

A total no. of 42 pots of 21 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 8817 culture tubes were multiplied under tissue culture. In aeroponics, 19704 minitubers of different varieties were harvested.

Maintenance of buffer stock in field at CPRS, Kufri

The nucleus and breeder seed potato production at Kufri and Fagu farms of CPRS Kufri has been suspended since, 2019. However, the maintenance of varieties viz., K. Jyoti, K. Himalini, K. Girdhari, K. Kanchan, K. Shailja, K. Giriraj, K. Himsona buffer seed stocks under different seed stages of Conventional and Hi-tech systems was carried out in small area. After keeping own seed stocks for raising the buffer seed stages and trap crop during 2021 as per the approved cropping scheme aimed at eradication of PCN at both the farms, the surplus stocks were sold in Subzi Mandi.

Table-4 (A): Station and variety wise supply (qtls) during 2020

S. No.	Variety	Modipuram	Jalandhar	Gwalior	Patna	Total
1.	Kufri Anand	247.50	-	-	-	247.5
2.	Kufri Ashoka	-	-	-	37.50	37.5
3.	Kufri Arun	-	-	-	11.40	11.4
4.	Kufri Bahar	2051.00	-	-	-	2051
5.	Kufri Badshah	-	126.73	-	-	126.73
6.	Kufri Chipsona-1	1865.75	52.08	1184.41	359.00	3461.24
7.	Kufri Chipsona-3	452.00	49.26	426.60	10.40	938.26
8.	Kufri Chipsona-4	402.00	-	-	-	402
9.	Kufri Chandramukhi	-	562.5	370.21	-	932.71
10.	Kufri Frysona	395.50	-	-	-	395.5
11.	Kufri Gaurav	-	163.279	-	-	163.279
12.	Kufri Garima	453.50	-	-	-	453.5
13.	Kufri Himalini	-	501.8	-	254.00	755.8
14.	Kufri Jyoti	-	1438.965	1077.75	165.00	2681.715
15.	Kufri Khyati	1704.00	75.755	-	469.55	2249.305
16.	Kufri Lauvkar	-	-	233.55	5.40	238.95
17.	Kufri Lalit	-	-	-	29.00	29
18.	Kufri Mohan	2547.50	-	96.55	73.85	2717.9
19.	Kufri Pukhraj	482.30	300.375	-	70.00	852.675
20.	Kufri Sindhuri	-	-	281.55	265.50	547.05
21.	Kufri Surya	554.00	45.6	357.55	44.00	1001.15
Total		11155.05	3316.344	4028.17	1794.60	20294.16

C. Supply of Microplants to Different Seed Agencies

A total 110 virus-free *in vitro* culture tubes of basic seed material of 21 varieties (Fig. 1) were supplied to 10 different seed producing organizations in India (Table-5) and a revenue of Rs. 5,55,000/- has been generated.

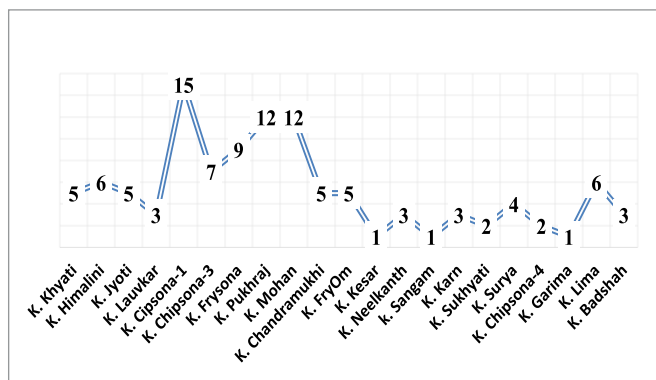


Fig. 1: Variety wise supply to different seed organizations

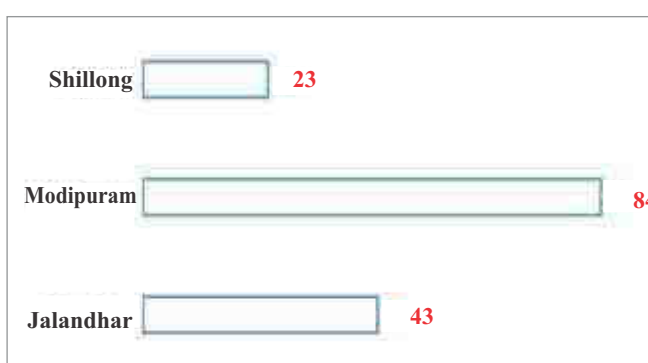


Fig. 2: Station wise supply of microplants

A total of 150 culture tubes of 21 varieties were supplied to different seed production stations/centers i.e. Modipuram, Jalandhar and Shillong (Fig. 2). A total revenue of Rs. 8.6 crores have been generated by the sale of breeder seed under revolving fund scheme (RFS) from Modipuram, Gwalior, Jalandhar & Patna center, respectively.

Table- 4 (B) Variety/stage & agency wise breeder seed supply from plains (qtls) during 2020

S. N.	Variety	Assam	Bihar	CG*	HP*	J&K*	MP*	PB*	TS*	UP*	UK*	WB*	NHRDF*	NSC*	Uni.*	ICAR	Farmers /	Total
1.	K. Anand	-	-	-	-	-	-	-	-	200.00	-	-	-	-	-	-	47.50	247.50
2.	K. Arun	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.40	8.00	11.40
3.	K. Ashoka	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	-	35.00	37.50
4.	K. Badshah	-	-	-	-	15.20	-	95.50	-	-	-	-	-	-	0.48	0.20	15.35	126.73
5.	K. Bahar	-	-	-	-	-	-	80.50	-	1076.00	-	-	45.00	-	125.00	85.50	639.00	2051.00
6.	KCM	-	-	60.50	100.00	-	-	85.00	0.50	2.05	-	216.00	-	-	17.70	117.75	333.21	932.71
7.	K. Chipsona-1	-	30.00	55.00	-	8.08	195.00	15.50	0.50	2134.00	-	-	73.00	-	79.685	76.00	794.475	3461.24
8.	K. Chipsona-3	-	-	223.00	-	21.23	-	-	0.50	247.05	-	-	62.00	-	15.53	8.40	360.55	938.26
9.	K. Chipsona-4	-	-	-	-	-	-	-	-	100.00	-	-	-	-	5.00	275.00	22.00	402.00
10.	K. Frysona	-	-	-	-	10.00	-	32.00	-	200.00	-	-	-	-	-	41.50	112.00	395.50
11.	K. Garima	-	-	-	-	-	-	-	-	200.00	-	-	-	-	-	241.00	12.50	453.50
12.	K. Gaurav	-	-	-	-	48.279	-	69.50	-	-	-	1.90	-	-	-	1.20	42.40	163.279
13.	K. Himalini	-	-	2.00	-	164.22	-	115.50	-	-	-	3.00	-	63.50	15.95	76.65	314.98	755.80
14.	K. Jyoti	15.00	-	-	100.50	50.00	-	190.00	0.50	0.05	55.00	483.10	120.00	15.00	11.15	12.45	1628.965	2681.715
15.	K. Khyati	-	50.00	22.00	-	29.45	-	-	-	1500.00	-	-	70.00	-	65.95	54.70	457.205	2249.305
16.	K. Lauvkar	-	-	-	-	-	-	32.00	0.50	0.05	-	-	-	-	-	194.40	12.00	238.95
17.	K. Lalit	-	-	15.00	-	-	-	-	-	-	-	-	-	-	-	-	14.00	29.00
18.	K. Mohan	100.00	-	50.60	-	-	-	50.00	-	850.00	80.00	-	120.00	-	170.05	449.00	848.25	2717.90
19.	K. Pukhraj	-	-	16.00	-	21.00	-	255.00	-	286.00	-	32.00	71.00	-	15.95	70.20	85.525	852.675
20.	K. Sindhuri	-	22.50	120.00	-	20.00	-	-	-	181.05	-	-	-	-	-	61.50	142.00	547.05
21.	K. Surya	-	-	-	-	34.20	-	-	-	687.10	-	-	59.00	-	40.05	1.00	179.80	1001.15
	Total	115.00	102.50	564.10	200.50	421.659	195.00	1020.50	2.50	7663.35	135.00	736.00	620.00	78.50	564.995	1769.85	6104.71	20294.16

*CG: Chhattisgarh; HP: Himachal Pradesh, J&K: Jammu & Kashmir; MP: Madhya Pradesh; PB: Punjab; TS: Telangana; UP: Uttar Pradesh; UK: Uttarakhand; WB: West Bengal; NHRDF: National Horticulture Research and Development Foundation; NSC: National Seeds Corporation; Uni.: University.

Table 5: Microplants supply to different Seed Producing Organization

S. No	Firms	Varieties Supplied
1.	M/ s Dauladhar Bioplants, P.O-Bajarerh, Tehsil-Shahpur, Distt- Kangra, HP	K. Lima, K. Pukhraj, K. Sangram, K. Himalini, K. Garima, KCM, K. Karan, K. Mohan, K. Neelkanth
2.	M/ s Bhatti Tissue Tech.Vill.-Alipur, PO Mithapur, Teh & Distt.- Jalandhar, PB	K. Karan, K. Pukhraj, KCM, K. Jyoti, K. Himalini, K. Lima
3.	M/ s Sekhon Biotech, Jalandhar, PB	K. Pukhraj, K. Badshah, K. Lauvkar, K. Himalini, K. Jyoti, K. Mohan, K.Chip-1, K.Chip-3, KCM, K. Frysona, K. Sukhyati, K. Khyati
4.	M/ s Merino India, Potato Pre -basic Seed Production	K. Khyati, K. Frysona, K. Pukhraj, K. Surya, K. Chip-4, K. Chip-3, K. Mohan
5.	Deputy Director Horticulture, Potato Technology Center, Shamgarh, Karnal	K. Mohan, K. Lima, K. Pukhraj, K. Neelkanth
6.	M/ s Centre of Excellence for Potato, Dhogri, Distt-Jalandhar, Punjab	K. Jyoti, K. Himalini, K. Chip-1, K. Pukhraj
7.	M/ s Jain Irrigation Systems Ltd, Jalgaon, Maharashtra	K. Pukhraj, K. Chip-1, K. Chip-3, K. Khyati, K. Surya, K. Frysona, K. Mohan
8.	M/ s Utkal Tubers India Pvt . Ltd., Whitefield Road, Garudacharapalya, Bangalore	K. Pukhraj, K .Chip-1, K .Chip-3, K . Lauvkar, K.C.M, K . Mohan, K . Frysona, K . Jyoti, K . Badshah, K. Himalini,
9.	M/ s Shashanka Agro -tech Pvt . Ltd., Ranchi, Jharkhand	K. Lima, K. Kesar, K. Karan
10.	M/ s Shivam Agri. Biotech Pvt. Ltd., Itawa, UP	K. Frysona, K. Lima, K. Mohan, K. Sukhyati, K. Neelkanth

Project 2: Standardization and refinement of seed production techniques under hi-tech system

1. Multiplication rate/ Rate of production of cuttings through ARC

Different varieties at different locations were considered to study the rate of production of cuttings (transplants) (Fig. 3). The first rounds of cuttings expand parent material in the first 4-6 weeks of production with the remaining months dedicated to commercial production.

2. Field Evaluation of rooted cuttings

The cuttings were transplanted and evaluated for their performance under open field and temporary net in late summer (June) and autumn (August) and under net house in winter (October). The survival percentage of the transplant were found higher under temporary net (70-94 %) in comparison to open fields (48-59 %) in summer and autumn planting. There was wide variation in the multiplication capacity among the varieties used. The maximum number of

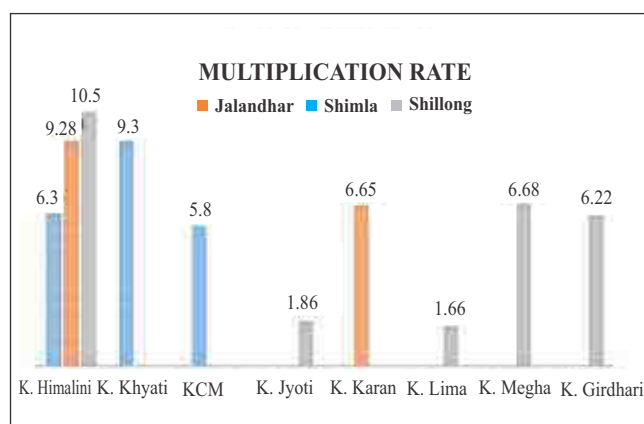


Fig. 3: Multiplication rate of potato varieties at different locations

tubers per plants was observed in K. Kanchan (13), K. Chipsona 3 (11), K. Himalini (10), K. Girdhari (8) and K. Megha (6) under temporary net. The growing facilities were used simple and inexpensive and could be setup anywhere. In addition, the cuttings were also given to potato state farm, KVK-East Khasi Hills, 3 farmers and CPRS, Patna for trials. The harvesting of the ARC has not been done in other locations (Fig. 4).



Fig.4 a: ARC transplanted under low-cost temporary net, b: different size of minitubers derived from ARC in Shillong, c: Series of ARC planted under nethouse in Jalandhar, d & e: Crop raised through ARC and ARC raised tubers at 70 DAT in Fagu

3. Effect of Paclobutrazol (PBZ) application on the aeroponic minituber production

The preliminary study was conducted to see the effect of paclobutrazol on mini-tuber production in potato (cultivar K. Jyoti, K. Chipsona-1), in the aeroponic system. The first factor of the study was paclobutrazol with 3 levels (0, 50 and 100 mg / l, 150 mg/l) and the second factor was time of treatment application in 2 levels (45 and 55 days after transplanting plants to the aeroponic system). Results showed that the interaction effect between paclobutrazol concentration and treatment application time was significant on the number of mini-tubers, plant height and internodes distance traits. Also, the use of 50 mg / l of Paclobutrazol during the early stage (45 DAT) of mini-tuberization produced the highest number of mini-tuber / plant (K. Jyoti-32, K. Chipsona-1-41) respectively.

The analysis of the associated hormones are under process

4. Cost-effective tissue culture media for large-scale propagation of commercial Potato (*Solanum tuberosum* L.) varieties

The study revealed that Isabgol + RO water + table sugar based medium enhanced the initial establishment of nodal cuttings in Kufri Giriraj and Kufri Megha followed by Sago + RO water + table sugar. The data were recorded on 25th days of culturing. The average number of roots, nodes per plantlets and shoot growth in isabogol and sago was similar to that of agar based medium exhibiting a typical growth curve (Fig. 5). The maximum cost reduction (90 %) was observed when Isabgol alone was used as the gelling agent, followed by sago (88 %), sago + Isabgol (84 %), sago + agar (80 %), or Isabgol + agar (77 %). Similarly, the costs of water and carbon sources were reduced by 86% and 95%, respectively, by using low-cost substitutes.



Fig. 5: Effect of single use or combinations of low-cost carbon source, water, and gelling agent(s) on potato. Sample a: control (agar alone); b: Isabgol; c: Sago; d: Sago plus Isabgol; e & f: Sago plus agar; and g: Isabgol plus agar

5. Influence of low pH and different level of EC increase Potato Mini-tubers Production in an aeroponic system

A study was conducted to test the impact of lowering the pH level of nutrient solution and different EC level for inducing tuberization of two potato cultivars grown in aeroponic system. At 25 days after transplanting, low pH level (3.5 for 8 h and 10 h) were applied to potato plants cv. K. Girdhari, K. Giriraj, K. Kanchan and K. Megha. Significant differences in mini-tuber production, stolon number and length and root length were observed among stress treatments and cultivars (Fig. 6). Low pH of nutrient solution at 3.5 @ 8 h with EC 2.0 dS m⁻¹ significantly increased most growth variables and exhibited faster tuberization, higher mini-tuber number and as well as significant increase in stolon number/plant and number of stolon branches/plant. The results of this study demonstrate that a judicious use of these stresses can effectively promote tuberization in aeroponics.



Fig. 6: Increased stolon number/plant and number of stolon branches/plant in K. Megha at 38 DAP

6. Effect of *Ascophyllum nodosum* on potato minituber production under aeroponic system

The effect of *Ascophyllum nodosum* (AN) (sea weed extract) were investigated on the production of potato minituber (Potato cv. Kufri Kanchan and Kufri Megha). Plants were foliar sprayed with AN @ 2 and 4 ml L⁻¹ at 30 and 50 days after transplanting and water spray was used in control. Significant interactions were observed between sea weed extraction and the time of foliar spray for plant height, stolen per plants, root length, mini tuber production, fresh and dry weight of mini tuber. The number of minituber, root length and fresh and dry weight of minituber increased at AN @ 2 ml L⁻¹.

7. Standardization of planting geometry for effective multiplication of aeroponic mini-tubers of new potato variety Kufri Karn under polyhouse conditions

The results revealed that the total number of tubers obtained per m² were significantly affected by intra-row spacing and were higher at closer spacing (30x10cm). The number of tubers followed a decreasing trend with increasing intra-row spacing. Tuber yield /m² was also found to significantly affected by the varying intra-row spacing but followed a trend opposite to the one followed for number of tubers. Yield at 30x15 cm and 30x20cm was statistically similar but was significantly higher than the one obtained at closer spacing 30x10cm. The proportion of >20g tubers was also affected significantly by the varying intra-row spacing. The proportion of >20g tubers was significantly higher at 30x20cm than 30x15 cm & 30x10cm. With increasing intra-row spacing, proportion of <3g tubers followed a decreasing trend the differences were

statistically non-significant (Table 1). Keeping in view the results, it can be concluded that for obtaining the maximum rate of multiplication aeroponic tubers should be planted at 30x 10cm spacing as the proportion of extremely small (<3g) tubers in the produce is not reduced significantly even at wider intra-row spacing's.

Table 1: Production behaviour of <3g aeroponic mini-tubers of K. Karn at different planting geometries

Treatment	Total tubers /m ²	Total yield/m ²	>20g tubers (%)	<3g tubers (%)
30 x10cm	196.1	3.35	29.3	23.8
30 x15 cm	178.9	3.53	33.1	23.0
30 x20 cm	152.4	3.57	37.9	21.6
C.D.0.05	17.2	0.15	3.8	N/A
SE(m)	4.3	0.04	0.9	0.5
SE(d)	6.0	0.05	1.3	0.7
C.V.	4.2	1.87	4.8	3.8

8. Effect of number of aeroponic tubers /hill at different planting geometries on the production behaviour of aeroponic mini-tubers of new potato variety Kufri Karn under polyhouse conditions

The proportion of larger (>20g) tubers was higher with 01 tuber /hill and was significantly affected by intra-row spacing. The proportion of such tubers was significantly higher at wider spacing (20cm) than 15 and 10cm spacing. The proportion of extremely small sized (<3g) tubers was also low with 01 tuber /hill and at 30x20cm spacing than others. Thus, it can be concluded that for achieving higher rates of multiplication with larger size of progeny tubers in potato variety Kufri Karn, the small (<3g) aeroponic tubers should be multiplied at 30x10cm using 01

Table 2: Production behaviour of small sized mini-tubers in Gen. 1 under field conditions

Cultivar	Total tubers/ ha (lakh)			Mean	Total yield (q/ ha)			Mean
	Size of mini-tuber used				Size of mini-tuber used			
	3-10g	10-20g	>20g		3-10g	10-20g	>20g	
K. Jyoti	4.38	3.25	3.63	3.75	152.6	161.0	165.8	159. 8
K. Girdhari	5.61	5.34	4.37	5.11	182.2	236.9	229.4	216.2
Mean	4.99	4.29	4.00		167.4	198.9	197.6	
CD _{0.05}								
Cultivar (A)		0.83		22.129				
Size of mini-tuber (B)		N/ A		27.102				
A x B		N/ A		N/ A				

tubers/ hill as the increase in number of tubers/m² obtained with 02 tubers/hill is not more than the number of extra tubers planted /m² as compared to 01 tuber /hill.

9. Studies on production behaviour of small sized mini-tubers of two potato cultivars in Generation 1 during 2020

The total number of tubers obtained was significantly affected by the genotype as K. Girdhari produced higher number of tubers (5.11 lakh/ha) than K. Jyoti (3.75 lakh/ha). The number of tubers produced was although higher with small size of mini-tuber (3-10g) but the differences were not statistically different (Table 2). Like number, yield/ha was also significantly higher with K. Girdhari than K. Jyoti. Also, a significant increase in total yield was noticed with increasing size of mini-tuber used (Table 2).

Project 3: Development of agro-techniques for enhancing seed potato quality

1. Evaluation of potato varieties under different spacing and canopy management practices

At Patna center experiment was conducted with potato variety Kufri Himalini. A total of ten treatment combinations (Five Treatments-Ridge and furrow planting with 20cm tuber distance, Ridge and furrow planting with 15cm tuber distance, Flat bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing) - 3 beds, Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) - 3 beds and Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) - 3 beds. Two days of haulm cutting 70 days and 80 days after planting were used. The treatments were replicated thrice under split plot design. Recommended package of practices at Patna center were adopted to grow a good potato crop. The potato seed were sorted and spread in diffused light for proper chitting before plating. The data on various aspects are being recorded.

At Gwalior center experiment was conducted with potato variety Kufri Khyati. A total of ten treatment combinations, five spacing Treatments-Ridge and furrow 60x20 (6 rows), Ridge and furrow 60x15cm (6 rows), Flat bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing) - 3 beds, Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) - 3 beds and Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) - 3 beds and two haulm killing dates. Two days of haulm cutting 70 days and 80 days after planting were used.

The treatments were replicated thrice under split plot design. The crop was planted on 29/10/2020. The crop was raised as per seed plot technique. Various observations viz Emergence (%), Days to 50% emergence, No. of shoots per plant at 45 and 60 days after planting (five randomly selected plants), Plant height at 45 and 60 days after planting (five plants), No. of leaves per plant at 45 and 60 days after planting, Canopy cover at 10 days' interval and Incidence of viruses (MM, SM and offtype) at 25, 50 and 70 DAP were recorded.

At Jalandhar center experiment was conducted with potato variety Kufri Jyoti. A total of ten treatment combinations, five spacing Treatments-Ridge and furrow 60x20 (6 rows), Ridge and furrow 60x15cm (6 rows), Flat bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing) - 3 beds, Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) - 3 beds and Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) - 3 beds and two haulm killing dates. Two days of haulm cutting 70 days and 80 days after planting were used. The treatments were replicated thrice under split plot design. The crop was planted on 18/10/2020. The crop was raised as per seed plot technique. Various observations on growth parameters were recorded and 70 days' haulm killing was done.

2. Standardization of Nitrogen requirement of potato variety Kufri Kesar

At Patna center experiment was conducted with newly released potato variety Kufri Kesar. Five doses of nitrogen i.e. Nitrogen @ 0kg/ha, Nitrogen @ 75 kg/ha, Nitrogen @ 150 kg/ha, Nitrogen @ 225 kg/ha and Nitrogen @ 300 kg/ha was used. The treatments were replicated thrice in randomized block design. The crop was planted timely and managed properly for growing a good potato crop. The seeds were sorted and spread in diffused light for proper chitting before planting. The data on various aspects is being recorded.

3. Studies on degeneration of potato seed of different varieties under changing climate scenario

The experiment was conducted at Gwalior center with factor A (varieties) seven varieties under seed production at Gwalior station viz., Chandramukhi, K. Lauvkar (Early), K. Surya (Early), K. Jyoti (Medium), K. Chipsona – 1 (Mid - late), K. Chipsona – 3 (Mid - late) and K. Sindhuri (late) and factor B (seed type) three seed type viz S1. Fresh breeder seed will be used as control every year, S2. Breeder seed will

be raised as per “Seed Plot Technique” methodology (Roguing and plant protection measures are taken from time to time). This seed will be carried forward for next year and S3. No roguing and plant protection measures will be taken in this treatment and the seed will be carried forward for next year. The experiment was replicated three times. The observations on various parameters were viz, Emergence (%). No. of shoots per plant, Plant height, No. of leaves per plant, Incidence of viruses (MM, SM and offtype) at 25, 50 and 70 DAP and Counting of virus vectors viz Aphid and whitefly at weekly interval were recorded

Project 4: Quality seed potato production of different potato varieties for the Hilly Regions

Production and supply of quality seed

1. CPRS, Ooty: Production of quality seed during spring 2019-2020: During spring season, two varieties Kufri Swarna and Kufri Sahyadri were planted in an area of 0.50 ha, a production of 3.04 t was obtained from Kufri Swarna from an area of 0.2 ha and 5.17 t from Kufri Sahyadri from 0.3 ha area. The seed tuber productions in spring for these varieties are essential to get right physiological aged seeds for planting in summer season.

Production of quality seed during summer 2020: Summer crop was planted in an area of 1.50 ha with

Kufri Swarna, Kufri Girdhari, Kufri Himalini, and Kufri Sahyadri the total quality seed produced was 8.69 t.

Supply of quality seed potato: A total of 21.37 t of quality seed was harvested from seed crop and experimental area during 2020-21 (spring and summer season). Out of which 7.19 t of quality seed was supplied to the farmer's/government agencies, 0.94 t was disposed as table potatoes and miscellaneous to the staff of ICAR- CPRS/ market. About 2.22 t of quality seeds was used for seed and experimental crop during autumn season. Remaining 11.00 t is left for sale, seed crop and experimental crop planting during spring 2021. A total revenue of Rs. 3, 01, 950 /- (Rupees two lakh eighty-nine thousand six hundred and fifty only) was generated during the year 2020 from quality seed tubers.

2. CPRS, Shillong: For quality seed production, K. Himalini, K. Jyoti, K. Giriraj, K. Megha, K. Girdhari, K. Kanchan, K. Chipsona-1 and Chipsona-3 were grown in 2020-2021. Total lockdown due to pandemic of Covid-19 have a negative impact on production. Intercultural practices i.e. earthing up and weeding could not be done in time as labour availability was affected. The Production of quality seed and its distribution/sale to different organisation/states are as under (table 1).

Table 1. Quality seed production and its distribution to different states organization and agencies

CULTIVARS	Total Production (q)	Quality Seed distribution to different University/ States			Total Distribution (q)
		CAU	Mizoram	Meghalaya	
K. Himalini	15.16	-	-	8.50	8.50
K. Jyoti	35.35	-	7.10	12.50	19.60
K. Giriraj	12.09	2.00	-	-	2.00
K. Megha	15.00	-	6.00	-	6.00
K. Girdhari	27.40	3.00	-	15.00	18.00
K. Chipsona-1	5.00	1.00	-	1.00	2.00
K. Chipsona-3	1.00	-	-	-	-
K. Kanchan	2.00	-	-	-	-
Total	112.60	6.00	13.1	37.00	56.10

Production of minitubers through aeroponic was carried out with 8 notified potato varieties. A total of 45,834 numbers of mini tubers with a total weighing of 108.69 kg were produced. Mini tubers of notified

varieties were produced for further multiplication in the station which will be used for local requirement of the NEH region.



DIVISION OF CROP PRODUCTION

PROGRAMME: IMPACT, ADAPTATION AND MANAGEMENT STRATEGIES FOR CLIMATE RESILIENT POTATO PRODUCTION

Potato is an economically important nutrient packed tuber crop that is a livelihood source for India's small and marginal farmers. Potato's significant production belongs to the Indo-Gangetic Plains region, contributing more than 80 percent to the nation's food basket. Temperature and carbon dioxide (CO₂) are the most critical climatic parameters in potato, and climatic variability is a threat to India's potential potato production as the crop growth cycle is sensitive to climatic parameter changes. At present, CO₂ level in the atmosphere has reached 410 ppm, which is likely to increase further in future scenarios. This programme focuses on analyzing the impact of climate change on potato production, evaluating different mulching techniques and irrigation practices, understanding the effect of elevated carbon dioxide on important physiological traits, and modelling pest dynamics in potatoes. All these designed activities of the programme are dealing with the uncertain climate change scenarios. Besides, the program aims to predict future climate change

patterns that can help to devise mitigation strategies for potatoes.

Climate change impact on potato productivity and relative adaptation strategies in Madhya Pradesh (VK Dua, Paresh Chaukhande, Jagdev Sharma & Anil Choudhary)

The climate change impact studies were carried out for Madhya Pradesh for three potato cultivars viz., Kufri Badshah (late), Kufri Jyoti (medium), and Kufri Pukhraj (early) maturity groups at forty-one (41) representative locations of the state for RCP 4.5 and 6.0 using WOFOST model. The overall productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj was 48.1, 44.1, and 46.4 t/ha, respectively, under the baseline scenario (2000). For the future climate scenarios when considering the combined effect of temperature and CO₂ fertilization, the productivity of Kufri Badshah is likely to decline in 2030 (1.2%), 2050 (4%) and 2080 (6.9%) over the baseline under

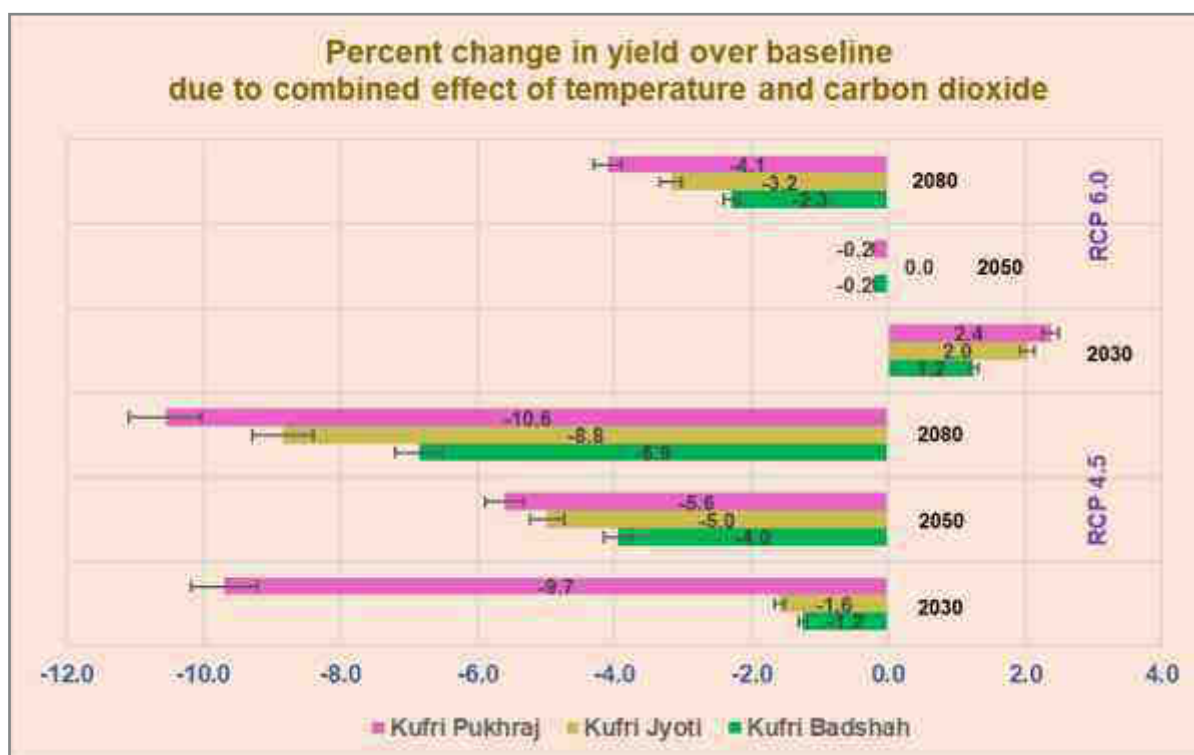


Fig. 1: Expected changes in WOFOST simulated potential yield (t/ha) of potato cultivars over baseline yield (t/ha) for future climate scenarios (RCP-4.5 & 6.0) in Madhya Pradesh (due to combined effect of temperature and CO₂)

RCP 4.5. Similar trends were observed for Kufri Jyoti (1.6, 5.0 and 8.8%) and Kufri Pukhraj (9.7, 5.6 and 10.6%) for 2030, 2050 and 2080, respectively. Simulation results for RCP 6.0 showed that when the combined effect of temperature and CO₂ fertilization is considered, the productivity of Kufri Badshah is likely to increase in 2030 (1.2%) but might decline in 2050 (0.2%) and 2080 (2.3%) over the baseline. An

increase in yield (2%) is expected in 2030. On the flip side, 2050 sees no change in yield, while yield decline (3.2%) is likely to see in Kufri Jyoti in 2080. Maximum increase in productivity 46.4 to 47.5 t/ha (2.4%) in 2030 and decline in yield in 2050 (0.2%) and 2080 (4.1%) was noticed in Kufri Pukharaj (Fig 1).

Effect of water levels and mulching on potato under drip and sprinkler irrigation

(Name Singh, Sanjay Rawal, SP Singh, Devendra Kumar & Vijay Paul)

Experiment conducted during 2019-20 at Modipuram with drip Irrigations applied at 125 % CPE (cumulative pan evaporation) produced significantly higher total tuber yield (41.1 t ha⁻¹) in comparison to irrigation scheduled at 75 % CPE water level which gave 38.4 t ha⁻¹. Paddy straw mulch @ 5 t/ha gave higher yield (41.1 t ha⁻¹) than other treatments, but, the results were non-significant (Fig 2a). In another experiment, sprinkler irrigation scheduled at 150 % CPE (cumulative pan evaporation) produced significantly higher total tuber yield (43.3 t ha⁻¹) in comparison to 100 % CPE water level which produced 40.4 t ha⁻¹ (Fig 2b). The effect

of mulching treatments was non-significant on total tuber yield and numbers as well as grade wise tuber yield and numbers. It may be due to frequent three times rains during the crop season. The sprayed crop with chemical formulation (CFs) did not show any significant effect on tuber yield and numbers. However, the interaction effect of water levels and mulch on tuber yield and numbers was non-significant. Summarizing the experiments, it may be concluded that mulching with paddy straw @ 5 t/ha gave significantly higher tuber yield than the spray of chemical formulations (CFs) under drip and sprinkler irrigation.

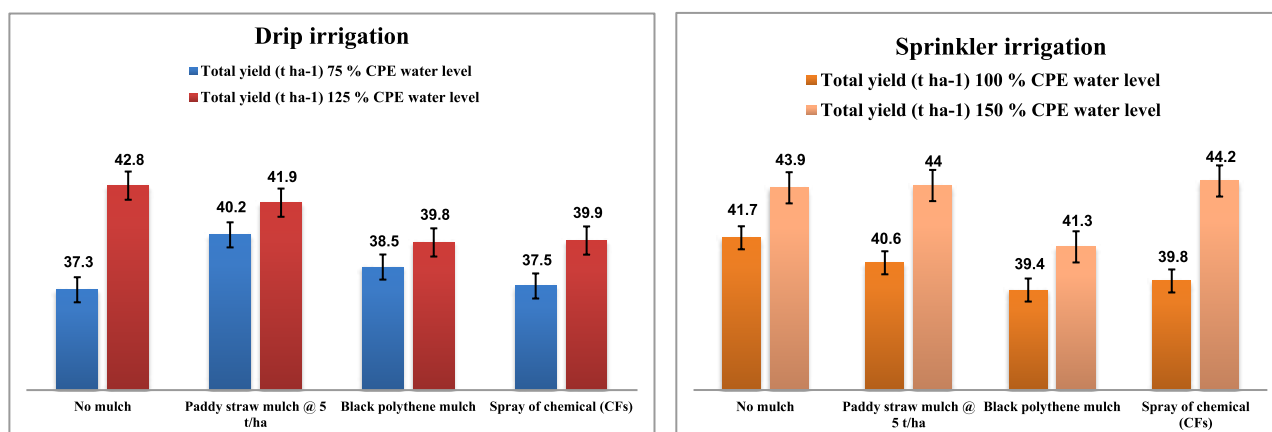


Fig. 2: Potato yield and tuber numbers as influenced by different water levels and mulching treatments under drip irrigation (a) and sprinkler irrigation (b)

Identification of climate resilient potato cultivars in relation to rising CO₂ level and temperature: (Prince Kumar, VK Dua, Devendra Kumar, VK Gupta, Jagdev Sharma, Som Dutt, Anil Sharma, Hemant Kardile, Sunayan Saha, Brajesh Nare, & Yogesh Gupta)

The increasing CO₂ level in the atmosphere, water scarcity, and temperature are the major impediments to India's potato production. In this context, an experiment was conducted at Jalandhar in the Open Top Chamber (OTC) with the treatments elevated

CO₂ (600 ppm) along with high nitrogen (N) level (125% recommended) and increasing temperature environment (+3 °C). Besides, two hybrids (HT/7-1105 and HT/7-1329) and commercial check varieties Kufri Surya (heat tolerant) and Kufri Gaurav

(N use efficient) were studied in the experiment. The results showed that the tuber yield of selected genotypes slightly increased with the increase in nitrogen application under all the conditions (Fig. 3). Elevated CO₂ compared to the ambient condition has positively affected tuber yield in all the genotypes at

recommended N and excess N levels. Further, elevated CO₂ coupled with temperature compared to ambient conditions has increased the tuber yield of all studied genotypes except for Kufri Gaurav, where it slightly decreased at recommended N and excess N levels.

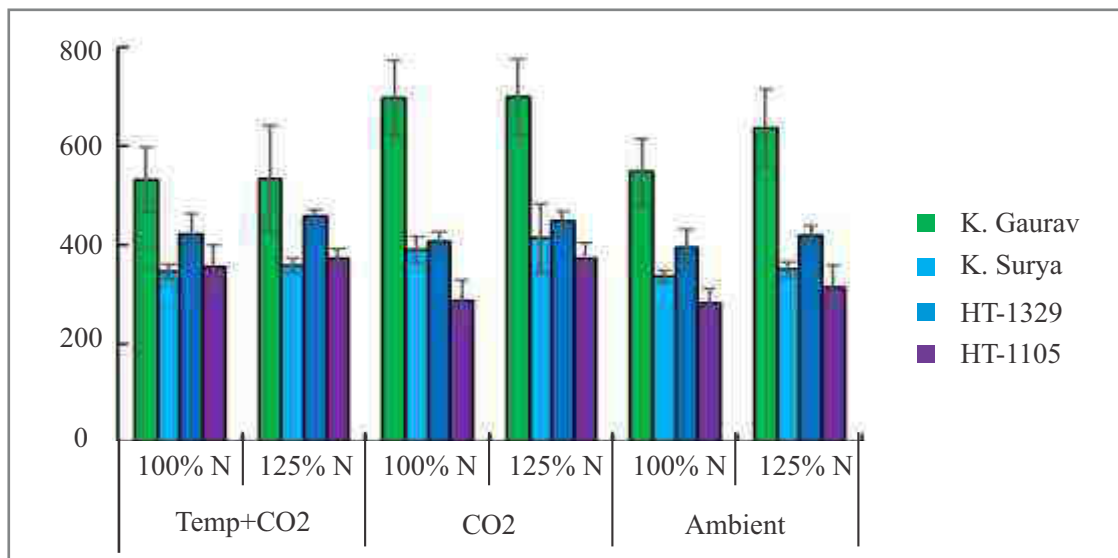


Fig. 3: Effect of different treatments on tuber yield (g/plant) of varieties/hybrids

Greenhouse gas emission studies in potato

(Preeti Singh, VK Dua, Sanjay Rawal, Jagdev Sharma, Arti Bhatia & Subhash)

A field experiment was conducted at Modipuram during 2019-20 (Fig.4) to determine the greenhouse gas emission (GHG) from potato fields. Treatment combinations consisted of nitrogen rates (180 and 270 kg ha⁻¹), method of application of nitrogen fertilizers (Broadcast and band placement) and sources of nitrogenous fertilizer (Urea and ammonium sulphate), and their effect was studied on N₂O emission from soil in potato (var. Kufri Pukhraj). Results showed that the cumulative emission of N₂O-

N from different potato treatments varied from 0.34 to 2.04 kg ha⁻¹. Application of urea led to significant increase in N₂O emissions (11-86%) over the application of ammonium sulphate. The emission was significantly higher (18-54%) under band placed urea as compared to broadcasting of urea. N₂O emission was significantly highest for 270 kg ha⁻¹ band placed urea fertilizer. As expected, application of N fertilizer significantly increased total tuber yield and the yield was highest (24.6 ton/ha) under 270 kg ha⁻¹ broadcasted urea, however, higher dose of fertilizers led to higher emissions.



Fig. 4: View of potato field during GHG studies at Modipuram

Potential impact of climate change on potato late blight outbreak in Punjab using Indo-Blightcast model *(Sanjeev Sharma & VK Dua)*

Punjab is the seed bowl of potato in the country and late blight is the major bottleneck in the successful cultivation of potato in the state. The potential impact of climate change on late blight appearance in Punjab was analysed using Indo-Blightcast model. 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 (years 2030 and 2050) for 13 districts. The model predicted that, in general, late blight favourable period is likely to be reduced in all the studied districts except Mansa, Ludhiana, Fategarh Sahib and Faridkot where it is likely to remain as a threat in the future climate (2030 & 2050) scenarios.

Effect of different dates of planting on late blight development in varieties having varying degree of resistance *(Mehi Lal & Subhash Chand)*

Studies were conducted at Modipuram on seven different varieties *viz.* highly resistant (Kufri Girdhari, Kufri Himalini), medium resistant (Kufri Chipsona-1, Kufri Garima & Kufri Mohan) and highly susceptible (Kufri Bahar & Kufri Sindhuri) to know how these behave under different temperature regimes. Planting was done at 15 days interval (17th Oct, 2nd Nov and 17th Nov, 2019). Area Under the Disease Progress Curve (AUDPC) was calculated for each variety on the basis of disease severity recorded at different interval (87, 92, 98, 104 & 106 DAP for 17th Oct planting; 81, 84, 88, 94 & 98 DAP for 2nd Nov planting and 74, 80, 86, 89 & 92 DAP for 17th Nov planting). The late blight appeared at maturity stage of the crop. The results revealed that under highly susceptible group, highest AUDPC was recorded for 17th Nov planted Kufri Bahar followed by 2nd Nov planting, while in Kufri Sindhuri, highest AUDPC was recorded for 17th Oct planted crop followed by 17th November planting (Fig.5). These variations in AUDPC may be due to genetic make-up of the varieties and prevailing environmental conditions.

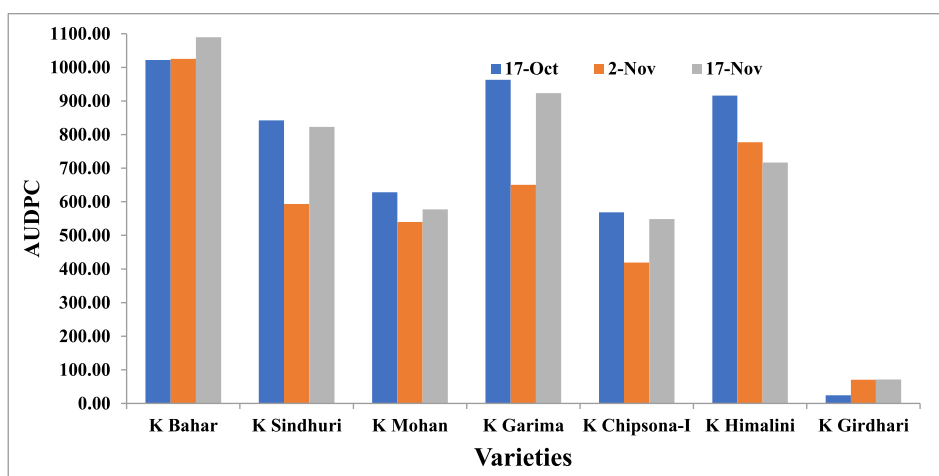


Fig. 5: Area Under the Disease Progress Curve (AUDPC) of seven cultivars planted at different interval

Periodic generation of data on arrival and build-up of aphid and whitefly population in Potato *(Mohd Abas Shah, Sanjeev Sharma & VK Dua)*

The population of peach-potato aphid, *Myzus persicae* (Sulzer), other aphid species, and whitefly was monitored at weekly interval in unsprayed potato fields from the 3rd week of October 2019 till the first week of March 2020 at Jalandhar. *Myzus persicae* first

appeared on the potato plants in the 1st week of November and crossed the threshold limit in the 3rd week of January (Fig. 6). Afterwards, the aphid population increased exponentially and started to decline by the last week of February.

The population of the winged morphs of other aphids started out at 70 aphids per 100 compound leaves in the first week after emergence of the crop (Fig. 6). The population declined thereafter and fluctuated between 14 and 35 aphids per 100 compound leaves.

The population showed increasing trend after third week of February. The flight activity of the aphids, monitored with yellow sticky traps, indicated that the flight was highest during the last week of October to first week of November, and again after the third week of February (Fig. 7).

In general, the population of whitefly adults showed a general decline in population over time which begun high initially (Fig. 8). The population remained above economic threshold (2 per plant) till the 2nd week of November and after that less than one whitefly per plant was recorded. The number of eggs laid per plant increased till first week of November

and declined gradually afterwards. The number of nymphs per plant showed a similar trend with a time lag of more than two weeks as compared to the number of eggs laid. Nymphs and eggs were recovered from the potato crops throughout the season although in very small numbers.

Up to 28 whitefly adults were caught on yellow sticky traps (YSTs) on an average in the last week of October however, the trap catch showed a sudden drop by the 2nd week of November (Fig. 9). It was mainly due to general decline in whitefly population and also the significant fall in temperature which inhibits the flight activity of whitefly adults.

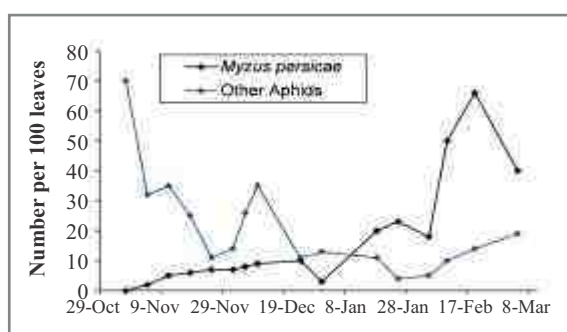


Fig. 6: Population dynamics of the alate morphs of *Myzus persicae* and other aphids on potato at CPRS, Jalandhar (2019-20)

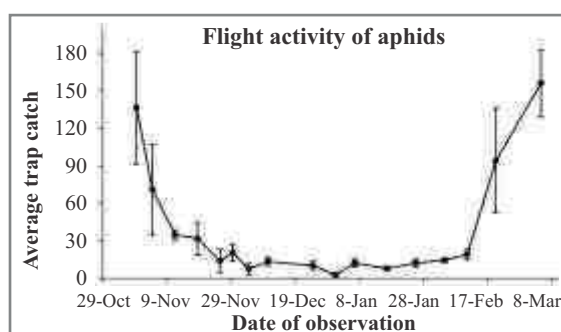


Fig. 7: Flight activity of aphids on potato at CPRS, Jalandhar (2019-20)

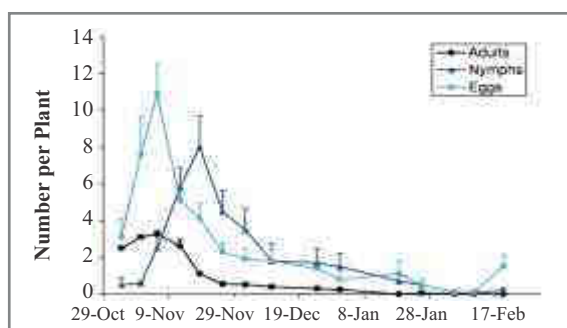


Fig. 8: Population dynamics of the eggs, nymphs and adults of *Bemisia tabaci* at Jalandhar

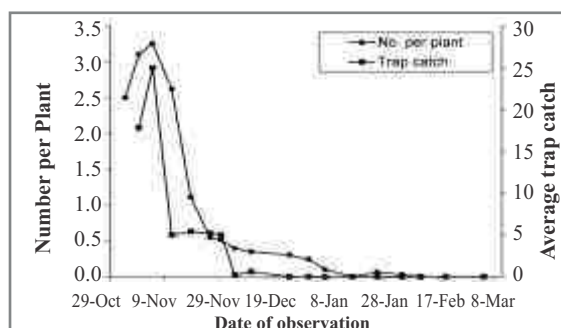


Fig. 9: Population dynamics of *Bemisia tabaci* sampled by (a) leaf count method and (b) YST catch in potato at CPRS, Jalandhar (2019-20)

Thermal requirement and temperature thresholds for development of peach-potato aphid, *Myzus persicae* (Sulzer) on potato (Mohd Abas Shah, Sanjeev Sharma & VK Dua)

The development and survival of the immature stages of *Myzus persicae* was evaluated on potato at eleven constant temperatures, separately for apterous and alate morphs to model the population growth and response of the two morphs to temperature. *Myzus*

persicae developed to adult stage from 5.4 °C to 31 °C but failed to achieve adult emergence at 32 °C, the highest temperature tested. However, winged adults were produced from 5.4 °C to 26.4 °C only. The immature survival rate was high from 7.3 to 26.4 °C, and decreased considerably beyond this range. The lower temperature thresholds (T_{min}) were estimated as 4.13 ± 0.38 °C and 4.35 ± 0.74 °C for apterae and alatae, respectively (Fig. 10). The thermal requirement for development of alate morphs was found appreciably higher in comparison to apterae,

128.20 $\pm$ 7.06 and 108.69 $\pm$ 3.07, respectively. Among the non-linear models, the estimates obtained from Bayoh model reflected the actual experimental value of temperature thresholds (Fig. 11).

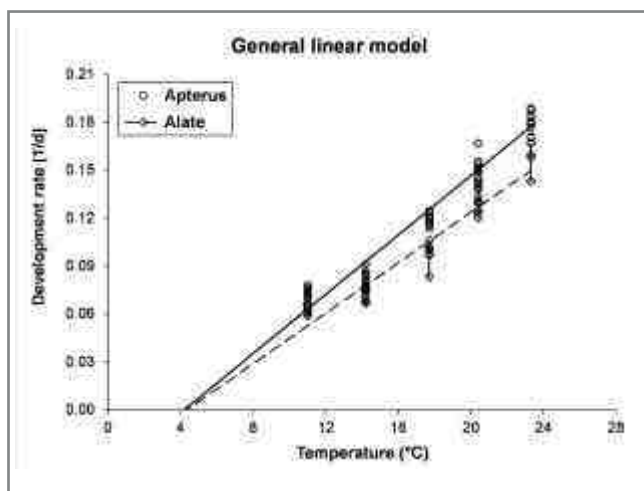


Fig. 10: Fit of the common linear model to the observed data on development rate of *Myzus persicae* apterous and alate morphs at constant temperatures

Solid lines represent fitted regression lines for apterae and the dashed-lines represent fitted regression lines for alatae. The fitted lines are extrapolated backwards till they touch the axis.

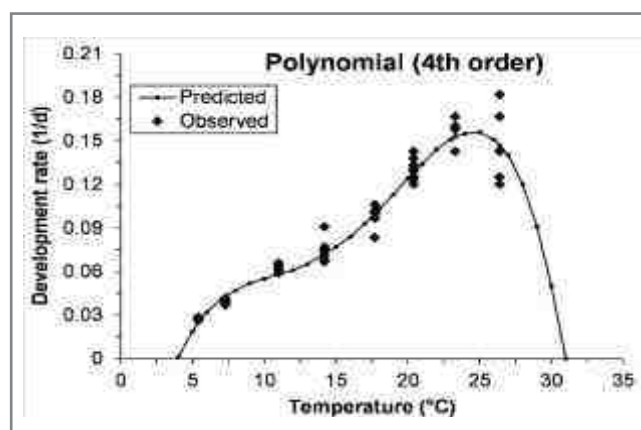
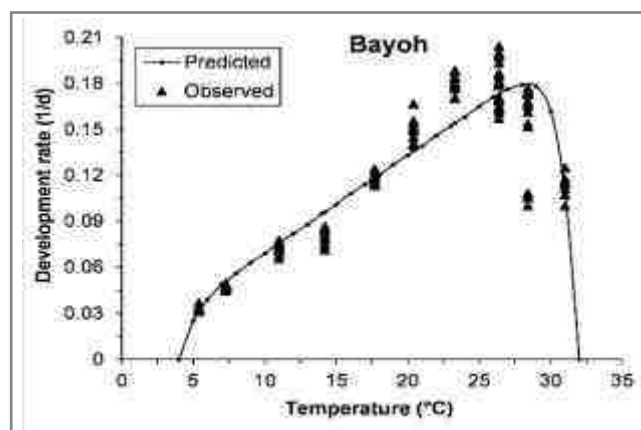


Fig. 11: Fitted non-linear models for temperature dependent development rate (1/day) of apterae (L) and alatae (R) of *M. persicae*



PROGRAMME: NUTRIENT AND WATER MANAGEMENT FOR IMPROVED PRODUCTIVITY AND SUSTAINABILITY OF POTATO

Since fertilizers application in potato account for a major component of total production cost as efficiency of applied nutrients is quite low in this crop. The under-application of fertilizers results in low economic returns whereas over-application of fertilizers besides increasing production cost, it also causes environmental hazards and creates nutrient imbalances and degrades soil health. Thus, under this program various experiments were conducted for enhancing nutrient use efficiency, site specific nutrient management and judicious application of fertilizers in different regions of the country. Studies were also conducted on validation and calibration of QUEFTS model, using nutrient omission plot technique, determining starter dose of P fertilizers, and foliar and split application of potassium.

Validation of QUEFTS model for nutrient recommendation (VK dua, Manoj Kumar, Jagdev Sharma, SP Singh & Prince Kumar)

QUEFTS model provides diagnostic tool to analyse experimental data and helps in making precise fertilizers recommendations for site-specific nutrient management using crop yields and NPK uptake trials. This model has been calibrated to potato crop at ICAR-CPRI. In order to fine tune this model based recommendations for specific varieties and compare with standard recommendations for the regions, experiments were conducted at Modipuram and Jalandhar during the year 2019-20 and crops were harvested in the year 2020.

Table 1. Effect of NPK application as per QUEFTS model on potato yield at Jalandhar

Treatment Code	Treatment Details	Tuber Yield (t ha ⁻¹)
T ₁	100% NPK	34.61
T ₂	75% NPK as per standard recommendation	32.69
T ₃	125% NPK as per standard recommendation	35.33
T ₄	100% NPK as per QUEFTS model	33.75
T ₅	75% NPK as per QUEFTS model	32.50
T ₆	125% NPK as per QUEFTS model	33.94
	CD _{0.05}	NS

At Jalandhar a field experiment was conducted during 2019-20 on Kufri Pukhraj. Prior to potato two crops of bajra were grown without any fertilizer application. No significant difference was obtained in tuber yields ranged from 32.50 to 35.33 t/ha with different NPK levels. QUEFTS model based recommendations produced statistically equivalent yield with lesser amount of N and P compared to standard recommendation for the region at all NPK levels (Table 1). The results indicated that there is a need to fine tune the model based recommendations. At Modipuram, QUEFTS model based NPK recommendations produced 25% higher yield at 75% NPK, 20% higher yield at 100% NPK and 17%

higher potato yield at 125% NPK as compared to standard recommendation for the region.

Nutrient omission plot technique (Jagdev Sharma, Prince Kumar, SP Singh & P Janani)

The under-application of fertilizers results in to low economic returns from the potato farming, and over-application of fertilizers besides increasing production cost also poses the severe environmental hazards. Thus, it is desired that the chemical fertilizers should be applied judiciously and precisely as per the requirement of crop. Hence, the field experiments were conducted using nutrient omission plot technique.

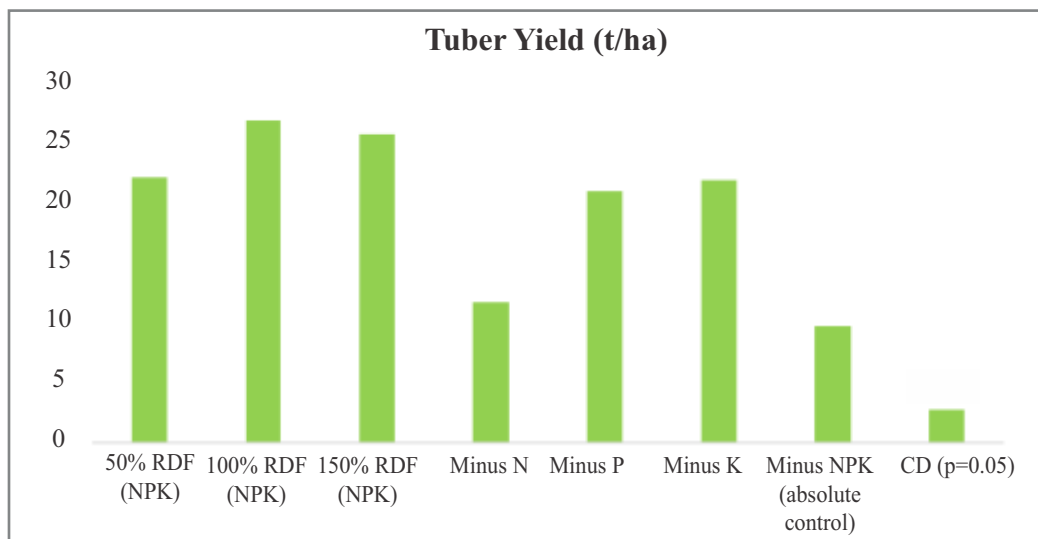


Fig. 1: Effect of nutrient omissions plot technique on yield of Kufri Pukhraj at Jalandhar

At Jalandhar, an experiment was conducted during 2019-20 (Fig.1) on potato var. Kufri Pukhraj. Before conducting field trial *bajra* crop was grown twice for maintaining uniformity of soil fertility. The highest tuber yield (26.87 t/ha) was obtained with the application of recommended dose of NPK, which was statistically at par with 150% of recommended NPK (25.58 t/ha). Compared to recommended dose of NPK, the application of 50% NPK and omission of N, P as well as K reduced potato yield significantly. Nitrogen was the most yield limiting nutrient and its omission reduced potato yield to the tune of 57 %

followed by P (22 %) and K (19 %). At Gwalior, omission of NPK resulted in lowest tuber yield 25.2 t/ha and the highest tuber yield (31.3 t/ha) was recorded with application of 100% NPK (RDF). The reduction in tuber yield under NPK omission was 19.3%. Omission of N and P produced 26.5 t/ha, it reduced the yield by 15.5% followed by N omission (27.1 t/ha) which was 13.5% lower than RDF treatment. But, omission of K resulted in minimum yield reduction (6.4%) compared to RDF NPK (Fig. 2).

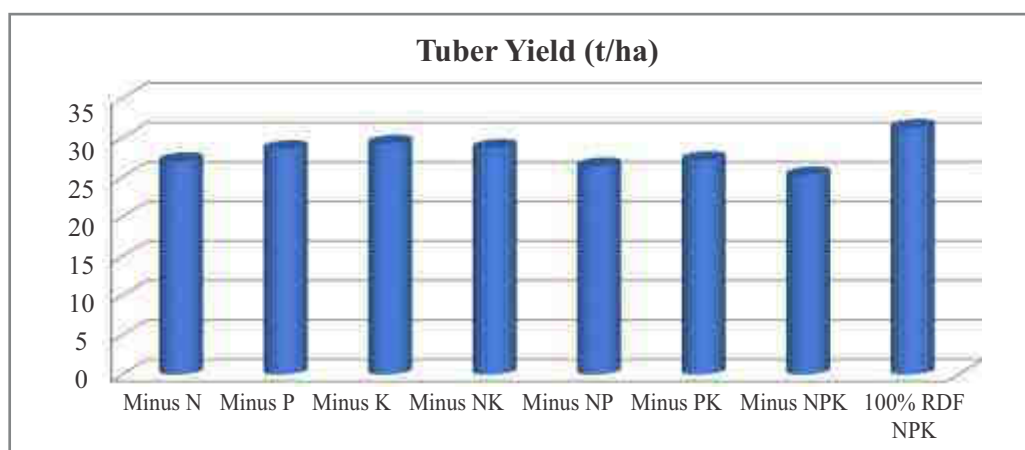


Fig. 2: Effect of nutrient omissions plot technique on potato at Gwalior

To find out nutrient supply capacity of acidic soil an experiment was conducted at Shillong. Results showed that potato tuber yield was significantly affected by nutrient omission treatments. Kufri Girdhari and Kufri Megha recorded higher yield (17.06 and 15.38 t ha⁻¹) from fully fertilized plots (100% RDF) and lowest yield (4.16 and 4.72 t ha⁻¹)

was recorded in control plot (no NPK and FYM application), respectively. Omission of nitrogen significantly reduced potato yield in all the treatments and it suggested that nitrogen is most limiting nutrient for potato production followed by phosphorous and potassium (Fig. 3).

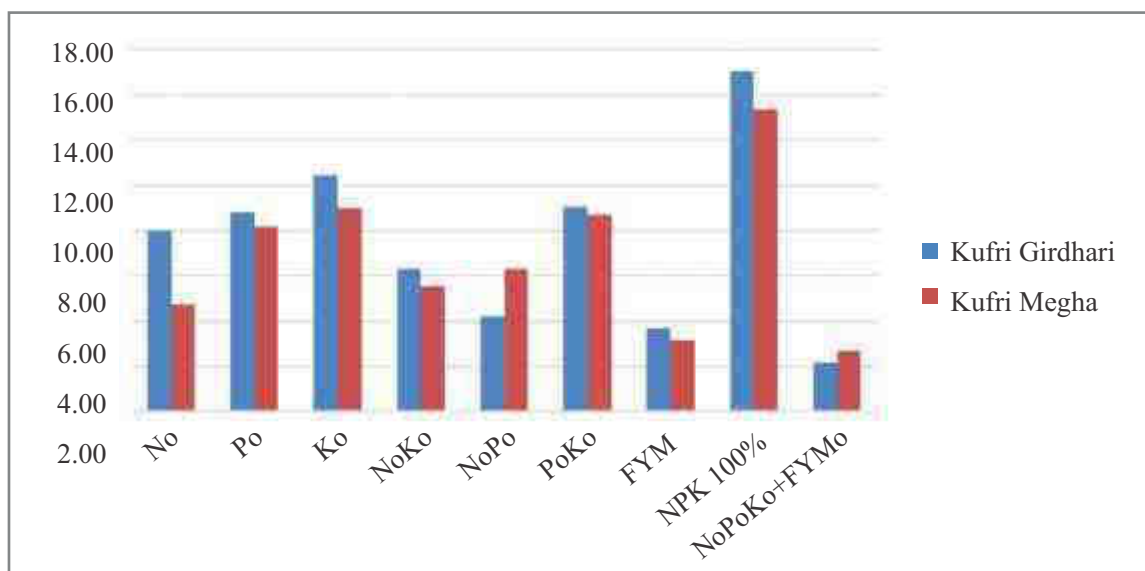


Fig. 3: Effect if nutrient omission technique on yield of Kufri Girdhari & Kufri Megha at Shillong

Determining starter dose of P fertilizer

(Jagdev Sharma & Prince Kumar)

Field trial on potato was conducted after *dhaincha* (green manure) crop grown without any fertilizer. Results revealed that potato var. Kufri Jyoti produced highest tuber yield at 40% of recommended P dose which was statistically at par with 50 and 100% recommended dose of P or when FYM applied without any chemical fertilizer. Omission of phosphorus (control) reduced potato yield significantly as compared to 30% P application or higher doses of recommended P. Minimum tuber yield was recorded when phosphorus was not applied, but, it was found statistically at par with the yield produced at 10, 20 and 30 % of recommended P applied. However, FYM application could meet P requirement of potato crop.

Optimization of phosphorus dose for potato in acidic soils

(Divya K. Lekshmanan)

At Ooty, an experiment was conducted using graded doses of P in the form of di-ammonium phosphate (DAP) with two cultivars *viz.* Kufri Sahyadri and Kufri Swarna. Soil was sandy clay loam texture having pH of 4.2, and 342, 106, 51 kg/ha available N, P and K, respectively. Treatments were T1: 0 P and 0 FYM, T2: 0P + FYM, T3: 10% P+FYM+N+K, T4: 20% P, T5: 30% P, T6: 40% P, T7: 50% P, T8: 100% P. Treatments where phosphorus applied at the rate of 40 and 50% of recommended P gave highest yield (15.81 and 15.72 t/ha, respectively), and was found at par with 30 and 100% P application. Kufri Sahyadri

recorded maximum yield with 50% P (16.86 t/ha) which was found on par with 40 and 30% phosphorus application. Similarly, Kufri Swarna resulted maximum yield with 40% P (16.29 t/ha), and it was also found at par with the application of 30, 50 & 100% of recommended P.

Effect of combined application of superphosphate, rock phosphate and phosphate-solubilizing bacteria (PSB) on growth and yield of potato in acidic soils

(P. Janani)

At Shillong, an experiment was conducted on potato var. Kufri Himalini during kharif season of 2020 with rock phosphate (RP), single super phosphate (SSP) and their mixtures with or without PSB (*Bacillus megaterium*) seed treatment under acidic soil having pH 4.60 and 380, 33.4, 286 kg ha⁻¹ available N, P and K, respectively). Phosphorus application as SSP or RP alone or their mixtures in combination with PSB significantly increased potato yield over no PSB treatments. There was an 8.41% increase in tuber yield due to PSB application. Maximum tuber yield (27.22 t ha⁻¹) recorded with 100% SSP which was at par with the yield (26.75 and 25.90 t/ha) produced by SSP:RP (75:25) and SSP:RP (50:50), respectively. The interaction between PSB and P application on tuber yield was significant. Results indicated that application of SSP+ RP (25:75) @ 140 kg P₂O₅ ha⁻¹ along with PSB was best source of P for potato in acidic soils of Meghalaya.

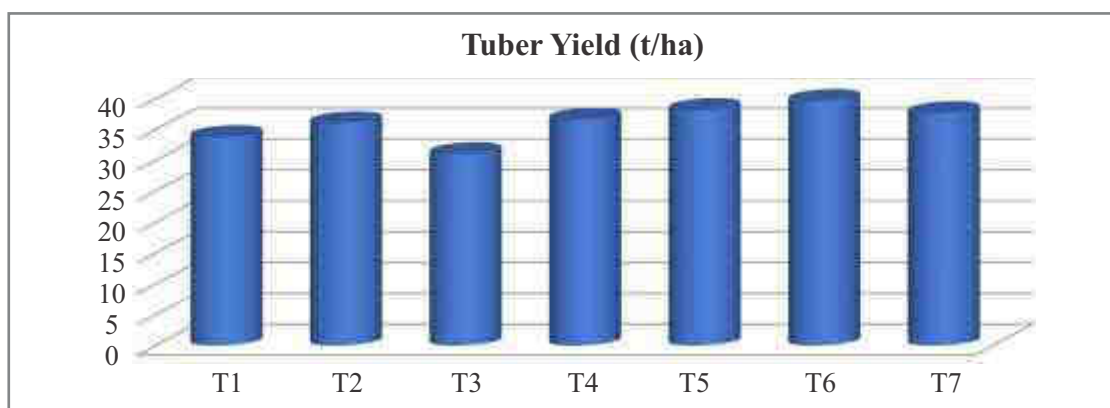


Fig. 4: T1- Minus K, T2- 100% RDF K basal dose, T3-100% RDF K 25 DAP/ earthing up, T4-50% RDF K basal + 50% at earthing, T5-75% RDF K basal + 25% at earthing up, T6-50% RDF K basal and 25% at earthing up + two foliar applications @ 1% K; T7-50% RDF K basal and 25% at earthing up + three foliar applications @ 1% K

Effect of split and foliar application of potassium on potato production (Manoj Kumar, SP Singh, Jagdev Sharma & Prince Kumar)

The standard recommendation for potassium supplementation in potato is application of entire dose of K as basal at planting. To improve potassium use efficiency, experiments on foliar and split application of K were laid out at Modipuram, Jalandhar and Patna. At Gwalior, split application of potassium was found superior over 100% basal application (Fig.4). Highest total tuber yield (40 t/ha) was recorded with the application of 50% RDF K as basal + 25% at earthing up + two foliar applications @ 1.2% K₂O at 25 and 50 days after planting. At Modipuram, the combination of split application of 75% of recommended K dose and two foliar sprays of

1% produced yield equivalent to 100% basal dose of K thereby saving of 25% K dose. At Jalandhar, experiment on potato var. Kufri Pukhraj was conducted after green manuring in the third week of October, 2019 and the crop was dehaulmed at 95 DAP. Application of 100% dose of K as basal (150 kg K₂O/ha) produced highest tuber yield which was statistically superior to rest of the treatments. Omission of potassium (K) resulted in significant yield reduction compared to 100% dose of potassium. Split application of potassium in soil was inferior to 100% application of K dose as basal (Table 2). Hence, the application of K at the time of planting is vital under Jalandhar conditions, if the previous green manure crop was grown without any potassium fertilizer.

Table 2. Effect of split application and foliar feeding of Potassium at Jalandhar

Treatment Code	Treatment Details	Tuber Yield (t/ha)
T ₁	Minus K (control)	34.50
T ₂	100% dose of K (150 kg K ₂ O /ha) as basal	40.43
T ₃	100% of the recommended dose of K at 25 DAP	35.65
T ₄	50% as basal dose and 50% at 25 DAP or at earthing up	35.63
T ₅	75% as basal dose and 25% at 25 DAP or at earthing up	36.93
T ₆	50% as basal dose and 25% at 25 DAP or at earthing up + two foliar applications	36.33
T ₇	50% as basal dose and 25% at 25 DAP or at earthing up + three foliar applications	36.50
	CD _{0.05}	2.68

Phosphorus management for improving nutrient availability in low pH soil (Divya K. Lekshmanan, Priyank H. Mhatre & E.P. Venkatasalam)

Effect of lime and PSB in increasing yield of potato in acidic soil

An experiment was conducted to study the effect of lime and phosphate solubilizing bacteria (*Bacillus megaterium*) along with single super phosphate (SSP) in acidic soils during summer season of 2020 with cultivar Kufri Swarna. Soil was sandy clay loam texture having pH 4.6 and 302, 98, 49 kg/ha available N, P and K, respectively. Graded doses of P viz. 0, 25, 50 and 100% of recommended (135 kg P₂O₅/ha) were applied with and without lime and phosphate solubilizing bacteria formulation (20 kg/ha) in different treatment combinations. Application of lime and PSB along with SSP significantly increased tuber yield. Highest tuber yield (21.29 t/ha) was recorded with the application of 100% P along with PSB and lime which was at par with yield produced by applying 50% P + PSB + lime. However, the lowest

yield (7.41 t/ha) was recorded with control treatment, the application of lime and PSB alone also improved potato yield over control.

Evaluation of rock phosphate (RP) as source of phosphorus in acidic soils

Trial was conducted to study the effect of rock phosphate and phosphate solubilizing bacteria (*Bacillus megaterium*) on potato var. Kufri Swarna and Kufri Shayadri during summer season of 2020. Graded doses of P ranging from 0 to 100% of recommended P were applied as rock phosphate and compared with single super phosphate (SSP) in acidic soils of Ooty. The highest yield (22.72 t/ha) was recorded where 100% P dose applied as single super phosphate which was at par with 100% P supplied as rock phosphate + PSB (20.12 t/ha). The rock phosphate + PSB can be used as an effective source of P (Table 3). However, the omitting of P application results in to low yield (11.35 t/ha). Similar trend was noticed in case of both the varieties.

Table 3. Effect of different levels of rock phosphate on potato yield at Ooty

Treatment	Potato Yield (t/ha)		Mean Yield (t/ha)
	Kufri Sahyadri	Kufri Swarna	
T1: 0% P	11.41	11.28	11.35
T2: 0% P+PSB	13.73	13.86	13.79
T3: 25% P	14.90	14.49	14.69
T4: 25% P+PSB	14.49	15.18	14.84
T5: 50% P	14.31	16.28	15.30
T6: 50% P+PSB	16.64	16.69	16.66
T7: 75% P	18.41	19.32	18.86
T8: 75% P+PSB	19.96	19.24	19.60
T9: 100% P	17.08	18.41	17.75
T10: 100% P+PSB	19.59	20.65	20.12
T11: 100% SSP	22.30	23.14	22.72
CD (p=0.05)	T=2.69	TxV=3.80	-

Determining starter dose of P fertilizer in high P soils

In high phosphorus content soils, an experiment was conducted during summer season of 2020 using diammonium phosphate (DAP) as P source with two potato cultivars viz., Kufri Sahyadri and Kufri Swarna. Recommended doses of NK and graded phosphorus doses ranging from 0 to 100% of recommended P were applied. Soil of experimental site was sandy clay loam in texture having pH 4.2 and 106 kg/ha available P. Data given in Table 4 showed

that all P doses increased yield significantly over control (5.66 t/ha). Application of 40% of recommended P resulted in highest yield (15.81 t/ha), and was found at par with 50% P (15.72 t/ha), 30% P (14.48 t/ha) and 100% P (14.62 t/ha). Kufri Sahyadri recorded highest yield with 50% P (16.86 t/ha) whereas potato var. Kufri Swarna gave higher yield (16.29 t/ha) at 40% recommended P application. Results suggested that 30% of recommended P dose is sufficient in acidic soils having high available P content.

Table 4. Effect of graded doses of phosphorus (P) on tuber yield at Ooty

Treatment	Potato Yield (t/ha)		Mean Yield (t/ha)
	Kufri Sahyadri	Kufri Swarna	
T1-0% P (control)	5.61	5.71	5.66
T2-0% P+FYM	7.38	7.63	7.50
T3-10% P+FYM	12.20	8.55	10.38
T4-20% P	12.59	12.60	12.59
T5-30% P	14.37	14.58	14.48
T6-40% P	15.33	16.29	15.81
T7-50% P	16.86	14.58	15.72
T8-100% P	14.01	15.23	14.62
CD (0.05)	P dose (T) = 2.21	T x V = 2.82	-

Enhancing water and nutrient use efficiency through modern irrigation methods in view of rising temperatures

(Name Singh)

Developing variety specific water and nutrient management schedule under limited water availability

At Modipuram, potato crop was planted in October, 2019 and harvested at full maturity after 95 days in February, 2020. The grade wise yield data along with other parameters were recorded and analysed statistically. Results advocated that effect of varieties and irrigation was significant on total tuber yield and numbers. Potato yields were in the order of Kufri Khyati > Kufri Pukhraj > Kufri Anand > Kufri Bahar > Kufri Garima > Kufri Sadabahar. Irrigation at 2.5 IW:CPE produced significantly higher yield (44.9 t ha⁻¹) followed by yield (43.2 t ha⁻¹) at 2.0 IW:CPE. All varieties produced significantly maximum yield and tuber numbers at 2.5 IW:CPE in comparison to 2.0 and 1.5 IW:CPE (Table 5). Similar trend was also noticed in case of graded tuber yields and numbers. Effect of potash was non-significant on total and grade wise tuber yields and numbers. High fertility 125 kg K₂O ha⁻¹ produced maximum yield (43.8 t ha⁻¹), but, it was found at par with 100 kg K₂O ha⁻¹ (Table 6). The yields of all potato varieties were increased with increase in K levels from 75 to 125 kg K₂O ha⁻¹, but, the differences were non significant. Similar trend was also noticed in case of graded tuber yield and numbers. Interaction effect of varieties x irrigation, varieties x potash and irrigation x potash was non significant on tuber yield and numbers. However, the yields of all varieties were higher at 2.5 IW:CPE along

with application of 125 kg K₂O ha⁻¹.

Nutrient requirement of Kufri Mohan and processing varieties through drip fertigation

To work out N&K requirement of potato through drip-fertigation, Kufri Mohan was planted with three levels of N & K viz. 75, 100 & 125% of recommended dose. In second trial, four levels of N&K fertility i.e. 75, 100, 125 & 150% of recommended dose were taken as main plots treatments and two processing varieties (Kufri Chipsona-1 and Kufri Frysona) taken in sub plots. 1/3 dose of each level of NK was given as basal and remaining 2/3 NK applied through drip-fertigation twice in a week in 6, 8, 10 & 12 splits starting just after emergence, respectively as per the treatments. Potato crop was planted in October, 2019 and harvested at full maturity in February, 2020. The grade wise yield data along with other parameters were recorded and analysed statistically. Results revealed that Kufri Mohan produced maximum total tuber yield (43.5 t ha⁻¹) at 125% recommended NK then other treatments, but, statistically it was found at par with 100% recommended level of NK which gave 40.7 t ha⁻¹ (Table 7). Similar trend was noticed in case of large size tuber yield and numbers.

In case of processing varieties, the total tuber yield was maximum (35.5 t ha⁻¹) at 150% recommended NK drip-fertigation against other treatments, but, statistically it was found at par with 125% recommended level of NK which gave 34.4 t ha⁻¹ (Table 8 & 9). Similar trend was also noticed in case of large tuber yield and numbers. Tuber numbers differ significantly by drip fertigation. Potato variety Kufri Frysona produced significantly higher total yield (29.8 t ha⁻¹) in comparison to Kufri Chipsona-1

which gave 27.5 t ha^{-1} . However, the reverse trend was noticed in case of tuber numbers, Kufri Chipsona-1 produced significantly higher tuber numbers ($610 \text{ thous. ha}^{-1}$) than Kufri Frysona ($550 \text{ thous. ha}^{-1}$). However, the interaction effect of varieties and NK fertigation was non-significant.

Develop/identify nutrients and water efficient potato cultivars and hybrids along with agro-techniques

Newly released water efficient hybrid (J. 92-167) was planted in October, 2019 with nine treatment combinations of three plant populations ($S_1 = 1,11,111 \text{ plants/ha}$ at $60 \times 15 \text{ cm}$, $S_2 = 83,333 \text{ plants/ha}$ at $60 \times 20 \text{ cm}$ and $S_3 = 66,666 \text{ plants/ha}$ at $60 \times 25 \text{ cm}$ and three nitrogen levels *viz.* 75, 100 & 125% of recommended N. Crop was harvested at full maturity in February, 2020. Data showed that tuber yield increased with increase in N level from 75 to 125% recommended N at all plant populations. Similar trend was also noticed in case of large tuber yield and numbers. Application of 125% of recommended N produced significantly maximum yield, but, it was found statistically at par with yield produced at 100% recommended N at all plant populations (Table 10). $83,333 \text{ plants/ha}$ at 125% recommended N gave significantly higher yield (54.2 t ha^{-1}) which was statistically at par with yield of $1,11,111 \text{ plants/ha}$ at 125% N (52.7 t ha^{-1}) followed by yield of $83,333 \text{ plants/ha}$ at 100% recommended N (51.6 t ha^{-1}). However, the tubers number were significantly higher at $1,11,111 \text{ plants/ha}$.

Developing low cost technology capsule using organic and inorganic sources of nutrients and micro-irrigation methods in potato (Name Singh, Manoj Kumar, SP Singh, Sunayan Saha, Prince Kumar & RK Singh)

Nutrient management using crops, organic & inorganic sources of fertility and micro irrigation methods

New project experiments were initiated at Modipuram and Gwalior to study the effect of different nutrient sources like green manure (GM) crop /pulses and other organic and inorganic sources of NPK under drip, sprinkler and furrow irrigation methods with an objective to enhancing water and nutrient use efficiency in potato. Potato crops were planted in last week of October, 2020 as per treatments. Observations on growth parameters *viz.* plant emergence, plant height, number of leaves and

stems/plant, total water applied in each trial etc. were recorded & analysed during crop period. The crop will be harvested at full maturity during next quarter ending March, 2021, and grade wise tuber yields and numbers alongwith other attributes etc. will be recorded and statistically analysed for reporting in next year, 2021.

To economize water and N through agronomic manipulations in potato an experiment planted at Modipuram to develop low cost production technology. Potato was planted on 31st Oct., 2020, and crop will be harvested at full maturity during next quarter ending March, 2021. Grade wise tuber yields and numbers alongwith other attributes etc. will be recorded and statistically analysed for reporting in next year. Similarly, another trial to work out new variety specific water and NPK requirement of potato has also been planted. The final results will be reported in next year, 2021.

Assessment of consumptive water use pattern and exploring water efficient technologies for potato under changing hydro-climatic regimes (Sunayan Saha, Name Singh, VK Dua, SP Singh, RK Singh, Prince Kumar, Jagdev Sharma, Shashi Rawat, Anil Sharma, Manoj Kumar Nanda & Brajesh Nare)

Long-term daily meteorological data of two potato growing centers of India, *viz.* Jalandhar, and Modipuram have been collected and pre-processed. Potential CWU or Reference Evapo-transpiration (ET_{ref}) trends of these locations are being analyzed. Experiments have been initiated with potato cv. Kufri Jyoti planted on 22 & 29 Oct., 2020 at Jalandhar and Gwalior, respectively to evaluate different irrigation scheduling strategy in combination with PGRs and paddy straw mulch. Trial was laid out in split plot design with four main plot treatments *viz.* stage specific & weather based variable rate drip irrigation, drip irrigation @ daily ET_{ref}, drip irrigation at 75% ET_{ref}, drip irrigation at 50% ET_{ref} and five sub-plots *i.e.* foliar sprays of Thio-Urea @400 ppm, KNO₃ @ 10 g L^{-1} and microbial biopolymer formulation @ 150 ml L^{-1} (developed at ICAR-NIASM) at critical crop stages (30, 50 & 65 DAP; for biopolymer one extra dose applied at 75 DAP), paddy straw mulch @ 5 t ha^{-1} and control. The crop emergence was normal and observations on plant growth, yield parameters, soil moisture and consumptive water use being recorded, after harvest in February the yield data will be statistically analysed and reported in next year, 2021.

Studies on rice husk ash as a source of phosphorus

(Jagdev Sharma, VK Dua, Prince Kumar & Anil Kumar)

Utilization of rice mill wastes like rice husk ash in agriculture has generated interest in recent times since it contains nutrients and its disposal is an issue for rice mills. Hence, two pot experiment was conducted to evaluate the rice husk ash (RHA) as a source of P for potato in the year 2020. Tubers of Kufri Jyoti and Kufri Girdhari were planted in cocopeat and the treatments included, T1-Control (without P), T2-10 g RHA/pot, T3-20 g RHA/pot (with P fertiliser). Application of 10 and 20 g RHA significantly increased plant height, above ground total biomass and phosphorus content in the above ground biomass over control (Fig.5). The study suggested that RHA has the potential to be used as source of phosphorus to potato crop. A field experiment has also been initiated at Jalandhar to test the nutrient value of rice husk ash.



Fig. 5: Effect of rice husk ash (RHA) on plant growth of Kufri Jyoti (LHS at 75 and 100 days (RHA))

Table 5. Productivity and tuber numbers of different potato varieties as influenced by irrigation levels

Treatment	Total Yield (t ha ⁻¹)							Tuber Numbers (000, ha ⁻¹)						
	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean
Irrigation at 2.5 IW:CPE ratio	42.5	48.2	51.8	39.8	39.7	46.8	44.9	671	751	641	642	548	771	671
Irrigation at 2.0 IW:CPE ratio	40.4	48.6	50.7	36.7	36.7	45.5	43.2	581	628	594	561	497	703	599
Irrigation at 1.5 IW:CPE ratio	42.4	49.1	50.6	36.1	36.2	43.9	43.0	615	679	624	573	530	750	628
Average	41.8	48.8	51.0	37.6	37.7	45.5	-	622	696	619	592	525	741	-
LSD at 5%	Variety (V) 2.2		Irrigation (I) 1.6		Interaction (V x I) NS			Variety (V) 35		Irrigation (I) 25		Interaction (V x I) NS		

Table 6. Productivity and tuber numbers of different potato varieties as influenced by levels of potash

Treatment	Total Yield (t ha ⁻¹)							Tuber Numbers (000, ha ⁻¹)						
	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean	Kufri Bahar	Kufri Pukhraj	Kufri Khyati	Kufri Garima	Kufri Sadabahar	Kufri Anand	Mean
75 kg K ₂ O ha ⁻¹	41.6	49.2	49.3	37.0	37.1	46.8	43.5	608	685	622	584	537	794	638
100 kg K ₂ O ha ⁻¹	41.4	48.3	52.6	37.7	37.8	45.1	43.8	638	691	621	599	514	702	628
125 kg K ₂ O ha ⁻¹	42.4	48.9	51.3	37.8	37.8	44.6	43.8	621	711	617	594	523	727	632
Average	41.8	48.8	51.0	37.6	37.7	45.5	-	622	696	619	592	525	741	-
LSD at 5%	Variety (V) 2.2		Potash (K) NS		Interaction (V x K) NS			Variety (V) 35		Potash (K) NS		Interaction (V x K) NS		

Table 7. Effect of NK fertigation on tuber yield and numbers of new potato variety Kufri Mohan

Treatment	Total Yield (t ha ⁻¹)				Tuber Numbers (thous. ha ⁻¹)			
	Large (>75 g)	Medium (25-75 g)	Small (< 25 g)	Total	Large (>75 g)	Medium (25-75 g)	Small (< 25 g)	Total
75% NK through fertigation	15.2	14.7	2.7	32.7	107	224	137	469
100% NK through fertigation	21.9	16.8	2.1	40.7	130	231	132	494
125% NK through fertigation	23.1	17.9	2.5	43.5	168	285	161	607
LSD at 5%	4.2	NS	NS	2.8	28	NS	NS	NS

Table 8. Effect of NK drip-fertigation on productivity of processing varieties of potato

Treatment	Potato Yield (t ha ⁻¹)		Mean
	Kufri Chipsona-1	Kufri Frysona	
75% NK through fertigation	19.3	20.9	20.1
100% NK through fertigation	23.4	25.6	24.5
125% NK through fertigation	33.3	35.5	34.4
150% NK through fertigation	33.8	37.2	35.5
Mean	27.5	29.8	-
LSD at 5%	Variety 1.5	Fertigation 2.1	Interaction (VxF) NS

Table 9. Effect of plant population & N levels on productivity of newly released potato hybrid (J. 92-167)

Treatment	Total Yield (t ha ⁻¹)				Tuber Numbers (000, ha ⁻¹)			
	Large (>75 g)	Medium (25-75 g)	Small (< 25 g)	Total	Large (>75 g)	Medium (25-75 g)	Small (< 25 g)	Total
S ₁ with 75 % RN	25.0	16.4	4.9	46.3	187	336	313	837
S ₁ with 100% RN	26.6	18.1	4.7	49.9	201	340	304	846
S ₁ with 125 % RN	29.8	18.3	4.6	52.7	231	334	333	899
S ₂ with 75 % RN	27.5	16.3	4.9	48.7	199	304	308	811
S ₂ with 100 % RN	29.6	17.0	4.9	51.6	227	225	296	750
S ₂ with 125 % RN	31.1	17.4	4.8	54.2	185	270	294	750
S ₃ with 75 % RN	28.2	13.6	4.9	46.6	223	308	273	804
S ₃ with 100 % RN	30.0	13.4	4.4	47.6	228	315	248	790
S ₃ with 125 % RN	31.5	14.6	4.1	50.2	248	286	266	800
LSD at 5%	2.7	3.6	NS	3.0	41	65	NS	84

Note: S₁ = 1,11,111 plants/ha at 60 x 15 cm spacing, S₂ = 83,333 plants/ha at 60 x 20 cm spacing and S₃ = 66,666 plants/ha at 60 x 25 cm spacing.



PROGRAMME: TECHNOLOGY DEVELOPMENT AND REFINEMENT FOR POTATO AND POTATO BASED CROPPING SYSTEMS

Field experiments and laboratory studies were started in this programme under nine research project activities during 2020. These were: Indian GAP for production of potato crop; Developing production technology for certified organic seed potatoes; Refining system based organic potato production technologies; Refining organic potato protection technologies for sustainable yields; Development of potato based cropping systems for different agro-ecologies; Precision farming studies for sustaining potato productivity; Development of rapid seed potato production technologies; Engineering technologies for potato production and utilization and Mechatronics in potato production. Progress in Indian GAP and precision farming activity was remarkable. Research activity wise salient findings and conclusions are given as follows:

Indian good agricultural practices (GAP) for production of potato crop (*Pooja Mankar, Sanjay Rawal, Sanjeev Sharma, SK Luthra, VK Gupta, Devendra Kumar, Mehi Lal, Subhash S & Pinky Raigond*)

Estimation of chemical residues in tubers

Four chemicals applied at recommended levels in cv. Kufri Himalini were estimated in potato tubers in a field study conducted at Shimla during 2020. In all treatment combinations, level of Pendimethalin, Chlorpyrifos, Imidacloprid and Mancozeb was below the Codex Alimentarius maximum residue level (MRL). Thus application of recommended chemicals and their prescribed doses are in safe limits in potato tubers after harvesting (Table 1).

Table.1. Chemical residue content in potato tubers after harvest

Chemical	Mean residues in tubers (mg kg ⁻¹)	Codex MRL (mg kg ⁻¹)
Pendimethalin	< 0.01	0.05
Chlorpyrifos	< 0.01	2.00
Imidacloprid	< 0.05	0.50
Mancozeb	< 0.05	--

Promoting Indian potato exports

A virtual meeting was organized on 5th August 2020 with leading Indian potato exporters, progressive potato growers and ICAR-CPRI scientists to discuss the ongoing scenario of potato export and to develop a roadmap. Requirement of suitable export potential potato variety in table and processing segment in main season, availability of early potatoes in the month of January for catching the international market during lean period, development of single platform for complete information of potato export right from production to marketing were the key issues emerged from this discussion. A roadmap was developed and field trials were initiated for early potatoes at Modipuram, and for main crop in district Agra and Sabarkantha.

Early potatoes for export

Western Uttar Pradesh has the potential to produce early potatoes for enhancing their export in global market. Field experiment was initiated during September 2020 with five promising potato varieties and hybrids viz., K Chipsona-3, K Sangam, K Neelkanth, HT/07-1329 and WS/07-113. At 60 days, K Neelkanth (30%) recorded maximum proportion of export grade tubers (>55mm) followed by heat tolerant hybrid HT/07-1329 (23%) and K Sangam (22%). K Neelkanth (53%) also had highest proportion of exportable tuber yield followed by K Sangam (46%) and HT/07-1329 (44%) as depicted in Fig. 1.

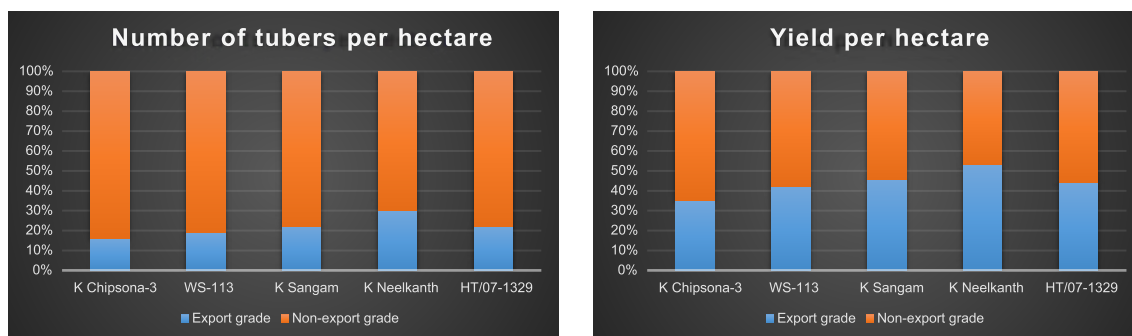


Fig.1: Potential of different genotypes in early planting

Export potential of potato varieties in main season

Field evaluation is continuing with 8 potato varieties *viz.*, K Bahar, K Chipsona-3, K Chipsona-4, K Frysona, K Ganga, K Mohan, K Neelkanth and K Sangam at 2 farmers field each in district Agra (UP) and Sabarkantha (Gujarat) in table and processing segment.

Assessment of export potential of potato germplasm

A field study has been initiated in current year with 84 potato germplasm accessions which are being evaluated for various export parameters *viz.*, size, shape, tuber skin, flesh colour apart from exportable proportion of yield.

Chemical residue estimation in tubers

A field study is going on for chemical residue estimation in tubers of cv. K Chipsona-1 and K Pukhraj with Institute recommendation of 8 chemicals *viz.*, Metribuzin, Pendimethalin, Mancozeb, Propineb, Dimethomorph, Cymoxanil, Imidacloprid and Chlorpyrifos in various combinations.

Developing production technology for certified organic seed potatoes (SP Singh, S Katare, M Sadawarti & Raj Kumar)

Organic seed production technology

Experiment was started at Gwalior for developing organic seed potatoes production module by having various treatment combinations of garlic, *babool*, *neem* and mint leaves, and comparing it with inorganic methods. Weeds were removed manually twice. Organic plots were sprayed with extract of boiled *neem* leaves+ buttermilk for pest control, and copper oxychloride+ *neem* oil mixture was sprayed twice for control of late blight. Three rogueing were done and random ELISA testing was also done. Haulm killing was done mechanically. Insect data was recorded and is under analysis. Variety K Chipsona-1 recorded highest number of tubers per plant and these

were comparable in organic treatments to inorganic one. 100% FYM+ neemcake treatment gave better yield performance over inorganic treatments (Fig.2 & 3).

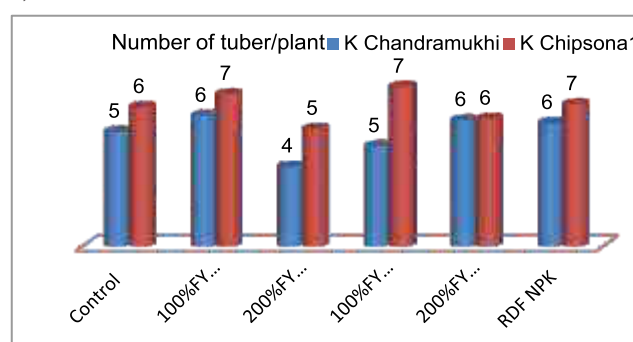


Fig.2: Influence of nutrition on tuber number

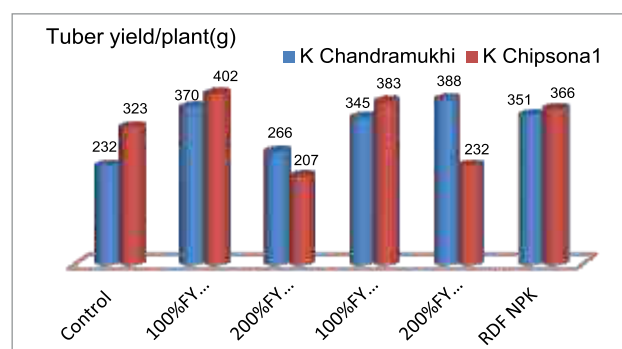


Fig.3: Influence of nutrition on tuber yield

Effect of haulm killing dates on production of seed size tubers

A field experiment was carried out at Jalandhar for studying the effect of different haulm cutting dates on seed size tuber yield. In K Pukhraj, dehaulming at 90 days resulted in maximum total tuber yield (42.1 t/ha), whereas, yield of seed size tubers was highest at 70 days (12.4 t/ha). Maximum total tuber number were maximum at 70 days (545 000/ha), while, seed size tuber number was highest at 80 days (205 000/ha). In case of K Jyoti, de-haulming at 80 days resulted in maximum total tuber (31.7 t/ha) and seed size tuber yield (12.2 t/ha). De-haulming at 90 days resulted in highest total tuber (480 000/ha) and seed size tuber (181 000/ha) numbers (Fig.4 & 5).

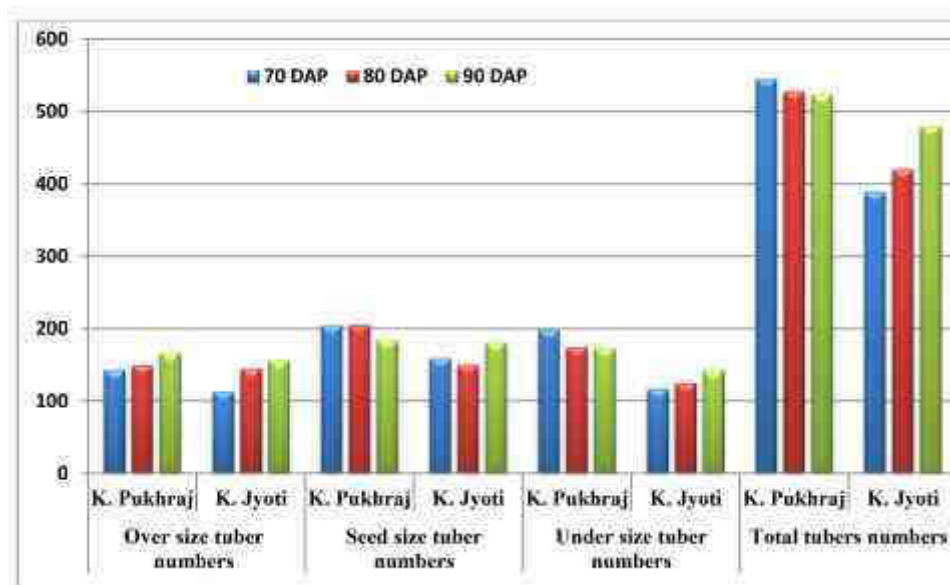


Fig.4: Graded and total tuber number (000/ha)

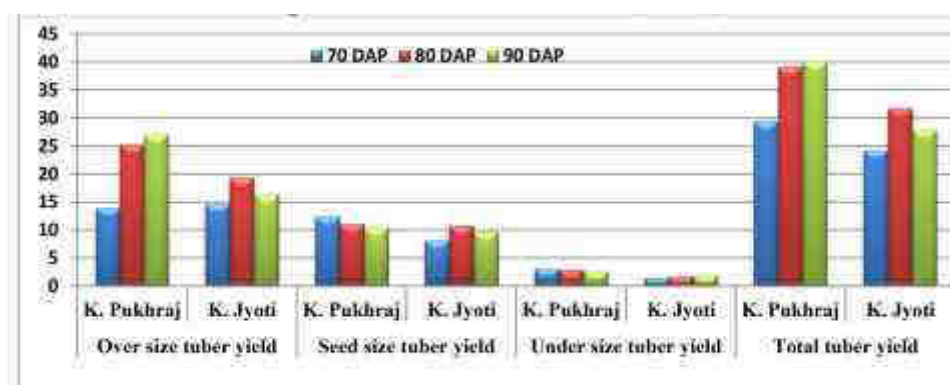


Fig.5: Graded and total tuber yield (t/ha)

Effect of planting dates on production of seed size tubers

A field study was conducted at Jalandhar for working out the effect of four planting dates on production of seed size tubers of cv. K Pukhraj and K Jyoti. Planting at 15 October resulted in maximum total tuber yield

in both the varieties K Pukhraj (38.1 t/ha) and K Jyoti (28.8 t/ha), and similar was the case with seed size tuber yield. Maximum seed size tuber number were found in 05 November planting in K Pukhraj (184 000/ha), while, in K Jyoti (153 000/ha) these were in 25 October planting (Fig.6 & 7).

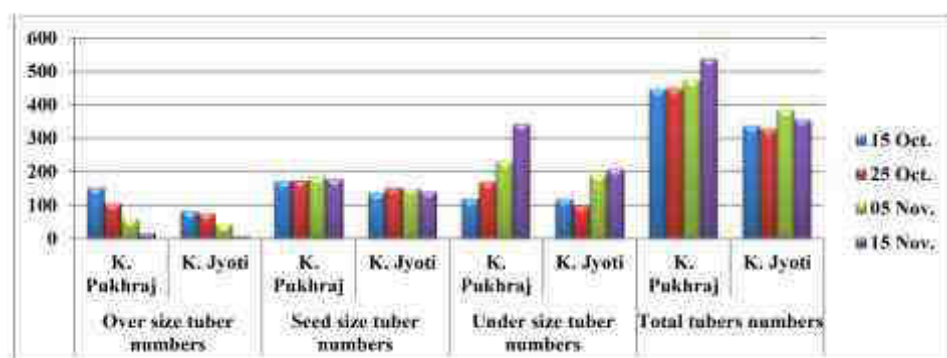


Fig.6: Graded and total tuber number (000/ha)

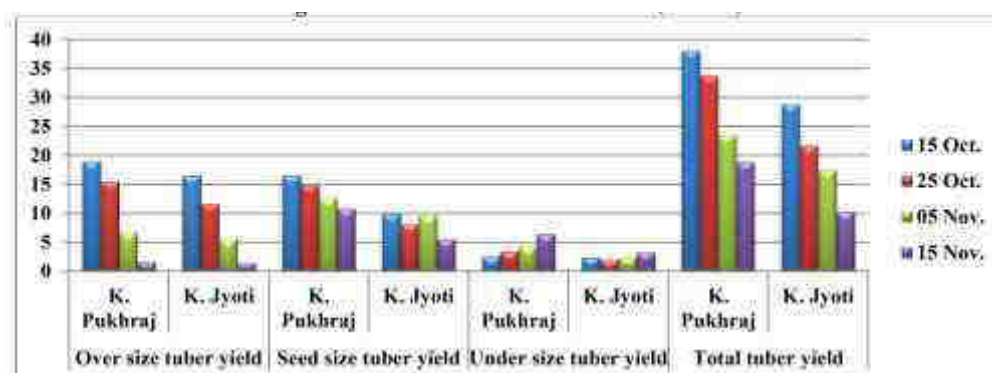


Fig.7: Graded and total tuber yield (t/ha)

Optimizing inter and intra row spacing for production of seed size tubers

Field experiment was conducted at Jalandhar to study the effect of 6 planting spacing in cv. K Pukhraj. Paired row planting with de-haulming at 90 days resulted in maximum total (43.4 t/ha) and seed

size tuber yield (20.4 t/ha). Total tuber number were also highest (705 000/ha) with this treatment. Whereas, seed size tuber number (308 000/ha) was maximum in paired row planting with 70 & 80 days duration (Fig.8 & 9).

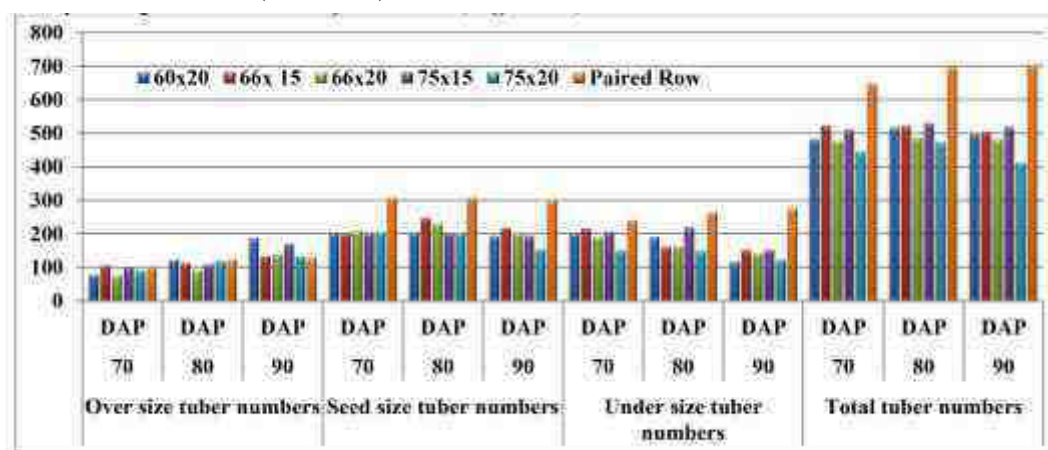


Fig.8: Graded and total tuber number (000/ha)

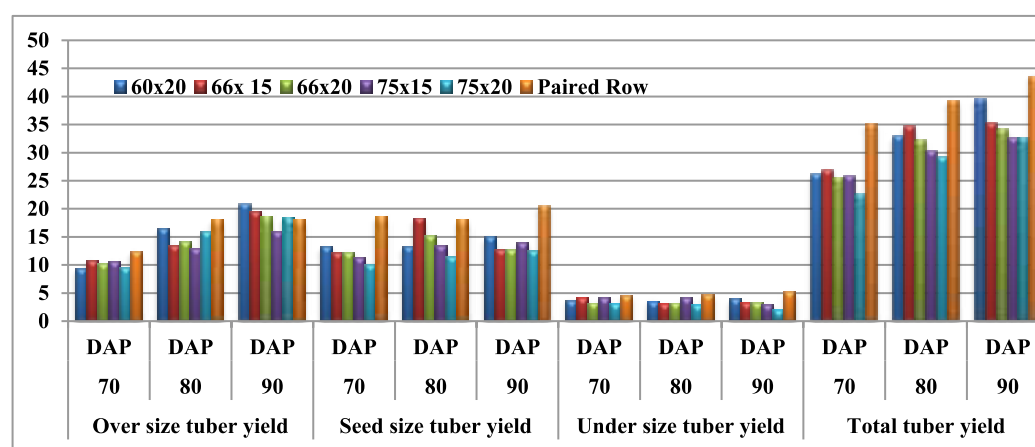


Fig.9: Graded and total tuber yield (t/ha)

Refining system based organic potato production technologies (Janani P, SK Luthra, VK Gupta, Clarissa Challam, N Sailo, S Rawal, Anil K. Choudhary, Pooja Mankar, SP Singh, M Sadawarti & Pinky Raigond)

Evaluation of potential potato germplasm for organic farming

A field trial has been started in current crop season with 84 potato germplasm accessions with the objective of their capacity to maintain yield under

nutritional constraints in organic farming system.

Evaluation of table potato varieties in Meghalaya

An experiment was conducted to evaluate the table potato varieties *viz.*, K Himalini, K Girdhari, K Jyoti, K Megha, K Kanchan and K Giriraj for commercial

cultivation in Meghalaya. Varieties, K Himalini (23.0 t/ha), K Girdhari (21.6), K Jyoti (20.2), K Giriraj (19.4) and K Megha (18.9) recorded significantly higher total tuber yield (Fig.10) over the control K Kanchan (17.1).

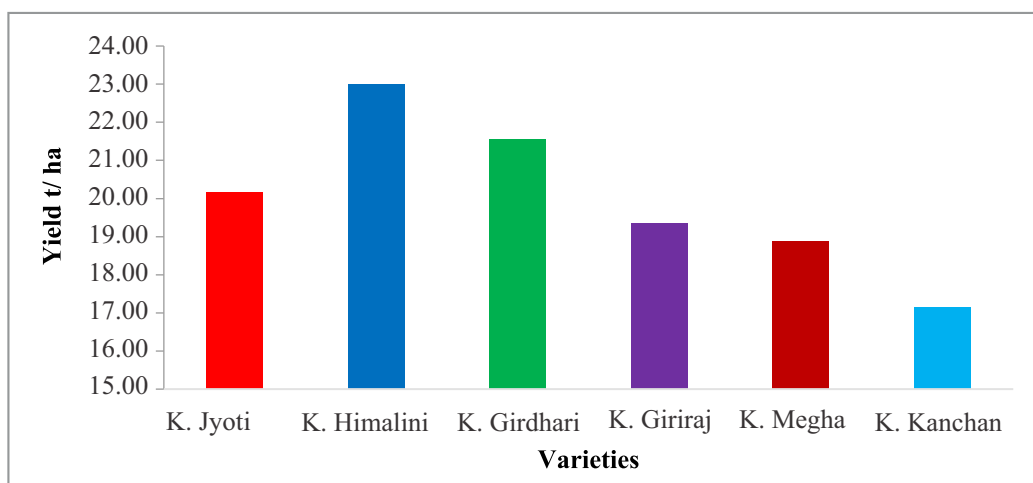


Fig.10: Performance of promising potato varieties in Meghalaya

Influence of cultivation methods on tuber dry matter and carbohydrate content

Tuber dry matter content varied between 14-25% and 12-27% in inorganic and organic potatoes, respectively. Varieties such as K Pukhraj, K Khyati, K Sindhuri, K Chipsona-3, K Chipsona-1, K Neelkanth and K Sangam exhibited higher dry matter content when raised under organic cultivation (Fig. 11). However, differences were non-significant. Organic cultivation significantly decreased the reducing sugars content in all the tested varieties. Reducing sugars ranged from 184 to 262 mg/100g FW and 152 to 222 mg/100g FW in inorganic and organic potatoes, respectively. On an average,

reducing sugars were 199 mg in organic potatoes and 230 mg in inorganic potatoes. Sucrose showed similar trend as that of reducing sugars i.e. content is low in organic potatoes. Sucrose varied between 21-58 mg/100g FW and 16-50 mg/100g FW in inorganic and organic potatoes, respectively, and average being 40 mg in inorganic and 34 mg in organic potatoes. In inorganic potatoes, amylose content varied from 21 to 32% and in organic potatoes content ranged from 21 to 35%. Varieties such as K Bahar, K Sindhuri, K Mohan, K Chipsona-1, K Garima and K Sangam exhibited higher amylose content when grown under organic cultivation (Table 2).

Table 2. Tuber dry matter and carbohydrates in organic and inorganic potatoes

Variety	Dry matter (%)		Reducing sugars (mg/100g FW)		Sucrose (mg/100g FW)		Amylose (%)	
	Inorganic	Organic	Inorganic	Organic	Inorganic	Organic	Inorganic	Organic
K Bahar	24	22	253	221	39	32	21	29
K Ganga	17	17	202	166	38	31	30	23
K Pukhraj	17	18	226	195	41	34	31	24
K Khyati	18	21	262	222	54	43	23	22
K Anand	24	21	223	189	37	27	32	30
K Sindhuri	20	24	240	222	21	16	20	22
K Chipsona-3	25	27	184	152	46	42	22	22
K Mohan	14	12	230	214	43	41	27	35
K Chipsona-1	21	26	215	189	31	25	22	24
K Garima	19	19	254	218	58	50	22	33
K Neelkanth	21	24	224	187	49	42	25	21
K Sangam	23	24	242	216	30	25	21	26
Mean	20	21	230	199	40	34	25	26

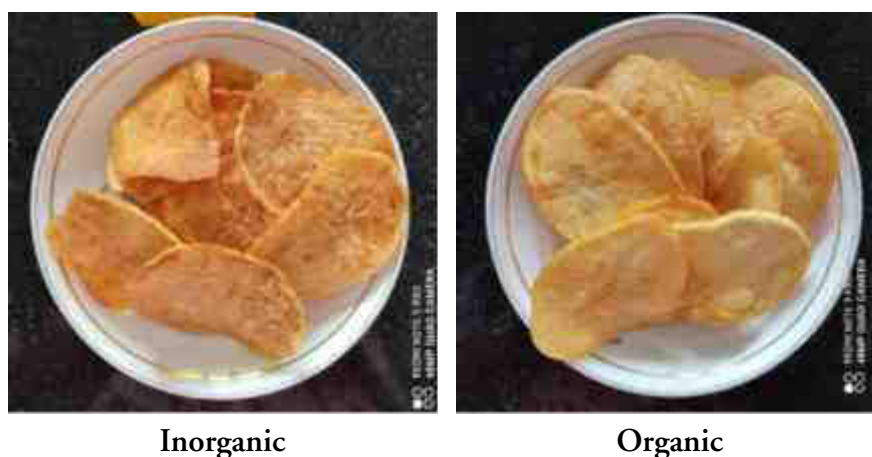


Fig.11: Chip colour of variety K Sangam

Effect of cultivation methods on total soluble protein, total free amino acids and glutamine

On fresh weight basis, total soluble protein varied between 0.89-1.52% and 0.75-1.75% in inorganic and organic potatoes. On average, protein content was higher in inorganic potatoes (1.22%) as compared to organic potatoes (1.01%). Only K Chipsona-1 had higher protein content under organic cultivation. Total free amino acids also showed similar trend. Amino acids ranged from 45 to 72 mg/100g FW and 36 to 53 mg/100g FW in

inorganic and organic potatoes, respectively. On average, inorganic potatoes contained 56 mg and organic ones contained 43 mg/100g FW amino acids. In general glutamine content was lower in organic potatoes, but varieties K Bahar, K Ganga and K Khyati exhibited higher glutamine content in boiled tubers. Average glutamine content differed non-significantly among organic and inorganic potatoes and average content was 30 and 29 mg/100g FW in inorganic and organic potatoes, respectively (Table 3).

Table 3. Total soluble protein, total free amino acids and glutamine in organic and inorganic potatoes

Variety	Total soluble protein (%)		Total free amino acid (mg)		Glutamine in boiled potato (mg)	
	Inorganic	Organic	Inorganic	Organic	Inorganic	Organic
K Bahar	1.50	1.06	58	36	54	59
K Ganga	1.17	0.93	51	41	14	22
K Pukhraj	1.25	1.00	71	45	23	16
K Khyati	1.28	0.47	58	47	38	84
K Anand	0.89	0.75	56	32	33	30
K Sindhuri	1.09	1.02	62	48	35	15
K Chipsona-3	1.52	1.49	45	39	24	22
K Mohan	1.28	0.95	72	45	17	17
K Chipsona-1	1.26	1.75	53	53	19	17
K Garima	1.20	0.82	51	44	24	17
K Neelkanth	1.08	0.80	50	45	37	19
K Sangam	1.06	1.03	48	44	42	21
Mean	1.22	1.01	56	43	30	29

Effect of cultivation methods on antioxidants

Total carotenoids varied between 29-214 µg/100g FW in inorganic and 38-403 µg/100g FW in organic potatoes (Fig.12). On average, carotenoids were present in higher concentration in organic potatoes

and concentration was 133 µg as compared to inorganic one that contained 108 µg carotenoids. Organic cultivation reduced total phenols in all the varieties. Content ranged from 203 to 614 mg/100g DW and 96 to 419 mg/100g DW in inorganic and

organic potatoes, respectively. Average content was 428 and 229 mg in inorganic and organic potatoes, respectively (Fig.13). Anthocyanin content (pelargonidin + malvidin) ranged between 2-26 mg/100g DW in inorganic and 5-29 mg/100g DW

in organic potatoes, respectively (Fig.14). Average content was 13 mg and 14 mg in inorganic and organic potatoes, respectively. Variety K Bahar and K Khyati exhibited maximum anthocyanin content under organic cultivation.

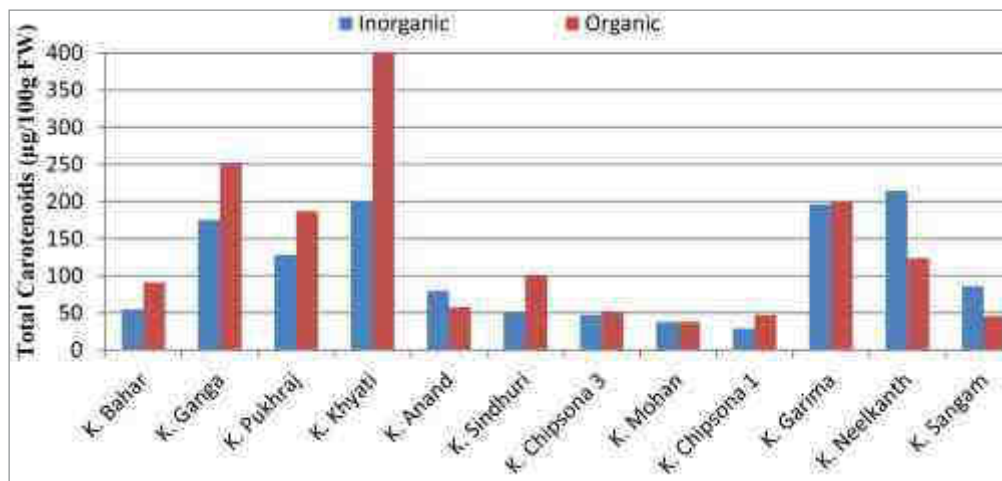


Fig.12: Effect of cultivation methods on total carotenoids

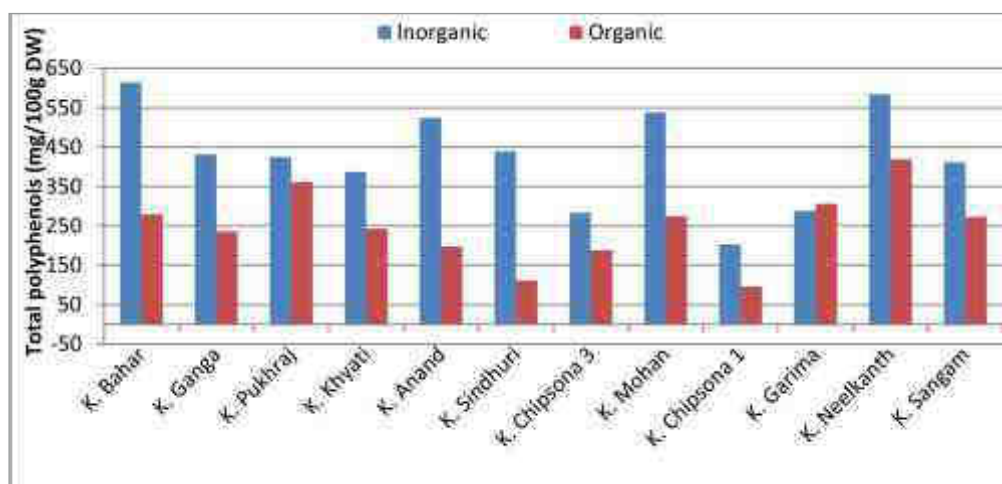


Fig.13: Effect of cultivation methods on total polyphenols

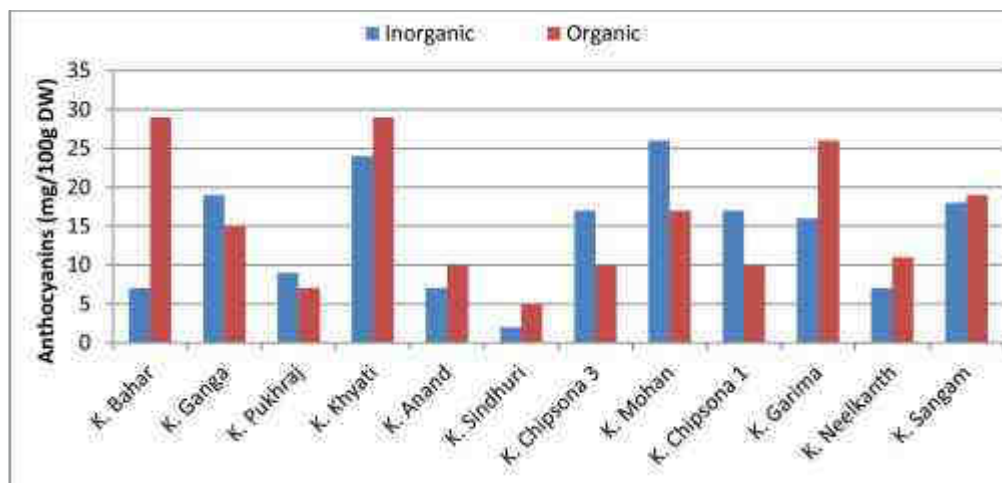


Fig.14: Effect of cultivation methods on anthocyanins

Organoleptic analysis

This revealed that organic cultivation enhanced after taste of varieties K Ganga, K Mohan, and K Sindhuri, whereas saltiness was observed in K Anand and K Pukhraj. Organic cultivation enhanced the overall acceptability of varieties K Chipsona-1, K Anand, K Sangam, K Khyati, K Garima and K Neelkanth.

Organic cultivation increased the flavouring compounds *viz.*, AMP+GMP in K Anand, K Ganga and K Garima, whereas flavouring compound glutamate was enhanced in K Chipsona-1, K Anand, K Ganga and K Bahar. Overall, the changes in flavour due to cultivation practices were mainly variety dependent (Table 4).

Table 4. Organoleptic evaluation and flavouring compounds

Variety	Cultivation method	Overall acceptability	AMP+GMP (µg/g FW)	Glutamate (mg/100g FW)
K Chipsona-3	Inorganic	Average	4.50	63
	Organic	Average	3.39	19
K Chipsona-1	Inorganic	Average	5.38	24
	Organic	Good	2.45	32
K Anand	Inorganic	Average	3.18	57
	Organic	Good	3.41	80
K Sangam	Inorganic	Good	2.97	97
	Organic	Very Good	2.91	20
K Ganga	Inorganic	Average	2.22	5
	Organic	Average	2.68	49
K Khyati	Inorganic	Good	3.46	45
	Organic	Excellent	2.36	32
K Mohan	Inorganic	Good	3.76	12
	Organic	Good	2.20	10
K Pukhraj	Inorganic	Good	3.60	74
	Organic	Average	2.46	24
K Bahar	Inorganic	Good	3.07	19
	Organic	Good	2.40	26
K Garima	Inorganic	Good	3.59	69
	Organic	Very Good	3.82	11
K Neelkanth	Inorganic	Good	3.37	49
	Organic	Very Good	3.05	14
K Sindhuri	Inorganic	Good	3.27	77
	Organic	Good	1.73	10

Refining organic potato protection technologies for sustainable yields (Mehi Lal, Anuj Bhatnagar, Sanjeev Sharma, Vinay Sagar, Subhash S, S Katare, M Abas Shah & Rahul Bakade)

Organic management of late blight disease

Organic based products/ restricted used chemicals were evaluated to develop late blight management strategies at Modipuram for cv. K Bahar and K Mohan. A total of 14 treatments (T1: fermented FYM @ 1 kg FYM/10 l, T2: fermented FYM - Dimethomorph 50% WP @ 0.1% + Mancozeb 75% WP @ 0.2%, T3: Copper oxychloride 50% WP @ 0.2%, T4: Copper hydroxide 53.8% DF @ 0.2%, T5: *Bacillus subtilis*-0.25%, T6: *Trichoderma viride* @

2.0%, T7: *Neem* kernel fermented @ 1.0%, T8: *Neem* oil @ 6.0% (1500ppm), T9: *Pseudomonas fluorescens* @ 1%, T10: Control, T11: two spray of Copper oxychloride 50% WP @ 0.2%, T12: two spray of Copper hydroxide 53.8% DF @ 0.2%, T13: *Neem* oil @ 3.0% local made (LM) and T14: *Neem* oil @ 6.0 % LM) were evaluated. It was observed that before appearance of late blight disease treatments T1 and T2 was looking good as spraying of fermented FYM was started at 35 days after planting at weekly interval. Minimum disease severity (DS) was recorded in treatment T2 in both the varieties i.e. K Bahar (15.67%) and K Mohan (8.17%) as against control where K Bahar and K Mohan recorded 96.67 and 77.33% of DS. *Neem* oil @ 6.0 % showed better

efficacy with lower DS in K Bahar (43.33%) and K Mohan (21.83%). Copper based fungicides also showed better results with 2 or 4 sprays. It can be

concluded that copper based fungicides and *neem* oil may be used for management of late blight of potato in organic farming (Fig.15).

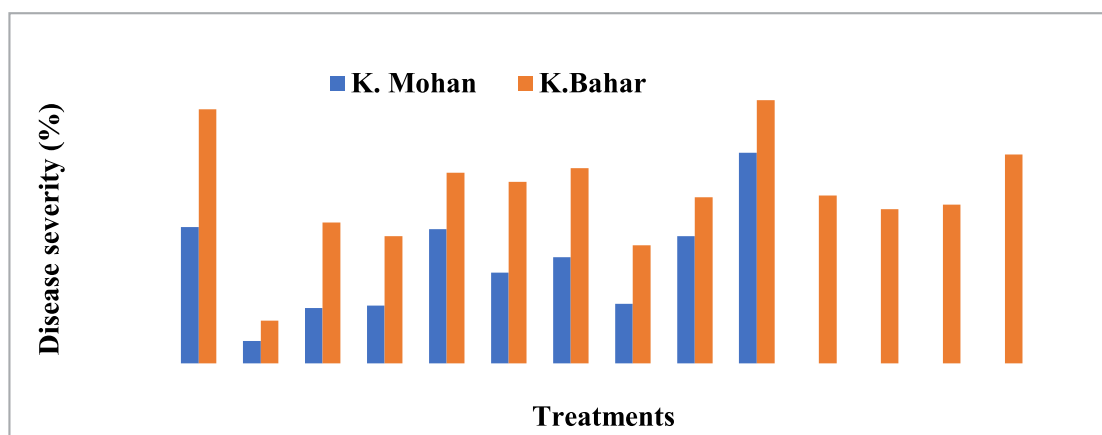


Fig.15: Effect of different organic based chemicals/ restricted used chemicals on late blight

Management of late blight using compost tea

Under hill conditions at Shimla, compost tea was evaluated against late blight under field conditions along with standard contact fungicides (mancozeb and chlorothalonil). Compost tea was prepared by steeping well decomposed FYM in water (1:10) for 7 days in a bucket wherein a wooden stick was used to stir the mixture once a day to enhance microbial consortia. The suspension was filtered through muslin cloth and used as a foliar spray. Fresh suspension was prepared every week. Application of compost tea was initiated 30 days after planting at weekly interval, whereas fungicides were applied prophylactically as per prediction by Indo-Blightcast model. Results revealed that least terminal blight severity (16.25%) was observed in chlorothalonil treated plots followed by mancozeb (21.25%), while it was highest in control (81.25%) followed by compost tea (80.0%). Yield was inversely proportionate to disease severity.

Organic management of black scurf of potato

Black scurf of potato is the main soil and tuber borne diseases of potato. At Modipuram, fungal bio-agents used as cell suspension (10^{10} CFU/ml) and on compost substrate, bacterial bio-agents used as cell suspension (10^8 CFU/ml), buttermilk+ copper rod, waste decomposer @ 6.0%+ *neem* kernel were evaluated for managing black scurf of potato. The results revealed that buttermilk+ copper rod, waste decomposer and one fungal bio-agent (up to 70% DI) showed better efficacy than untreated control (95% DI).

Conventional and novel strategies for management of insect/vectors

In this context, two experiments were initiated. Study at Modipuram consisted 7 treatments (T1: *Beauveria bassiana*, seed treatment-ST @ 10g/kg, T2: Shreya, CTCRI product-ST @ 10 ml/kg, T3: *B. bassiana*-ST + Shreya-spray @ 30 DAP, T4: Shreya-ST @ 10 ml/kg + *B. bassiana*-spray 10g/l @ 30 DAP, T5: Imidacloprid 17.8 SL-ST @ 4 ml/10 l, T6: Imidacloprid 17.8 SL-ST @ 4 ml/10 l + Thiamethoxam 25 % WG-spray @ 4 g/10 l, T7: untreated control. Observations on number of sucking pests were recorded 20 days after planting and subsequently at 10 days interval. Similarly, experiment was conducted at Gwalior having seven treatments (T1: *Azadirachtin* 1500 ppm @ 5.0 ml/l, T2: *Verticillium lecanii*- 2 x 10^8 c.f.u @3 g/l, T3: *B. bassiana*- 2 x 10^8 c.f.u @5 g/l, T4: *Metarhizium anisopliae*@3 g/l, T5: Thiamethoxam 25% WG @ 0.5 g/l, T6: farmers practice- Imidacloprid 17.8 SL @0.5ml/l, T7: untreated control). Observations on whitefly, aphids and thrips are under the progress. Results of both experiments will be analysed and interpreted after harvest of crop.

Management of late blight in Meghalaya under organic farming system

A field experiment was conducted to evaluate the efficacy of different copper compounds (T1: Copper oxychloride 0.2% @ 6 days interval from 40 DAP- K. Jyoti; T2: Copper hydroxide 0.2% @ 6 days interval from 40 DAP- K. Jyoti, T3: Copper oxychloride 0.2% @ 10 days interval from 40 DAP- K. Jyoti, T4:

Copper hydroxide 0.2% @ 10 days interval from 40 DAP- K. Jyoti, T5: Control- K. Jyoti, T6: Copper oxychloride 0.2% @ 6 days interval from 40 DAP- K. Himalini, T7: Copper hydroxide 0.2% @ 6 days interval from 40 DAP- K. Himalini, T8: Copper oxychloride 0.2% @ 10 days interval from 40 DAP- K. Himalini, T9: Copper hydroxide 0.2% @ 6 days interval from 40 DAP - K. Himalini, T10: Control- K. Himalini). The highest tuber yield (9.22, 9.14, 9.09 and 8.47 t/ha) was recorded in the plots treated

with copper hydroxide @ 0.2 % as one prophylactic spray at the time of canopy closure, subsequent sprays at six and ten days intervals. In K. Jyoti, 100% disease incidence was recorded eight days after first appearance of symptoms in all the treatments. In K. Himalini, all copper fungicides significantly delayed the disease appearance in comparison to the unsprayed control. However, none of them was able to arrest the disease incidence below 100%, 24 days after first appearance of symptoms (Fig.16).

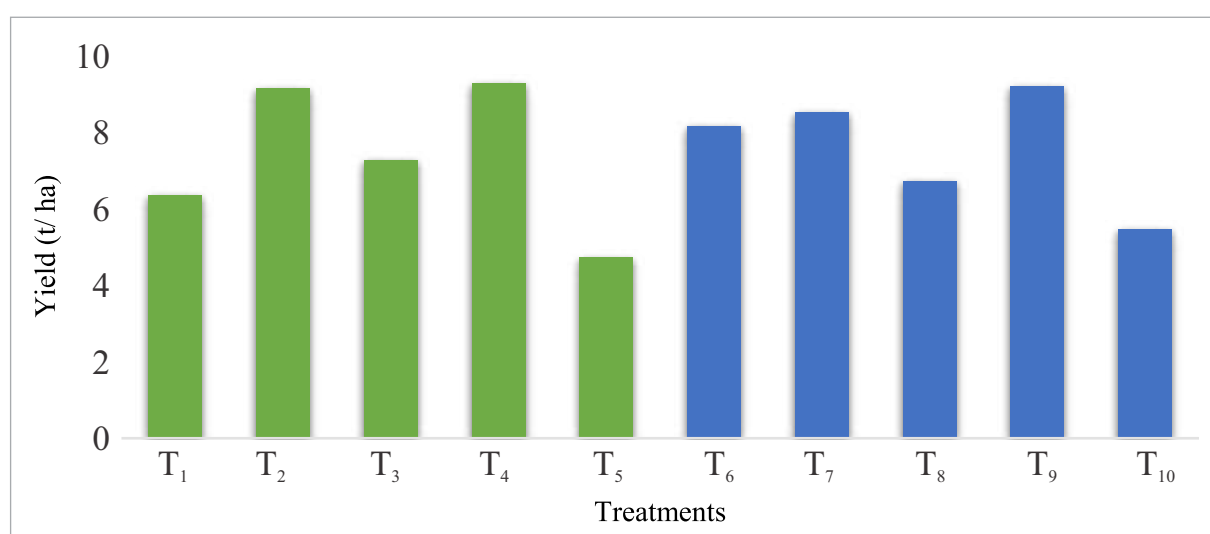


Fig.16: Effect of copper fungicide on total tuber yield of potato (t/ ha)

Development of potato based cropping systems for different agro-ecologies (SP Singh, VK Dua, Sanjay Rawal, Anil Sharma, Anil K Choudhary, RK Singh, Pooja Mankar & Janani P)

A field experiment has been initiated during *Kharif* 2020 consisting 4 systems (CS₁: Potato- Garden pea; CS₂: Potato- Broccoli; CS₃: Potato- Garlic; CS₄: Potato- Matricaria) and 4 integrated nutrient management (INM) practices in a split-plot design at Shimla (Fig. 17). In 1st year, total tuber yield of K Himalini was found to be significantly higher in treatment INM₄ (17.9 t/ ha) which was followed by INM₃ (16.8 t/ ha), INM₁ (16.2 t/ ha) and INM₂ (15.8 t/ ha), respectively. These results indicated that application of 100% RDF+ FYM @ 10 t/ ha)+ PSB+ AMF in potato crop proved beneficial to harness 10.7 and 6.5% higher yield over the 100% RDF and INM₃, respectively in first season across different cropping systems

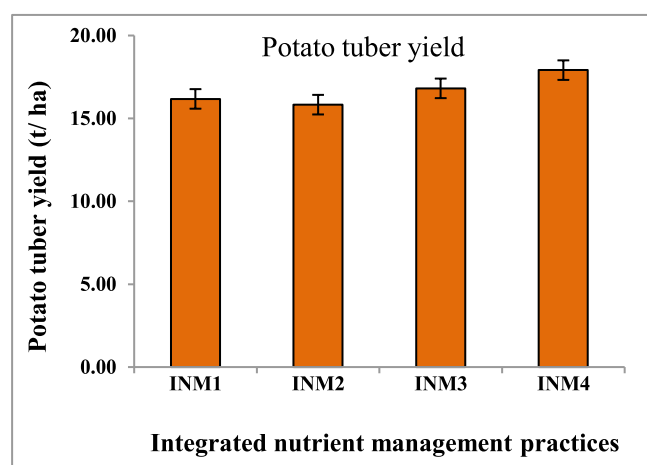


Fig.17: Influence of integrated nutrient management practices on total tuber yield (The vertical bars represent $LSD_{0.05}$ values). [Treatment: INM₁: 100% NPK @ 150:100:100 kg/ ha in potato; INM₂: 75% NPK+ FYM @ 10 t/ ha; INM₃: 75% NPK+ FYM @ 10 t/ ha+ PSB+AMF; INM₄: 100% NPK+ FYM @ 10 t/ ha+ PSB+AMF]



Fig. 18: Field experimentation on diversified potato based cropping systems under INM in wet-temperate NW Himalayas

Disease dynamics in potato based systems

Observations were recorded on foliar diseases of potato especially on Phoma and leaf spot complexes in 3 cropping systems *viz.*, potato-wheat-paddy (C1), potato-onion-maize (C2) and potato-green gram-groundnut (C3). The results revealed that in treatment T1- absolute control (no nutrient applied), T3-100 % NPK through organics manure and T7-100% organic manure+ crop residue showed higher disease incidence in all three cropping systems than the remaining inorganic sources of nutrients (Fig. 19). Similarly, results on black scurf of potato exhibited that highest disease incidence was recorded in treatment T3-100% NPK through organics (7.33%) followed by T7-100 % organic manure+ crop residue (7.00%) in C1 system. Highest disease incidence of black scurf was observed in treatment T1- absolute control (24.33%) followed by T4-50% NPK organic+50% NPK organic (23.33%) in C2 system. While in C3 system, highest incidence (8.33%) was in T3-100% NPK through organics followed by T1- absolute control (Fig. 20). It can be concluded that cropping sequences as well as sources of nutrients (organic & inorganic) are affecting both foliar and soil & tuber borne diseases of potato.

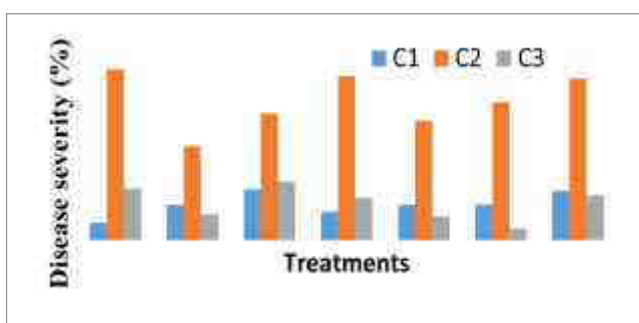


Fig. 19: Incidence of Phoma and leaf spot complexes in Potato-Wheat-Paddy (C1), Potato-Onion-Maize (C2) & Potato-Green gram- Groundnut (C3) cropping system

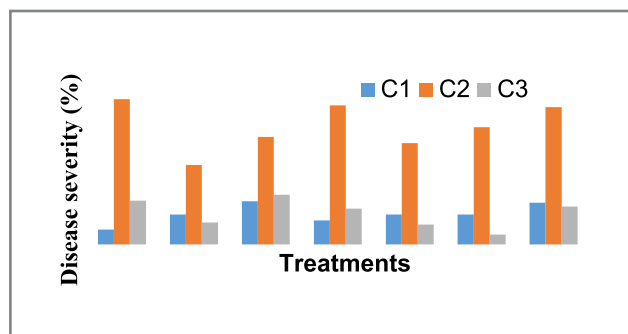


Fig. 20: Incidence of black scurf of potato in Potato-Wheat-Paddy (C1), Potato-Onion-Maize(C2) & Potato-Green gram-Groundnut (C3) cropping system

Evaluation of potato based cropping systems in west central plains

At Gwalior, rice yield was highest with recommended dose of NPK (Fig. 21). Application of decomposed crop residue + Azotobacter + PSB + Jeevamrit was second best treatment but there was 17.0% reduction in paddy yield compared to recommended dose of NPK under no mulch. In mulching, paddy yield under RDF-NPK showed drastic reduction in paddy yield (2231 kg/ha) as it was 2842 kg/ha under crop residue. FYM + Jeevamrit showed 29.9% reduction over RDF-NPK without mulch. Paddy straw mulch did not enhanced rice yield rather its application caused drastic reduction in yield of RDF-NPK applied treatment (Fig. 22).

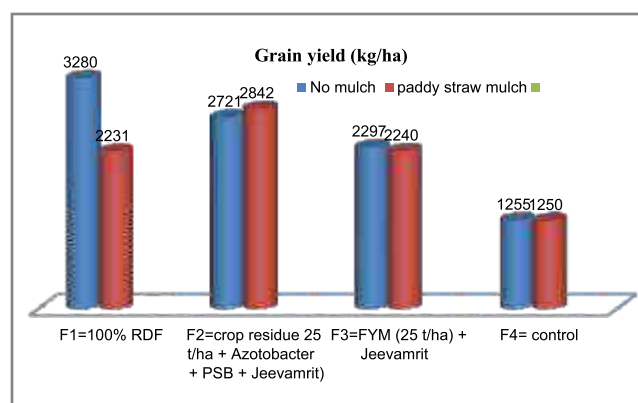


Fig. 21: Paddy yield as influenced by different treatments

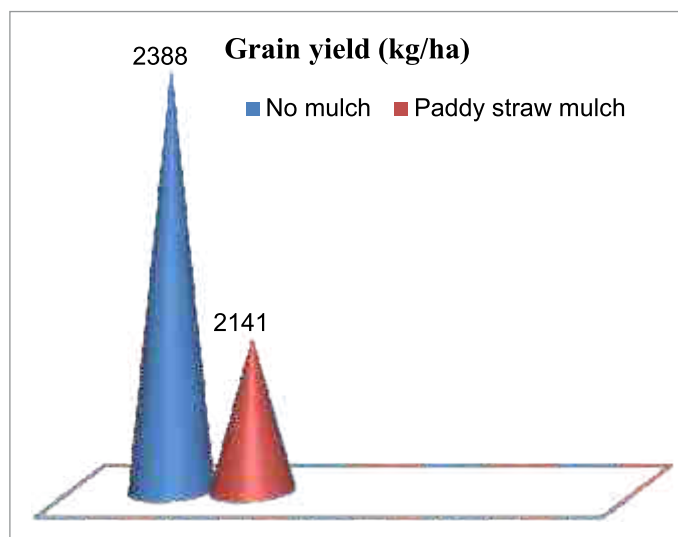


Fig. 22: Paddy yield as influenced by paddy straw mulch

Potato was planted in November after harvest of rice crop. Highest tuber number (7) and yield (222g/plant) were recorded under 100% RDF followed by crop residue and FYM treatments (Fig. 23 & 24).

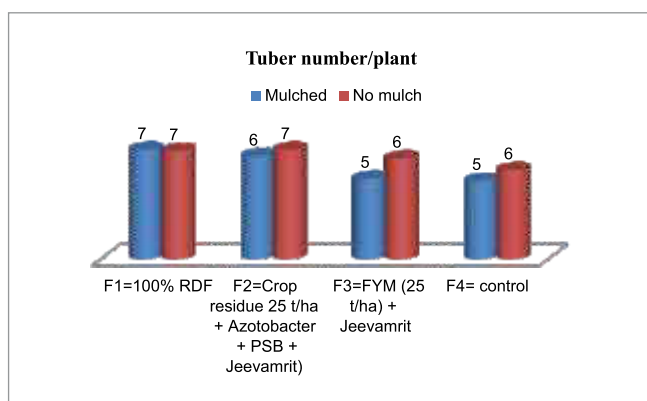


Fig. 23: Influence of paddy straw mulch on tuber number

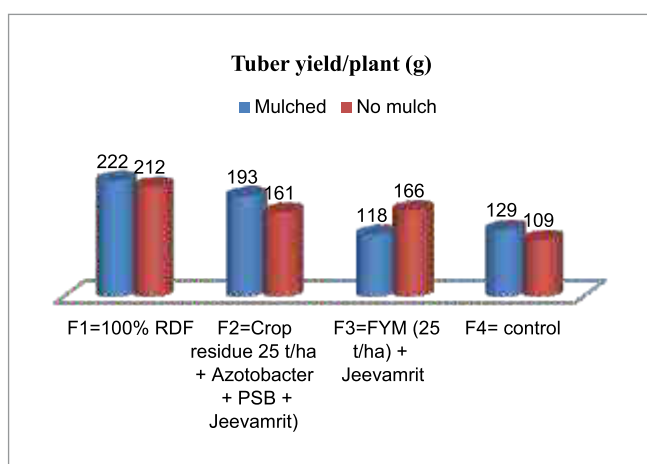


Fig. 24: Influence of paddy straw mulch on tuber weight

Feasibility of potato cultivation under zero-tillage in rice-potato sequence

A field experiment was started after harvesting rice crop. Rice was harvested at three levels *viz.*, ground level, at 30 cm height and at 60 cm height. Planting of potato was done by hill tilling, row tilling and entire field tilling. Potato was planted on undisturbed raised beds made for rice sowing. Emergence was normal under all tillage operations.

Precision farming studies for sustaining potato productivity (Sanjay Rawal, Anil K Choudhary, Paresh Chaukhande, Pooja Mankar & Brajesh Nare)

Development of drone based potato crop management technologies

At Modipuram, the Institute initiated a collaborative programme for use of drone in developing precise crop management technologies in collaboration with M/s Bayer Crop Science Limited, India, Thane (West) and M/s General Aeronautics Pvt. Ltd., Bengaluru. First activity of the project would start in January, 2021 with spraying of pesticides on potato crop after getting legal approvals from DGCA and MoCA, and the local administration. The objective is to do comparative analysis of drone based and conventional spray against late blight disease and potato vectors by measuring penetration efficiency, drift and phytotoxicity. A field experiment has been laid out in approximately 1.2 ha area with eight treatments and a control.



Fig.25: Test flight of drone in potato crop at Modipuram

Development of field specific fertilizer applicator

Tractor operated fertilizer broadcaster is used for application of granular fertilizer as basal dose. It is conventionally operated by power-take-off system, which provide a constant application rate at various level of forward speed of travel during the field operation and it results in non-uniform application of

fertilizers. Therefore, a speed synchronized uniform rate fertilizer broad caster is under development at Jalandhar to apply precise amount of granular fertilizer (Urea, MOP, SOP etc.) as per recommendation for field. Function of the system will be to sense forward speed of travel, calculate amount of fertilizer to be applied as per the requirement for field and actuate the metering system precisely to allow predefined amount of fertilizer. System will be able to apply fertilizer in range of 20-320 kg/ha. Mechanical components of the system have been developed. Fabrication of speed sensing system is under process.

Development of rapid seed potato production technologies *(Sukhwinder Singh, Sugani Devi, Anil Sharma, Brajesh Nare, Ratna Preeti Kaur & Som Dutt)*

Rapid seed potato production in soilless system

Experiments in coco-peat based soilless system installed on raised structures were continued at Jalandhar. Study indicates that with SSP (Smart seed production) technique two crop cycles from tissue cultured plants and three cycles from minitubers in a season can be taken under north-western climatic conditions of India. Technique has been recommended for filing patent by CPRI-ITMC. Work on developing new soilless media based on paddy straw has also been initiated.

Formulation for tuber number enhancement

In most of high yielding potato varieties, seed size proportion, both by number and weight ranges between 40-50% even after following strict fertilizer application and haulm cutting schedule. This makes business of seed potato production lesser remunerative and farmers shy away from growing potato crop purely for seed purpose. Instead they produce potatoes without following much seed production protocols and segregate the produce for table and seed purpose just based on size. As a result, quality of seed produced is not up to required standards. Seed size tuber proportion need to be enhanced significantly for making seed potato business more viable. At Jalandhar, experiments on two formulations intended for seed treatment, were conducted on eight cultivars for enhancing total tuber number and seed size proportion. Total as well as seed size tuber proportion increased significantly. One formulation has been recommended for filing patent by CPRI- ITMC (Fig.26).

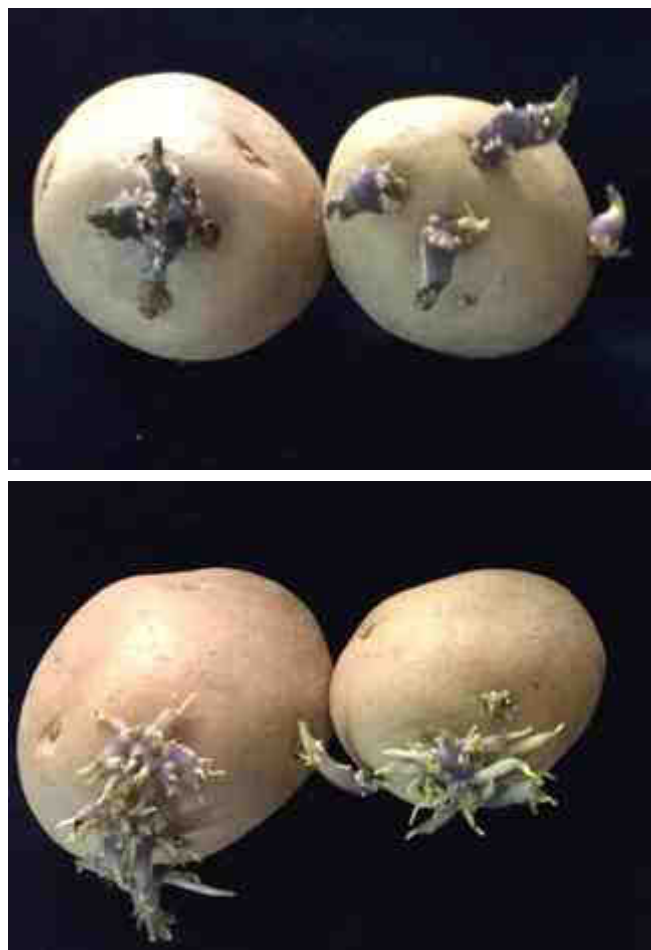


Fig.26: Sprouting in tubers of treated crop at Jalandhar

Safe spraying system

A manual pulled type spraying system was designed at Jalandhar for safe and uniform application of pesticide/herbicide on field crops. The system consists of a frame with two wheels, chemical tank, spray pump, spray boom and a battery. Tank is mounted on the frame and connected with spray pump which delivers the liquid up to a pressure of 400 kPa towards spray boom. Spray boom is installed at the back side of frame. A handle is attached with frame to pull the system in field manually. Effective width of the system is 4.5m, which covers 6 rows of potato field. Field capacity of the system has been observed as 1.0 ha/h from the preliminary field trails. Field testing and modification of the system are under process.

Hand tools for potato cultivation

Two new designs of women friendly hand tools have been developed at Jalandhar. One of them is designed for quick transplanting of potato micro plants in to the soilless or soil media. It has a handle attached with a covered mild steel board which penetrate in to the soil quickly and make space to accommodate a plant

up to a depth of 15 cm. Another tool is designed for weeding, digging, earthing-up and scraping of soil. It has two ends attached with a handle. One end is for weeding or digging of soil whereas the other end is for earthing-up or scraping of soil.

Paddy straw management in potato planting

Various types of machinery are available for straw chopping, incorporation in soil and collection of straw from field. These machines take a lot of energy and time for its proper management and preparation of the fields for potato crop. Therefore, three experiments were conducted at Jalandhar for paddy straw management during potato planting. The treatments are: Incorporation of paddy straw with super seeder+ irrigation+ single pass of cultivator (15 days)+ planting of potato as conventional method+ irrigation; Tilling of 20 cm wide and 6-8 cm deep strip after harvesting of paddy+ planting of potato at a depth of 5 cm+ covering with 1cm soil+ mulching of paddy straw+ irrigation 5 days after planting; No tillage + placing of tubers on harvested field and

covered tubers with paddy straw+ irrigation same day of planting.

Solar drying unit

Three different solar drying units have been developed for dehydration of potato chips/shreds/sticks at Jalandhar. Dome type structures of the drying units were fabricated using GI rectangular pipes and installed on a concrete floor area. These drying units have three different configurations of covering materials *viz.*, Unit I: is covered with double layered 6 mm thick polycarbonate sheet; Unit II: is covered with 200 micron single layer polythene sheet and Unit III: is covered with double layered polythene sheet and is equipped with a unit to provide insulating air gap of 5-10 cm between two layers. It was observed that temperature inside all drying units was approximately 15-22 °C higher as compared to ambient diurnal temperature. The units have to be further tested for their performance and capacity (Fig.27).



Fig.27: Solar drying tunnel for potato products

VEGFAST for roof tops

CPRI-VEGFAST technology developed at Jalandhar is intended for kitchen gardening on the rooftops/ yards/ balconies especially in cities and towns where agricultural land availability is scarce. System consists of a VEG trough, soil based media, canopy management structure, drip irrigation system and ready to shift planting material. VEG trough is a simple structure provided to hold sufficient amount of soil based media and to maintain proper aeration in the root zone. Seven different designs of the VEG troughs have been developed as per the requirements

of vegetables/ herbs/ microgreens/ medicinal crops. Distinct feature of this system are: safe and fresh vegetables/ salads/ microgreens can be grown in city environment; affordable and quick (30 minute per unit) to install; water use efficient system as there is no run off and percolation; Most of the summer and winter vegetables can be grown; soil the most abundantly available nature gifted media used and concrete surface can be converted into green area. VEGFAST technology has been commercialized to 19 firms till now (Fig. 28).



Fig.28: Technology commercialization and training program on VEGFAST technology

Mechatronics in potato production (*Brajesh Nare, Sukhwinder Singh, Sunil Gulati, Anil Sharma & RP Kaur*)

Counting machine

A new design of counting machine has been developed at Jalandhar for counting of potato minitubers and other similar products. Optical sensors were employed in this system to sense the potato minitubers or other similar objects while passing through the beam of sensor. Sensors are capable to sense 500 tubers per second but the object should be passed across beam one by one. Therefore, an electromagnatic vibrator is installed with a feeding tray through which minituber can be moved in a single line towards the sensors. Furthermore, due to non-uniform size of minitubers (6-25 mm GMD), it is difficult to control the flow rate. A set of magnetic stopper are installed with the feeding tray to control the flow of the minituber precisely. Further, a control

panel was installed to count the number of minitubers passed through sensors and display it on screen. Machine was tested with different size and varieties. Capacity of counting machine was observed as 20,000 to 25,000 minitubers per hour (Fig. 29).



Fig.29: Technology commercialization and training of stakeholders



DIVISION OF PLANT PROTECTION

PROGRAMME: BIOLOGY, ECOLOGY AND MANAGEMENT OF INSECTS AND NEMATODE PESTS OF POTATO

Project: Biology, Epidemiology and Management of Insect Pests of Potato

Survey, monitoring and collection of various potato pests (Anuj Bhatnagar, Mohd. Abas Shah, Subhash Katare, Kailash C. Naga, Subhash S & Priyank HM)

Aphids

The population of aphid species was monitored at weekly interval in unsprayed potato fields from October to December 2020 at Modipuram and Jalandhar. The population of the winged morphs of aphids started out at 48 aphids per 100 compound leaves after 25 days of emergence of the crop (Fig. 1). The population declined after that and fluctuated between 10 and 19 aphids per 100 compound leaves. Initially aphid population dominated by *Aphis gossypii*, subsequently it was predominated by *Myzus persicae* at Modipuram. Aphid flight activity was monitored with yellow sticky traps (YSTs) at Jalandhar. *Myzus persicae* first appeared on the potato plants in the 1st week of November and crossed the threshold limit in the 3rd week of January (Fig. 2). Afterwards the aphid population increased exponentially and started to decline by the last week of February. The population of the winged morphs of other aphids started out at 70 aphids per 100 compound leaves in the first week after emergence of the crop (Fig. 2). The population declined after that and fluctuated between 14 and 35 aphids per 100 compound leaves. The population showed increasing trend after third week of February. The flight activity of the aphids, monitored with yellow sticky traps indicated that the flight was highest during the last week of October to first week of November, and after

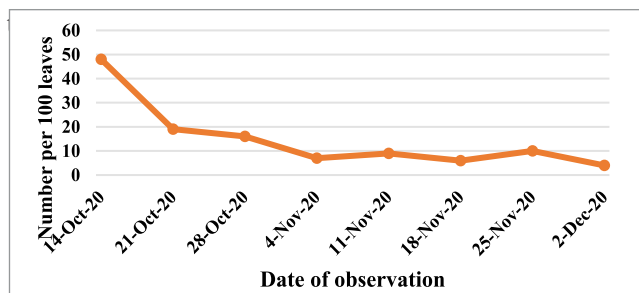


Fig. 1: Population dynamics of the alate morphs of aphids on potato at CPRS, Modipuram

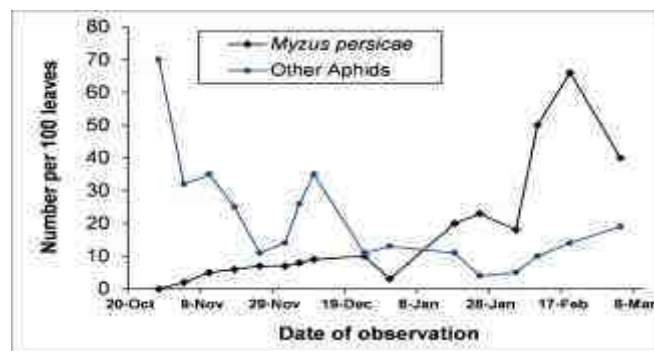


Fig. 2: Population dynamics of the alate morphs of *Myzus persicae* and other aphids on potato at CPRS, Jalandhar (2019-20)

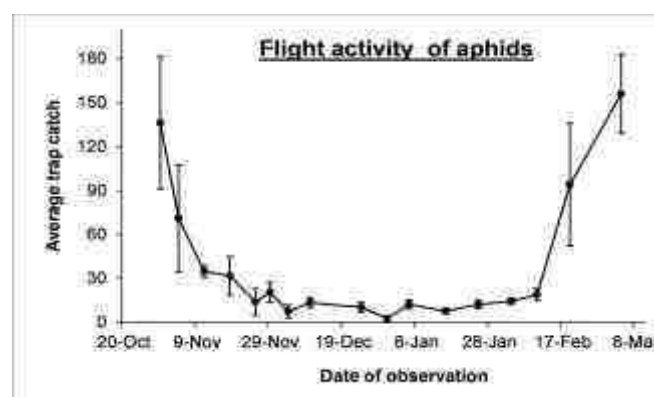


Fig. 3: Flight activity of aphids on potato at CPRS, Jalandhar (2019-20)

Whitefly

The population of whitefly, *Bemisia tabaci* was monitored at weekly interval in unsprayed fields from October to December 2020 by leaf count method in the early potato crop at Modipuram and Jalandhar. In general, the population of whitefly adults showed a general decline in population over time at Jalandhar which began high initially (Fig. 4). The population remained above economic threshold till the 2nd week of November and after that less than one whitefly per plant was recorded. The number of eggs lay per plant increased till first week of November and declined gradually afterwards. The number of nymphs per plant showed a similar trend with a time lag of more than two weeks as compared to the number of eggs laid. Nymphs and eggs were recovered from the potato crops throughout the season although in very small numbers. Up to 28 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 2nd week of November (Fig. 5). Similar trend was observed at Modipuram (Fig. 6).

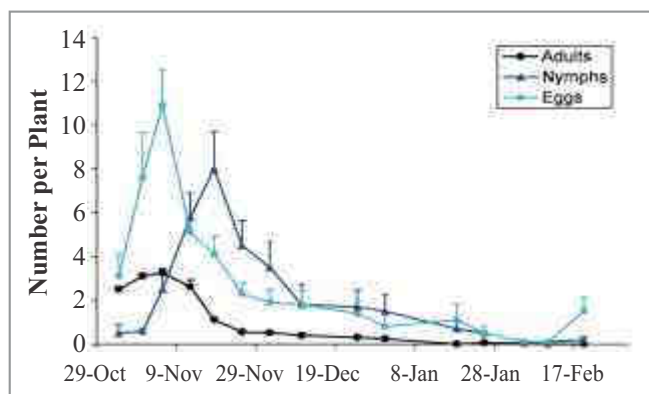


Fig. 4: Population dynamics of the eggs, nymphs and adults of *Bemisia tabaci* at Jalandhar

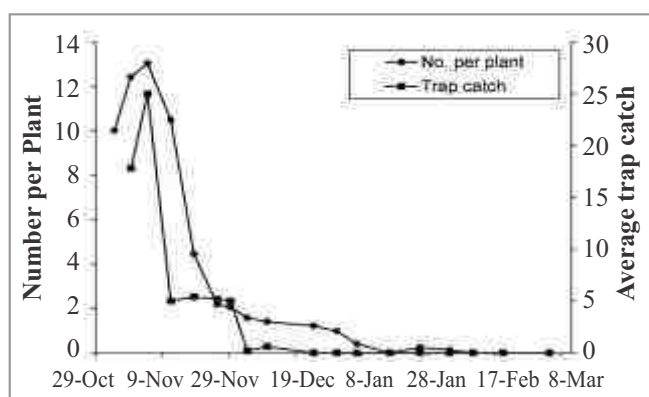


Fig. 5: Population dynamics of *Bemisia tabaci* sampled by (a) leaf count method and (b) YST catch in potato at CPRS, Jalandhar (2019-20)

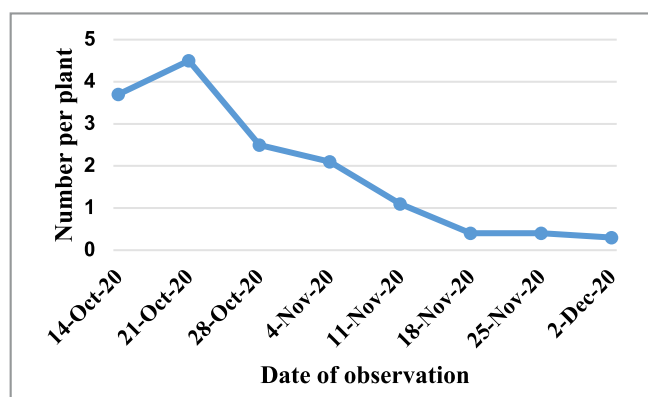


Fig. 6: Population dynamics of *Bemisia tabaci* at Modipuram

Leafhopper

The population of leaf hopper, *Amrasca biguttula biguttula* was monitored at weekly interval in unsprayed potato fields from the 3rd week of October till the first week of December 2020 by leaf count

method in the early crop at Modipuram. The population remained above ETL (1 hopper/leaf) throughout the crop growth except last week before haulm cutting (Fig. 7). The population remained high between last week of October to 2nd week of November and then started declining over time.

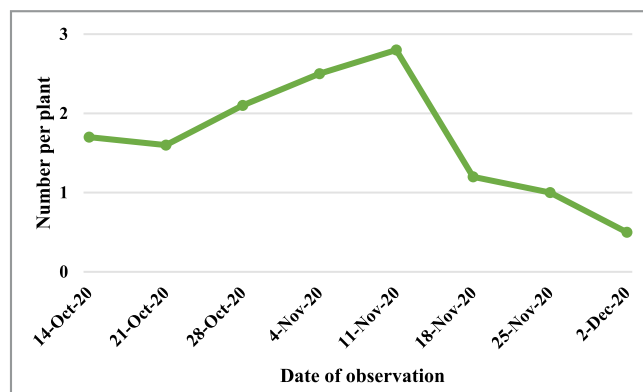


Fig. 7: Population dynamics of leaf hopper, *Amrasca biguttula biguttula* at Modipuram

Temperature dependent development of peach-potato aphid, *Myzus persicae* (Sulzer) on potato (Mohd Abas Shah, Sanjeev Sharma & VK Dua)

The development and survival of *M. persicae* immature stages was evaluated on potato at eleven constant temperatures, separately for apterous and alate morphs to model the response of the two morphs to temperature. *M. persicae* developed to adult stage from 5.4°C to 31°C but failed to achieve adult emergence at 32°C, the highest temperature tested. However, winged adults were produced from 5.4°C to 26.4°C only (Table 1). The immature survival rate was high from 7.3 to 26.4°C, and decreased considerably beyond this range (Fig. 8).

The lower temperature thresholds (T_{min}) were estimated as $4.13 \pm 0.38^\circ\text{C}$ and $4.35 \pm 0.74^\circ\text{C}$ for apterae and alatae, respectively. The thermal requirement for development of alate morphs was found appreciably higher in comparison to apterae, 128.2006 and 108.69 ± 3.07 , respectively.

Table 1: Survival (%) and developmental time (days) of apterous and alate virginoarae of *Myzus persicae* at constant temperatures

Temp. (°C)	n ^a	Survival to adult (± SE)	Apterous		Alate	
			n ^b	Mean ± SE	n ^b	Mean ± SE
5.4	306	34.83 ± 3.35	67	30.59 ± 0.41 a	39	36.72 ± 0.31 a
7.3	197	87.84 ± 2.52	139	20.98 ± 0.16 b	32	25.48 ± 0.32 b
11.0	222	91.57 ± 1.52	181	13.71 ± 0.19 c	24	17.10 ± 0.25 c
14.2	186	89.36 ± 3.00	149	12.46 ± 0.23 c	20	13.74 ± 0.40 d
17.7	363	94.65 ± 1.63	290	8.37 ± 0.06 d	52	10.32 ± 0.22 e
20.4	196	95.79 ± 2.91	147	6.59 ± 0.10 e	42	7.71 ± 0.13 f
23.3	215	97.94 ± 1.03	189	5.52 ± 0.05 f	18	6.50 ± 0.16 g
26.4	685	88.45 ± 2.47	581	5.64 ± 0.08 f	24	6.91 ± 0.26 g
28.4	384	50.49 ± 8.23	193	6.95 ± 0.39 e	-	-
31	287	7.28 ± 1.88	21	8.78 ± 0.19 d	-	-
32	203	0.00 ± -	-	-	-	-

^aTotal number of 1st instar nymphs used at each temperature.

^bNumber of adults

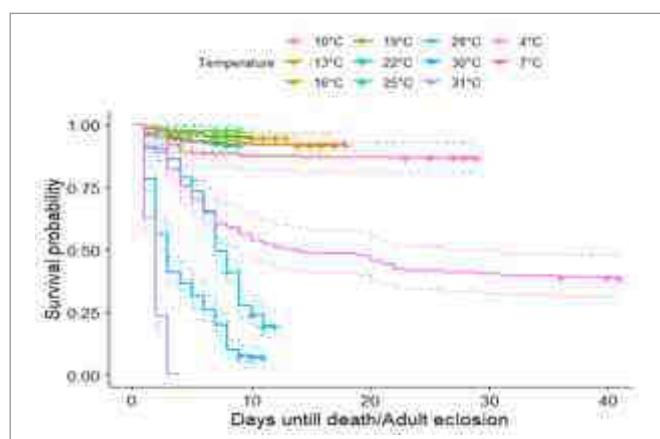


Fig. 8: Survivorship of *Myzus persicae* immatures at constant temperatures

Survey for leaf miner, *Liriomyza* spp. in potato fields in Nilgiri Hills (Priyank HM)

In summer and autumn season of 2020, the potato cultivation in Nilgiris Hills was severely affected by a new pest problem i.e. leaf miner. To know its spread and damage on potato crop, a random survey was conducted in twelve villages during autumn season. The leaf miner was observed infesting the potato fields in all the surveyed areas with 92-100% incidence (flies/maggots/mines) and the intensity of leaf damage up to 100%. The nature of damage caused by this pest on potato is shown in Fig. 9. In survey it was also observed that, other than potato the pest can also infest other important crops (beetroot,

beans, double beans, broccoli, cabbage, carrot, lupin, etc.) and several weed species of this area. Additionally, the pest damage was observed in all popular potato cultivars of this area viz., Kufri Jyoti, Kufri Girdhari, and Kufri Himalini.



(a) Adult leaf miner on foliage



(b) Infected plant and leaf mining

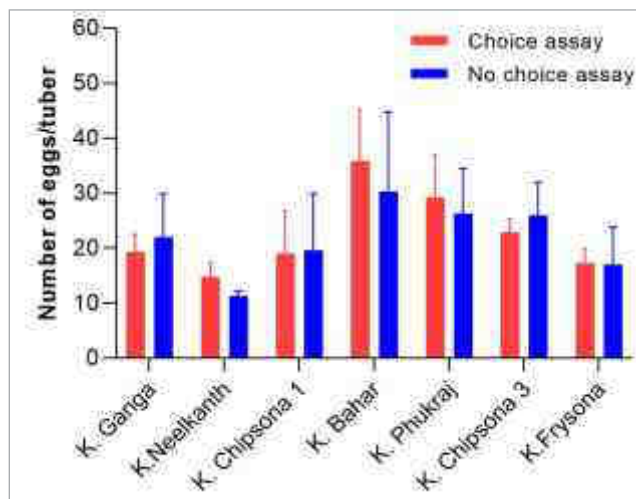


(c) Field infestation

Fig. 9: Leaf miner attack in potato crop at Nilgiris

Assessment of susceptibility of tubers of different potato varieties to potato tuber moth infestation (PTM) (Subhash S, Priyank HM, Anuj Bhatnagar)

Laboratory evaluation of the susceptibility of tubers of seven potato varieties namely Kufri Ganga, Kufri Neelkanth, Kufri Chipsona 1, Kufri Bahar, Kufri Pukhraj, Kufri Chipsona 3 and Kufri Frysona to infestation by PTM was carried out through the study of its ovipositional preferences using choice and no-choice tests. The choice test between seven potato varieties indicated that the mean number of eggs laid varied among seven potato varieties. The highest mean number of eggs laid on Kufri Bahar (35.87 ± 9.40) (Mean $\pm$ S.E.) followed by Kufri Pukhraj (29.27 ± 7.68), Kufri Chipsona 3 (22.93 ± 2.43), Kufri Ganga (19.33 ± 3.24), Kufri Chipsona 1 (19.07 ± 7.83) and Kufri Frysona (17.33 ± 2.60). Kufri Neelkanth (14.80 ± 2.62) showed the lowest mean number of deposited eggs. Similarly, the non-choice test showed that all tested varieties were infested by PTM; but the lowest number of eggs was deposited on variety Kufri Neelkanth (Fig.10).


Fig. 10: Oviposition preference of potato tuber moth, *Phthorimaea operculella* against different potato varieties

Bio-control potential of *Steinernema cholashanense* (Nguyen) on larval and pupal stages of potato tuber moth, *Phthorimaea operculella* (Zeller) (Priyank HM)

Larval susceptibility

To study the nematode infectivity against *P. operculella* larvae different concentrations of IJ (5, 10, 20, 40, 80 and 100 larva) were used. The results showed that *S. cholashanense* is capable of infecting larval stages of *P. operculella* under laboratory conditions. Larval mortality of *P. operculella* differed significantly among treatments after two days ($F = 18.87$, $df = 6, 77$, $P < 0.0001$) and four ($F = 23.39$, $df = 6, 77$, $P < 0.0001$) days after treatment. The bioassay results revealed that, percentage mortality was increased significantly with increase in IJs concentrations ($F = 40.74$, $df = 6, 154$, $P < 0.0001$) and time ($F = 18.87$, $df = 1, 154$, $P < 0.0001$). The probit analysis indicated that the LC_{50} values at two and four days after treatment for *P. operculella* were 20 and 10 IJs larva⁻¹, respectively (Table 2).

Table 2: Mean number of nematodes required to cause 50% (LC50) and 90% (LC90) mortality in fourth-instars larvae of potato tuber moth, *Phthorimaea operculella* at 2 and 4 days after treatment (DAT) (n = 12) in the laboratory conditions

Treatment (DAT)	LC ₅₀ ^A	95% FL	LC ₉₀ ^A	95% FL	Slope $\pm$ SE	Pearson's χ^2	P ^B
2	20 ^b	14–27	58 ^a	39–119	2.72 $\pm$ 0.53	1.6	0.17
4	10 ^a	7–13	25 ^a	17–54	3.19 $\pm$ 0.84	0.33	0.86

SE: standard error; FL: fiducial limits.

^ALC values between DAT considered significantly different, if the 95% FL do not overlap.

^BP value for the χ^2 value. A non-significant χ^2 indicates a good fit of the line to the data.

Pupalsusceptibility

When IJs were inoculated to the pupae of *P. operculella* the higher concentrations (400 and 600 IJs pupa⁻¹) showed 30% mortality followed by 20% for lower doses (80, 100 and 200 IJs pupa⁻¹) but pupal mortality did not differ significantly ($P = 0.6113$) between the IJs concentrations (Fig. 11).

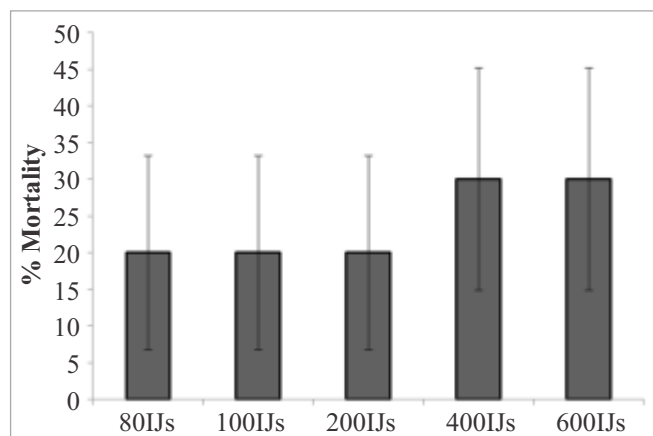


Fig. 11: Per cent pupal mortality (mean ± SE) of potato tuber moth, *Phthorimaea operculella* at different concentrations of entomopathogenic nematode, *Steinernema cholashanense* at 10 days after treatment in the laboratory conditions (n = 10)

Reproduction potential of *S. cholashanense* in *P. operculella*

The results of the reproduction assay revealed that *S. cholashanense* was able to penetrate and reproduce within the haemocoel of fourth-instar larvae of *P. operculella*. This is the first scientific study on the reproductive potential of *S. cholashanense* on *P. operculella*. When 100 IJs larva⁻¹ were inoculated to fourth-instar larvae of *P. operculella*, 8.25% IJs penetration was recorded with the final IJs yield of 701.52 IJs mg⁻¹ larval weight (Fig. 12).

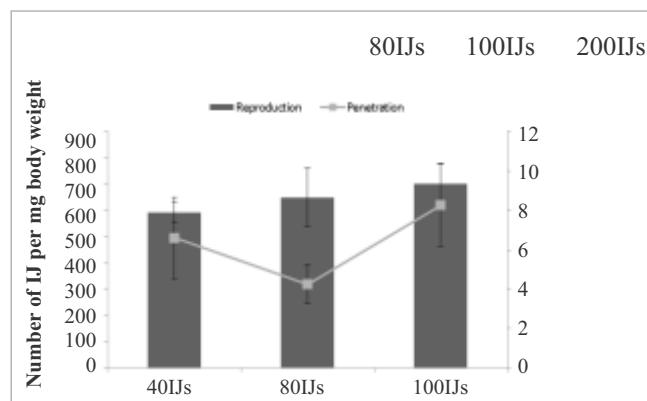


Fig. 12: Percent penetration (mean ± SE) and multiplication per milligram body weight of host (mean number of IJ ± SE) of entomopathogenic nematode, *Steinernema cholashanense* into the fourth-instar larvae of potato tuber moth, *Phthorimaea operculella* (n = 10)

Conventional and Novel Strategies for the Management of Insect Pests of Potato

Management of sucking pests of potato through bio pesticides (Anuj Bhatnagar, Mohd. Abas Shah, Subhash Katore, Kailash C. Naga, Subhash S)

In all the 3 sprays, significant reduction in the aphid population was observed in plots treated with Spinosad @ 0.75 ml/l which was also on par with standard check Imidachloprid @ 0.5 ml/l (Fig. 13) one day after spraying. Leaf hoppers population was lowest in the plots treated with Abamectin benzoate @ 0.75 ml/l and found to be on par with standard check among all the three sprays (Fig. 14) whereas the population of whiteflies was significantly reduced in Spinosad @ 1 ml/l treated plots and also on par with standard check (Fig. 15). Treatment details: T1-Spinosad @ 0.5 ml/l; T2-Spinosad @ 0.75 ml/l; T3-Spinosad @ 1.0ml/l, T4-Abamectin benzoate @ 0.5 ml/l; T5-Abamectin benzoate @ 0.75 ml/l; T6-Imidacloprid @ 0.5 ml/l; T7-Control

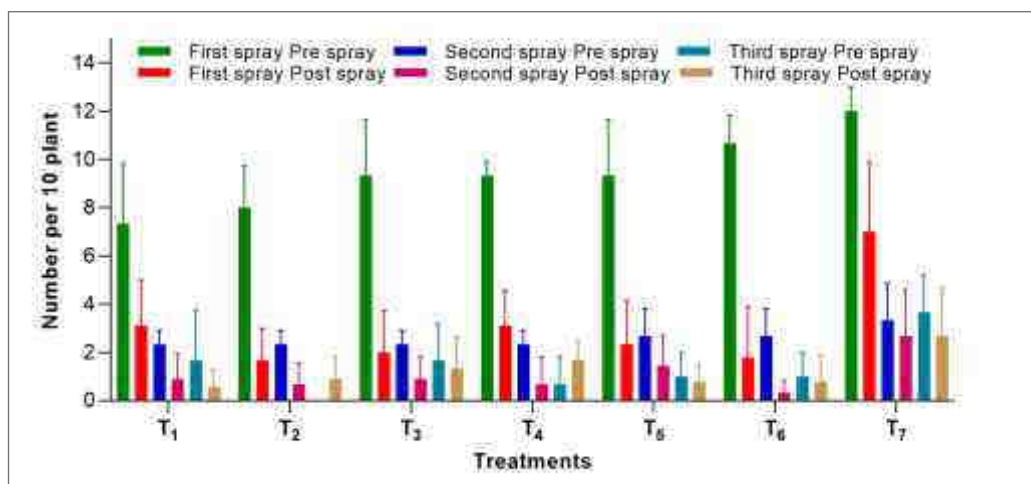


Fig. 13: Efficacy of bio pesticides against aphid, *Myzus persicae* (Post spray observation is a mean of 1, 2 and 3 DAS for each spray)

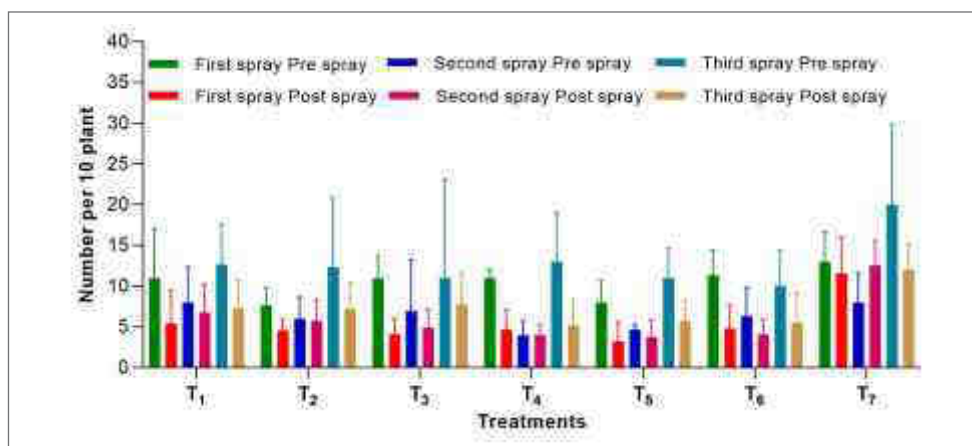


Fig. 14: Efficacy of bio pesticides against Leaf hopper, *Amrasca biguttula biguttula* (Post spray observation is a mean of 1, 2 and 3 DAS for each spray)

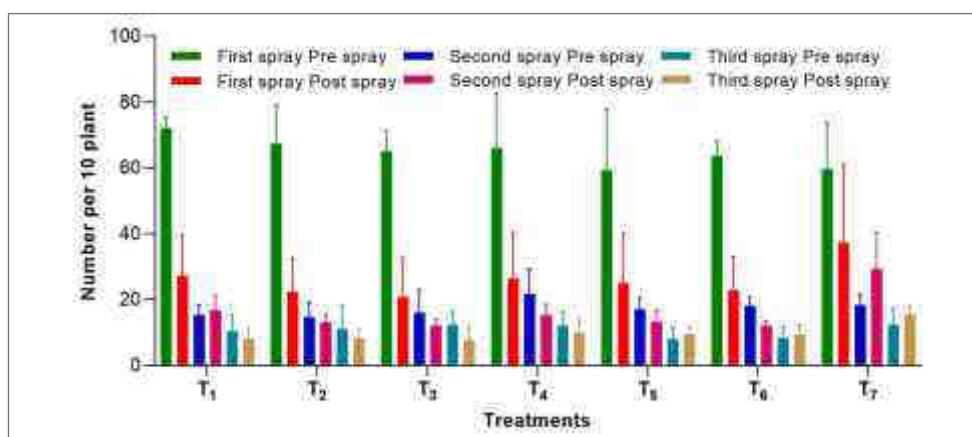


Fig. 15: Efficacy of bio pesticides against whiteflies, *Bemisia tabaci* (Post spray observation is a mean of 1, 2 and 3 DAS for each spray)

Evaluation of rice straw mulch for the management of vector-virus complex in potato (Mohd Abas Shah, Sanjeev Sharma & Raj Kumar)

The effect of rice straw mulch, chopped (3 – 4 inch) and un-chopped (14 – 20 inch) @ 5 and 10 ton per ha was evaluated on the orientation behaviour and landing rate of whitefly and aphids in potato crops; in

comparison to silver reflective mulch, black plastic mulch and untreated control. The landing rate of whiteflies was considerably reduced in the plots covered with straw or plastic mulch (Fig. 16). However, the effect of mulches was not significant after canopy closure.

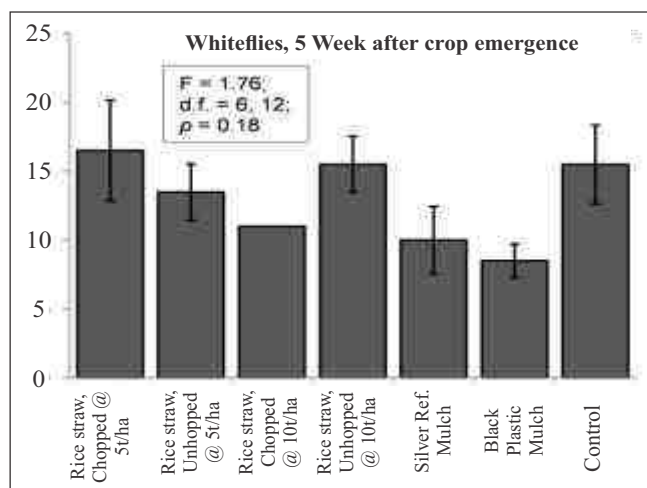
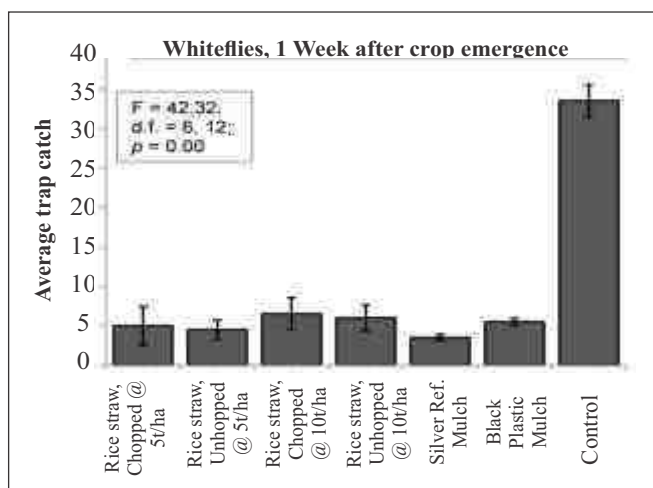
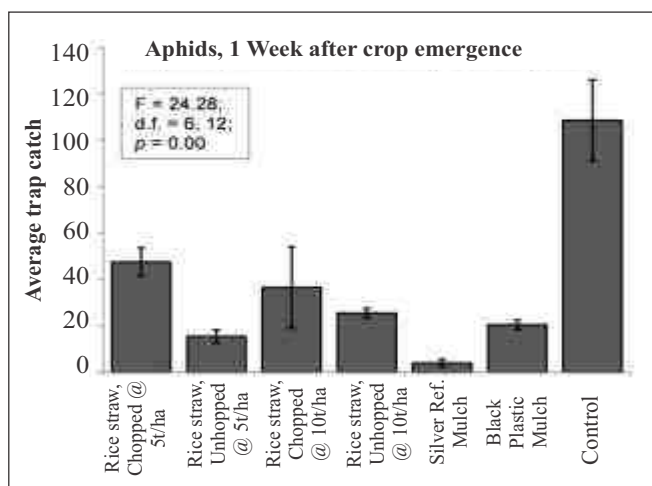


Fig. 16: Effect of mulches on landing rate of whitefly, *Bemisia tabaci*

Against the aphids, the effect of plastic mulches was most significant followed by that of raw straw mulch. After canopy closure, no significant variation was found between the mulched plots and control plots



(Fig. 17). The straw mulches can be used to protect the potato crops from aphid and whitefly vectored viruses during the early phase of crop growth i.e., crop emergence to canopy closure.

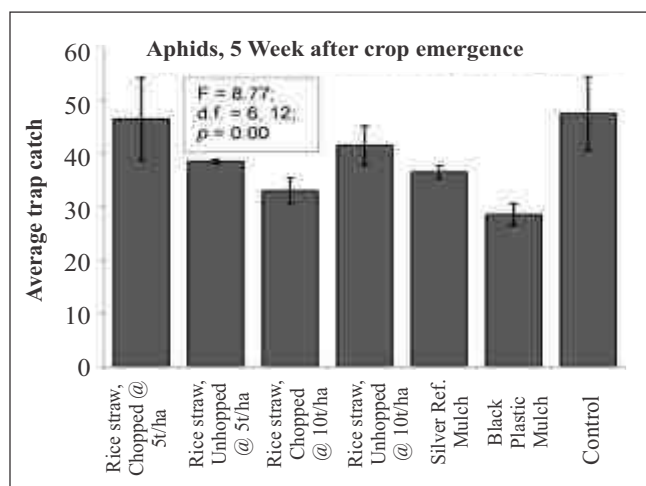


Fig. 17: Effect of mulches on landing rate of aphids in potato

Screening potato somatic hybrids against whitefly, *Bemisia tabaci* (Kailash Chandra Naga, Jagesh Tiwari, Subhash S, Anuj Bhatnagar)

Choice assay was performed to screen somatic hybrids against whitefly, *Bemisia tabaci*. Approximately 5000 whitefly adults (5-6 days old) were released on somatic hybrids arranged randomly in insect proof cages. The *B. tabaci* adults were allowed to lay eggs for five days removed from plants; the plants were thoroughly examined for whitefly adults and transferred in new cages. The three compound leaves sampled at top, middle and bottom

and examined for number of eggs under stereo zoom microscope at five days after whitefly adult inoculation. Similarly second and third observations were made on 27 days after inoculation to observe pupae. The number of eggs and pupae recorded were divided with the area used for the observation to calculate the mean number/cm². The somatic hybrid LES -29 showed least preference for whitefly egg laying followed by Card-6, CPH, IOP-59, P-12, PLD-47, P-1, whereas, Kufri Himalini recorded the highest egg laying (Fig. 18). Similar patterns were recorded in the number of pupae on somatic hybrids.

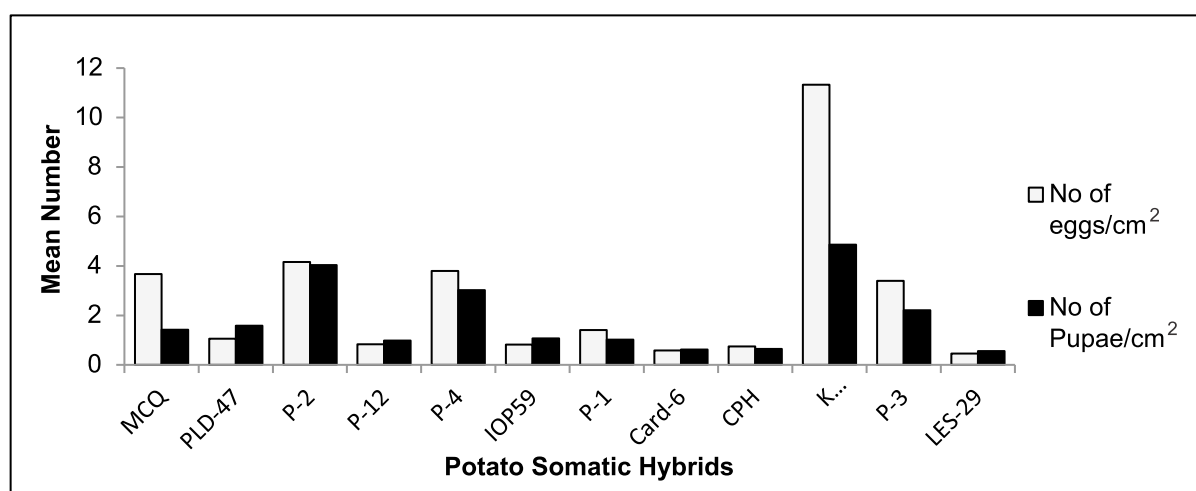


Fig. 18: Screening potato somatic hybrids against whitefly

Estimation of genome size of *Macrosiphum euphorbiae* using flow cytometry (Kailash Chandra Naga, Hemant B Kardile, Rahul K Tiwari & Subhash S)

Potato aphid, *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae) is a colonizing species and vector for many economically important potato viruses. There is dearth of genomic information about this economically important aphid species. Hence, to get insight into the genomic architecture, genome size was determined using flow cytometry. First the aphid species was identified by sequencing the mtCOI region using universal primer for arthropods LCO1490/HCO2198 (Forward: 5' -GGTCAACAAATCATAAAGATATTG-3' ; Reverse: 5' -TAAACTTCAGGGTGACCAAAAATCA-3'). Further, the aphid samples about 10 adults *M. euphorbiae* were taken in 15 ml falcon and immersed in 1 ml of (modified hypopropidium iodide) HPI buffer. Tissues were homogenized in 1

ml of modified HPI buffer using the surgical blade. The homogenate was filtered through the 40-micron filters and incubated on ice under dark conditions with occasional shaking. The samples were analyzed on flow cytometer (BD FACS Canto II) by external standard method using chicken erythrocyte nuclei (CEN) (BD Biosciences, Cat No. 349523) as the external reference standard (Fig. 19). The genome size was estimated using the formula: $2C = 2.5 \times \text{Mean position of sample nuclei peak} / 2C \text{ Mean position of CEN nuclei peak}$. The estimated size of *M. euphorbiae* was 0.53 pg or 519.4 Mbp. The genome size of *M. euphorbiae* is approximately 2.9, 2.2 and 1.9 times larger than that of *Drosophila melanogaster*, honey bee (*Apis mellifera*) and mosquito *Anopheles gambiae* respectively. The generated genome size information will provide the foundation for futuristic genomic research on potato aphid, *Macrosiphum euphorbiae*.

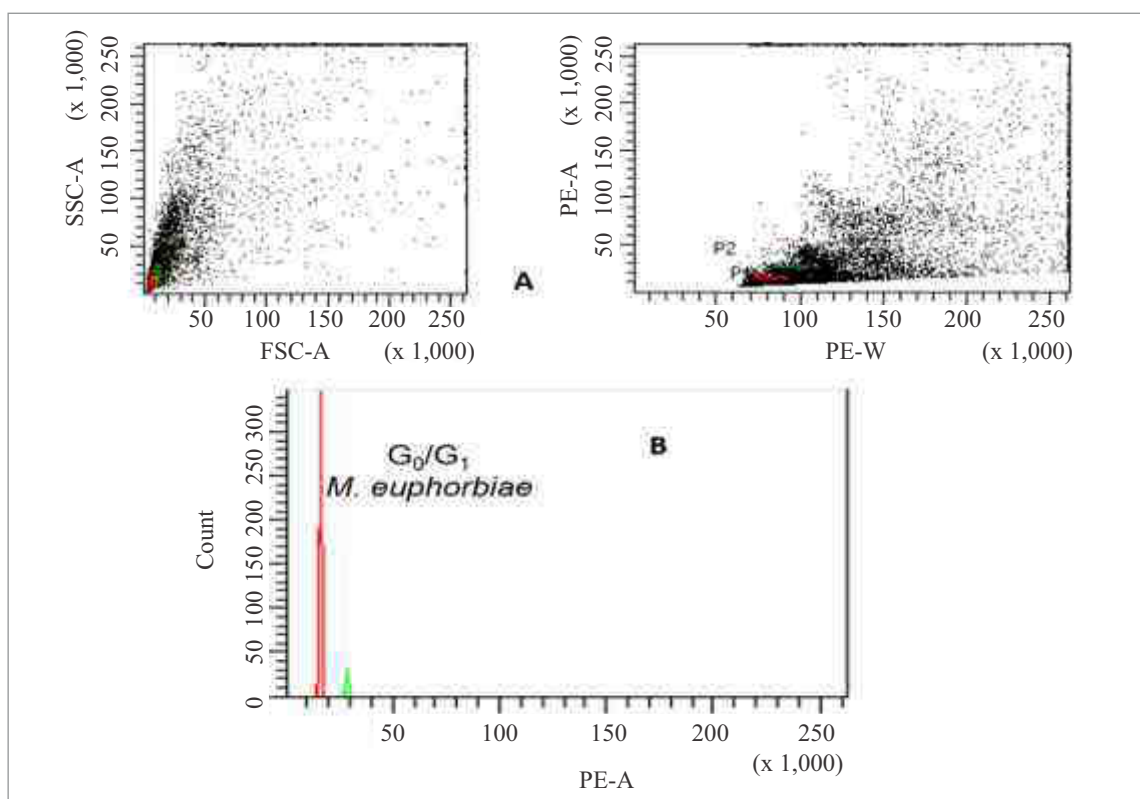


Fig. 19: The dot plot and bar graph of flow analysis; B, PI-fluorescence histogram of G0/G1 and G2/M cells of *M. euphorbiae*

Project: Biology, Ecology and Management of Nematode Pests of Potato

Novel dsRNA based nematicide formulation for the management of potato cyst nematodes (*Globodera spp.*) (Aarti Bairwa, Sundaresh S, Sanjeev Sharma, Priyank HM & EP Venkatasalam)

Based on the *in vitro* and *in vivo* results of the RNAi approach, dsRNA based nematicide formulations were developed for selected pathogenicity genes responsible for locomotory (*flp32c*) and sensory function (*ams1*) (Fig. 20a & 20b). Drenching with dsRNA resulted in increased infestation in case of *flp32c* (71.0%) and reduced infestation in *ams1*

(45.5%) as compared to untreated control (68.0%) (Fig.21). In addition, there was no further development of J₂s and resulted premature death in *flp32c* due to increased locomotion which depleted the food reserves (Fig. 22a & 22b). The reduced infestation in case of *ams1* dsRNA treated pot is due to silencing of sensory organs gene which is responsible for finding out the host.



Fig. 20a: Drenching of dsRNA formulation



Fig. 20b: Effect of dsRNA formulation on plant growth 40DAP

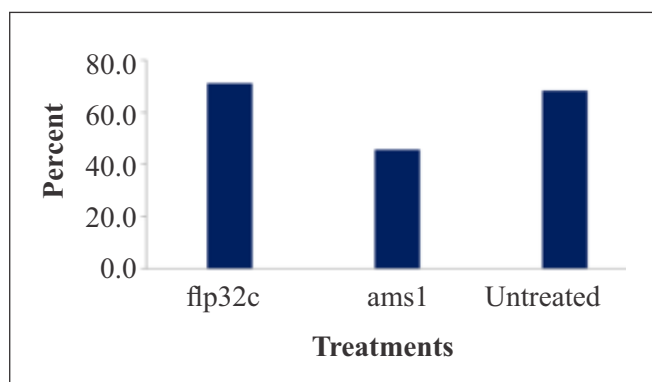


Fig. 21: Effect of dsRNA formulation on nematode infestation

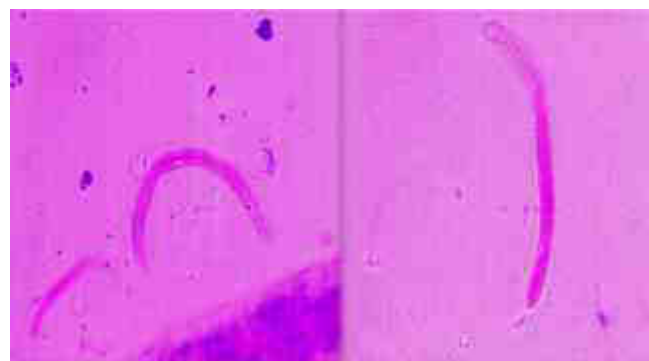


Fig. 22a: Pre-mature death of *flp32c* treated juveniles (J₂s)

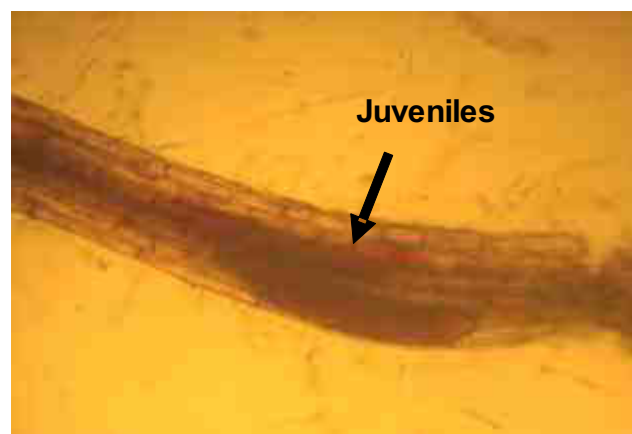


Fig. 22b: Development of Juveniles inside the root (15 DAI) in untreated control

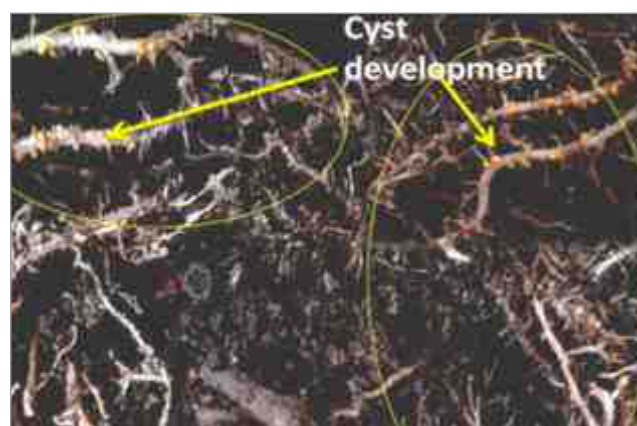
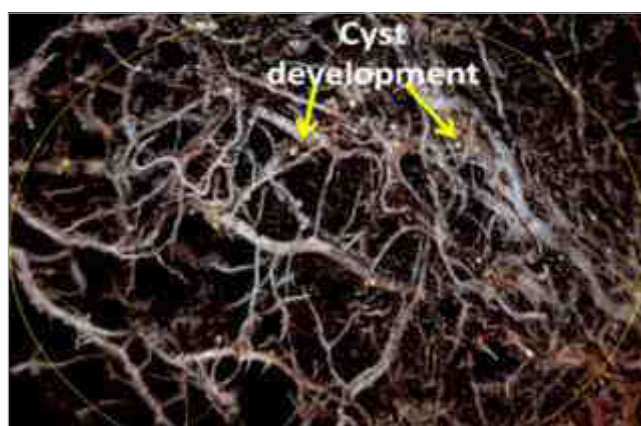
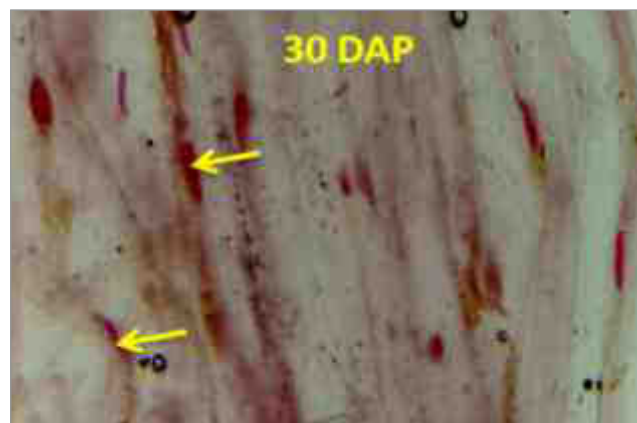
Genetic diversity of *Globodera pallida* in Ooty and Shimla (Aarti Bairwa, Priyank HM, Sundaresha S, Sanjeev Sharma & Ashwani K Sharma)

The *Globodera pallida* populations of Ooty (GpO) and Shimla hills (GpS) were compared at molecular level. The sequence of GpO (MW084957) was compared with sequences in GenBank using BLAST and it showed 99.00% similarity with *G. pallida* population from Italy, Europe (KJ409622); Slovakia, Central Europe (KJ409613); Czech Republic, Central Europe (JQ692592); Ukraine, Eastern Europe (AJ606687). Whereas, GpS (MW084958) had 99.00% identity with Algeria (LT159835); Gourdie, Scotland (HQ670248); United Kingdom (DQ847111) and Portugal (MN475966). Based on these results, it is concluded that Ooty and Shimla population of *G. pallida* are different and they would have been introduced from different regions as GpO population is close to European populations while GpS is close to Algeria, Scotland, United Kingdom and Portugal populations.

Efficacy of Nimitiz (Fluensulfone 2% GR) on PCN under pot condition (Aarti Bairwa)

The efficacy of new nematicide, Nimitiz (Fluensulfone 2% GR) (@ 0.5gm/plant) was checked on PCN population under pot condition along with

untreated control. There was a significant reduction in PCN infestation from 51.25-62.85% in Fluensulfone 2% GR treated pots as compared to untreated control (Fig. 23).



Treated

Control

Fig. 23: Effect of Fluensulfone on nematode development

Bio-management of Potato cyst nematode (Priyanka M, EP Venkatasalam)

Paecilomyces lilacinus @20 kg/ha (T1) was found more effective in reducing the PCN populations (Rf-1.4) followed by carbofuran 3G @65 kg/ha (T4) (1.6). Whereas, in terms of tuber yield carbofuran 3G @65 kg/ha (T4) recorded the highest potato yield (16.1 t/ha) followed by *Paecilomyces lilacinus* @ 20 kg/ha (T1) (14.9 t/ha). The lowest yield (11.7 t/ha) and highest Rf (2.6) was recorded with untreated control (Fig. 24).

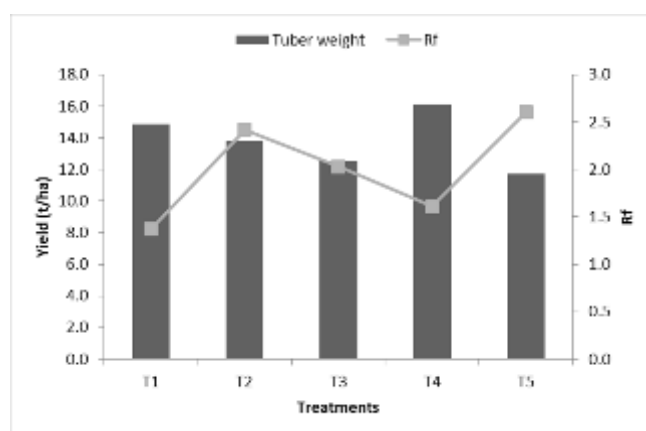


Fig. 24: Evaluation of different biological control agents against PCN

Morphological and morphometric characterization of native strain of *Steinernema cholashanense*, CPRSUS01 (Priyank M, EP Venkatasalam & Aarti Bairwa)

The native strain of EPN was characterized morphologically as well as morphometrically. The morphological characters of first generation males and females of *S. cholashanense* CPRSUS01 are shown in Fig. 25 whereas, the morphometrics of the infective juvenile, first-generation males and females are presented in Tables 3. In general, the body length in all the nematode growth stages (infective juveniles, males, and females) of the Indian isolate was found smaller than the original description of *S. cholashanense* from China. Morphometrically, the body size of IJ of *S. cholashanense* CPRSUS01 was comparatively shorter than the original description 776 vs 843 μm . In first-generation females, the body size of the Indian isolate [2556 μm] was greatly varied

and observed almost half of the Chinese isolate [4692 μm] (Table 3).

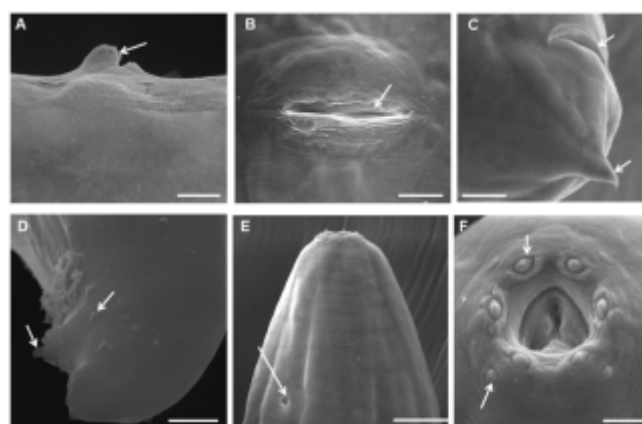


Fig. 25: SEM Photographs of *S. cholashanense* first-generation males and females. (A) Vulval region of female showing vulval lips (B) Vulval slit (C) Female tail with anal opening and tail tip (D) Posterior region of a male showing spicule and genital papillae. (E) Anterior region of the female showing the position of excretory pore (F) Female face view showing six labial papillae and four cephalic papillae.

Table 3. Morphometrics (mean $\pm$ SD) of *S. cholashanense* CPRSUS01 infective juveniles, first generation male and female. All measurements are in micrometre (μm) except ratio and percentage (*n = number of specimens used for morphometric study)

Characters	First generation males (n=15)	First generation females (n=20)	Juveniles (n=20)
Body length (L)	1117.33 $\pm$ 115.89	2557.50 $\pm$ 421.54	775.79 $\pm$ 63.75
A	9.89 $\pm$ 1.53	12.73 $\pm$ 1.51	30.13 $\pm$ 2.07
b	8.00 $\pm$ 1.33	14.79 $\pm$ 2.17	6.17 $\pm$ 0.37
C	36.69 $\pm$ 5.65	80.85 $\pm$ 15.13	10.02 $\pm$ 0.72
c'	0.76 $\pm$ 0.09	0.59 $\pm$ 0.11	5.12 $\pm$ 0.35
Maximum body diameter	116.12 $\pm$ 24.52	203.35 $\pm$ 39.19	25.76 $\pm$ 1.34
Excretory pore	62.76 $\pm$ 6.64	76.65 $\pm$ 7.23	52.01 $\pm$ 3.39
Width at Excretory pore	40.29 $\pm$ 3.11	78.35 $\pm$ 7.75	17.12 $\pm$ 0.93
Nerve ring	105.45 $\pm$ 8.93	131.85 $\pm$ 5.58	86.89 $\pm$ 6.75
Stoma length	4.97 $\pm$ 0.97	6.58 $\pm$ 1.08	--
Stoma width	5.40 $\pm$ 0.70	10.30 $\pm$ 1.13	--
Pharynx length	141.33 $\pm$ 12.64	172.60 $\pm$ 8.28	125.79 $\pm$ 9.04
Basal Bulb (L)	34.13 $\pm$ 2.86	42.31 $\pm$ 3.55	19.48 $\pm$ 1.69
Basal Bulb (W)	29.59 $\pm$ 2.14	39.54 $\pm$ 2.12	10.51 $\pm$ 0.83
Width at BB	63.16 $\pm$ 7.48	121.44 $\pm$ 9.61	22.59 $\pm$ 0.81
Cardia	8.16 $\pm$ 2.25	12.06 $\pm$ 1.70	6.71 $\pm$ 1.96
Tail length	30.85 $\pm$ 3.85	32.33 $\pm$ 5.56	77.46 $\pm$ 3.83
Anal body width	40.62 $\pm$ 3.64	54.65 $\pm$ 7.30	15.18 $\pm$ 1.04
Rectum	7.63 $\pm$ 1.91	14.55 $\pm$ 1.70	10.75 $\pm$ 1.42
D%	38.65 $\pm$ 2.97	44.44 $\pm$ 4.05	41.44 $\pm$ 2.45
E%	201.43 $\pm$ 20.87	242.87 $\pm$ 41.34	67.25 $\pm$ 4.79
Spicule length (Curve)	59.6 $\pm$ 2.44	--	--
Gubernaculum length	40.55 $\pm$ 3.25	--	--
Testes	920.99 $\pm$ 88.07	--	--
Mucron length	3.53 $\pm$ 1.27	--	--
Vulval width	--	189.65 $\pm$ 37.02	--
anterior end to vulva	--	1367.25 $\pm$ 227.22	--
V%	--	53.72 $\pm$ 5.62	--
Hyaline tail length (HT)	--	--	35.14 $\pm$ 3.93
Hyaline tail width (HW)	--	--	5.49 $\pm$ 0.55
H'=HT/HW	--	--	6.42 $\pm$ 0.64

PROGRAMME: RE-DEFINING EPIDEMIOLOGICAL PARAMETERS AND MANAGEMENT APPROACHES FOR POTATO PATHOGENS

Project: Emerging Pathogens of Potato and their Management

Disease Monitoring and Pathogens Profile (Sanjeev Sharma, Mehi Lal, Rahul Kumar Tiwari & Vinay Sagar)

Though late blight appeared in western and central UP during December 2019 but its spread was fast only in the month of January and February, 2020 due to untimely rain. Due to high disease pressure fungicides could not manage the disease effectively and 10-15% yield losses were expected. In Himachal Pradesh, appearance of late blight was delayed by 6 days as compared to last year. This year blight appeared on 17th July, 2020 on cv. Kufri Jyoti in Shimla hills and its overall severity ranged from 25-90% in Himachal Pradesh depending upon the cultivar raised and plant protection measures adopted.

Potato is severely affected by *Fusarium* in the form of wilt in fields and tuber rots in cold stores. A survey was conducted in the year 2019-20, in cold stores of

Punjab and western Uttar Pradesh to decipher the occurrence of dry rot causing *Fusarium* species in potato. Total 21 cold stores were surveyed and samples of rots were collected based on phenotypic appearances. The dry rot incidence ranged between 5-15% and 3-16% in cold stores of Punjab and western Uttar Pradesh, respectively.

Comparative Genomics of Potato Pathogens

Characterization of *Phytophthora infestans* (Sanjeev Sharma, Sundaresha S & CM Bist)

Understanding of pathogen variability is essential to devise suitable management strategies. Since last five years, population of *P. infestans* is being monitored for sensitivity to cymoxanil, dimethomorph and fenamidone fungicides and this year also all the tested isolates were observed to be sensitive to these new fungicides. Besides, the population was also monitored for sensitivity to oxathiapiprolin- a new chemistry oomycide and isolates were observed to be sensitive to this molecule too (Fig. 1).

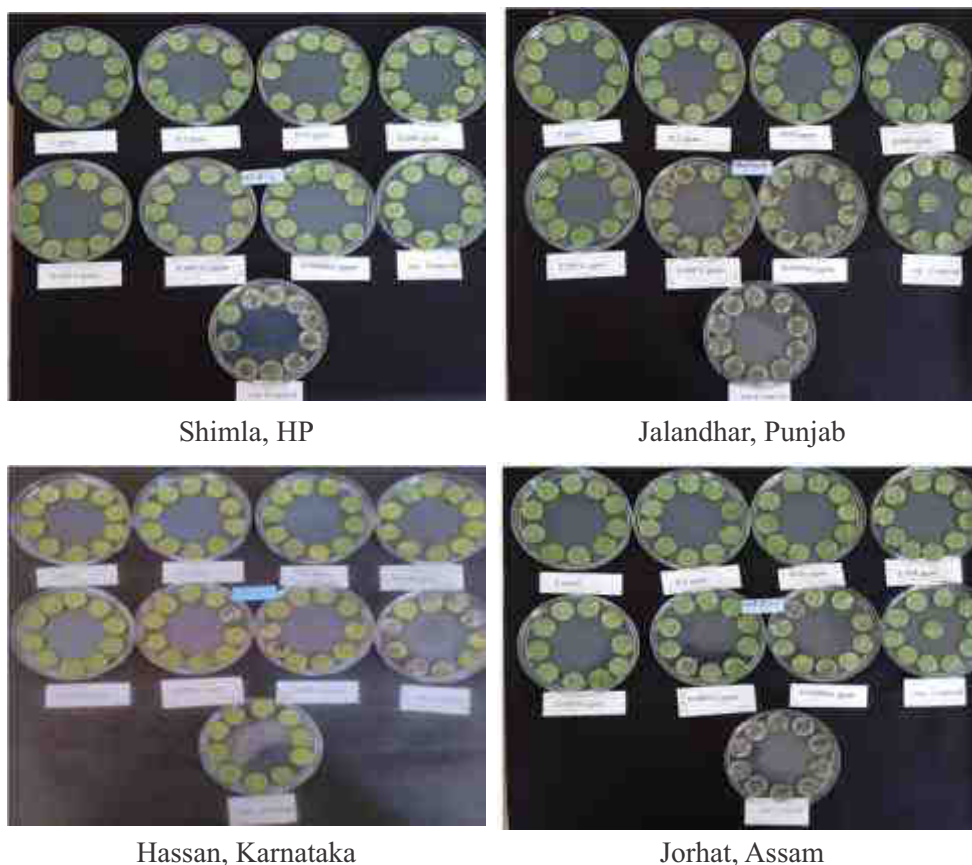


Fig. 1: Evaluation of oxathiapiprolin against *Phytophthora infestans*

Genotyping of *P. infestans* has relied on a diverse range of molecular methods. Simple Sequence Repeat (SSR) markers have proven valuable for tracing pathogen population change for a range of reasons. The SSR markers are more robust and the results are more comparable between laboratories

than other methods. Earlier we characterized our Indian population of *P. infestans* using SSR markers individually but this time 12-plex PCR assay was used to genotype few isolates of *P. infestans*. Results revealed that the isolates belong to 13_A2 clonal lineage (Fig. 2).

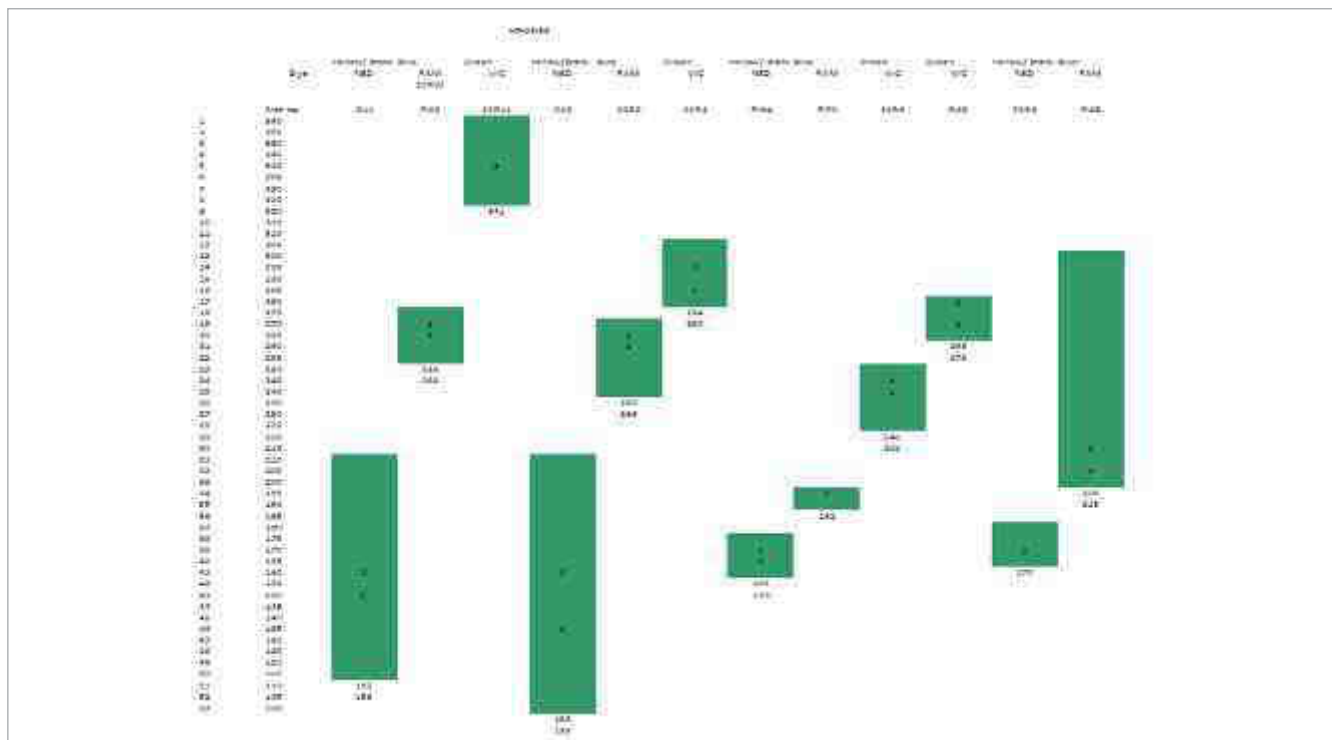


Fig. 2: Genotyping of *Phytophthora infestans* isolates using SSR markers reveals 13_A2 clonal lineage

Characterization of *Alternaria* species (Sanjeev Sharma & Vinay Sagar)

In recent years, early blight has become widespread and turned into one of most important diseases after late blight. Recent studies have shown that the *Alternaria* population on potato is much more elaborate than a two-species disease complex. Ten species of *Alternaria* have been implicated to cause foliar diseases of potato worldwide. Knowledge of which *Alternaria* species are associated with potato foliar diseases nationwide is essential in designing management schedules. Isolates collected from Himachal Pradesh, Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra and West Bengal were purified and studied for morphological parameters. Results revealed variations in colony colour and spore morphology (Fig. 3). Spore length ranged from 15.47 μm to 123.17 μm , spore width from 7.39 μm to 51.29 μm and beak length from 0 to 30.27 μm . The isolates are being further processed for identification of species associated with these leaf spots.

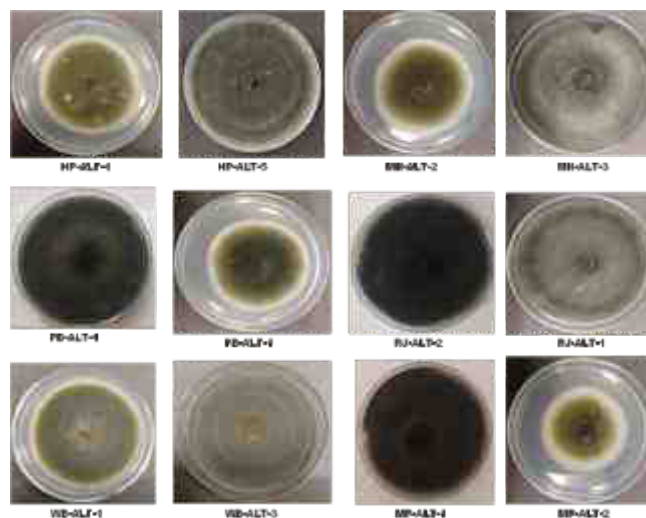


Fig. 3: Morphological variability in *Alternaria* isolates

Characterization of *Fusarium* species (Rahul Kumar Tiwari)

The dry rot isolates collected from Punjab and western Uttar Pradesh were purified and subjected to morphological characterization which includes colony morphology, spore length breadth ratio, conidial septa, presence or absence of microconidia

and macroconidia. The morphological identification revealed that species viz. *Fusarium oxysporum*, *Fusarium solani*, *Fusarium sambucinum* and *Fusarium verticilloides* are common in causing dry rots

in the surveyed region (Fig. 4). However, further molecular characterization is in process to support these findings.

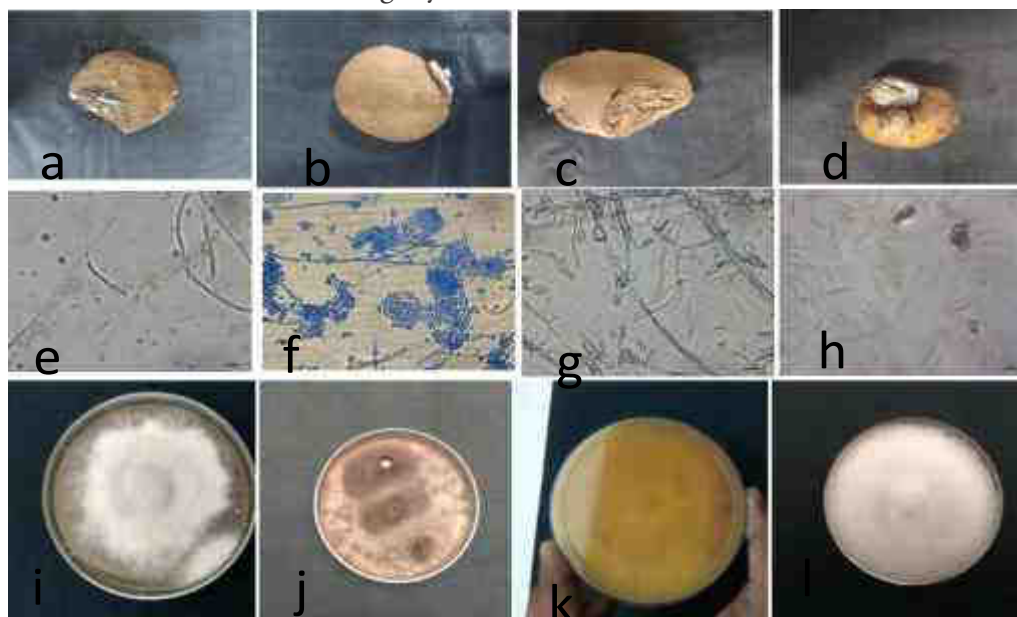


Fig. 4: Symptoms of dry rot (a-d); Spore morphology in microscope (e-h); Colony morphology (i-l)

Molecular Diagnostics and Detection of Potato Pathogens

Identification of Phytoplasma associated with symptomatic plants at different locations (Vinay Sagar, Sanjeev Sharma, Sundaresha S, Ravinder Kumar & Rahul K Tiwari)

A total of 23 samples of potato with inward rolling symptoms (14 from Jalandhar, 04 from Gwalior, 03 from Patna, 01 from Dholi and 01 from Kalyani) and 08 samples of potato tubers with hairy sprouts/ blind tubers (04 from Rohru and 04 from Kufri) were tested for Phytoplasma infection. Only one sample of blind tubers from Kufri found infected with *Candidatus* Phytoplasma fragariae

Epidemiology and Forecasting of Potato Pathogens

Forecasting of late blight and early blight (Sanjeev Sharma, Mehi Lal & Shashi Rawat)

Indo-Blightcast model was used to predict appearance of late blight across the agro-ecologies in India during *rabi* 2019 and *kharif* 2020 and it predicted late blight accurately at each location (Table 1). Accordingly the advisories were issued to respective regions to protect the crop from late blight onslaught.

Table 1: Performance of Indo-Blightcast model during *rabi* 2019 and *kharif* 2020

Location	Prediction date of late blight	Actual date of late blight appearance
Bankura (WB)	25.12.2019	02.01.2020
Burdwan (WB)	30.12.2019	01.01.2020
Hooghly (WB)	30.12.2019	08.01.2020
Shimla (HP)	13.07.2020	17.07.2020

Besides, the model developed for prediction of early blight was also validated. Last year the model was validated for Shimla hills and this year validation was extended to Pune and Uttarakhand. The model predicts early blight after accumulation of P-days

values above 300 units and flashes a message 'watch out for early blight symptoms'. After the prediction, fields were observed for the appearance of symptoms and results are presented in Table 2.

Table 2: Validation of early blight forecasting model

Location	Prediction date of early blight	Actual date of early blight appearance
Pantnagar (Uttarakhand)	16.11.2019	01.12.2019
Pune (Maharashtra)	05.12.2018	15.12.2018
Pune (Maharashtra)	11.12.2019	23.12.2019

The model predicted early blight accurately thereby indicating the efficacy and accuracy of the model. Thus, both these models could be successfully used for prediction of early and late blights.

Pathogenicity of dry rot pathogens (Rahul Kumar Tiwari, Sanjeev Sharma, Ravinder Kumar, Milan Kumar Lal, Mohd. Abas Shah & K.C. Naga)

After morphological identification, the pathogenicity of *Fusarium* species was also tested in order to differentiate the pathogenic species from saprophytic ones. Two cultivars namely Kufri Jyoti and Kufri Pukhraj were used for evaluation of pathogenicity of *Fusarium* isolates. The uniform size healthy tubers were surface sterilized and wounded with a cork borer up to 3 mm depth. The mycelial plug was taken out from the pure culture of respective species and inoculated on the tuber wounds. Healthy non inoculated tubers were kept as control. After one month and two months of incubation at 18°C and 85-90% RH the lesion index and volume of tuber rot was calculated using the formula and scale previously used by Trabelsi *et al.* (2015). *F. sambucinum* was found most aggressive in causing dry rot in tubers (Fig. 5).

Management of Potato Pathogens Chemical management (Dr Mehi Lal, Sanjeev Sharma & Subhash)

Since *P. infestans* adapts very quickly to the fungicides after its regular application; hence, it is essential to test



Fig. 5: Aggressiveness of *Fusarium* species in causing dry rot in potato

new fungicides on regular basis for their efficacy and subsequently for their inclusion in spray schedules for management of late blight. In first experiment ten treatments consisting of existing and new fungicides (Fluopicolide 62.5+ propamocarb hydrochlorid 625 SC @ 0.3%, Cyazofamid @ 0.04%, and Benalaxyl M 4%+ mancozeb 65% WP @ 0.3%) were evaluated for two consecutive years (2018-19 & 2019-20) against late blight of potato. Amongst the tested fungicides, dimethomorph @ 0.1 % (13.17% DS), Fluopicolide 62.5+ propamocarb hydrochlorid 625 SC @ 0.3% (14.17% DS) and Cyazofamid @ 0.04% (33.67%), showed less disease severity as against control (97.67%, Fig. 6).

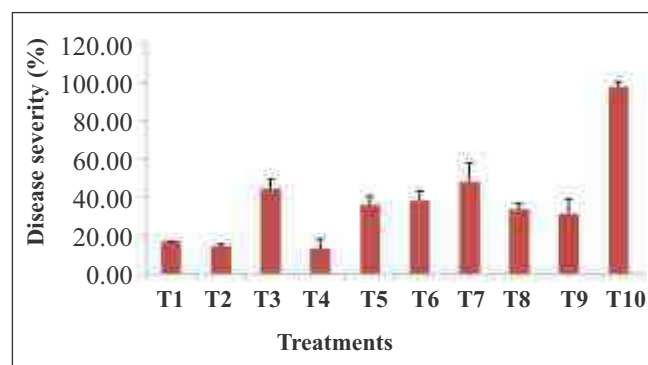


Fig. 6: Effect of new chemicals on management of late blight of potato

[T1: Fluopicolide 62.5+ propamocarb hydrochlorid 625 SC @ 0.25%, T2: Fluopicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3%, T3: Azoxystobin 11.5% + mancozeb 30% WP @ 0.25%, T4: Dimethomorph 50% WP @ 0.1%, T5: Cymoxanil 8% + mancozeb 64% WP @ 0.3%, T6: Fenamidon 10% + mancozeb 50% WG @ 0.3%, T7: Benalaxyl M 4% + mancozeb 65% WP @ 0.3%, T8: Cyazofamid @ 0.04%, T9: Cyazofamid @ 0.04% + mancozeb 75% WP, T10: Control]

Similarly, fungicides were tested for developing spray schedules applying one spray of contact fungicide and two sprays of systemic/translaminar fungicides for managing late blight of potato. Amongst tested schedules, treatment (T2) consisted of mancozeb 75% @ 0.2% (before the appearance of disease) - Azoxystobin 11.5% + Mancozeb 30% WP @ 0.25% (at onset of the disease) - Azoxystobin 11.5% + Mancozeb 30% WP @ 0.25% (after 7 days) of second spray recorded lowest disease severity (23.83% DS) followed by (T1) Mancozeb 75% @ 0.2% (before the

appearance of disease)- Fluopicolide 62.5+propamocarb hydrochlorid 625 SC @ 0.3% (at onset of the disease) – Fluopicolide 62.5+ propamocarb hydrochlorid 625 SC @ 0.3% (after 7 days) of second spray (24.17 % DS) followed by (T5) Mancozeb 75% @ 0.2% (before the appearance of diseases) –Dimethomorph 50% WP @ 0.1% + Mancozeb75% @ 0.2%(at onset of the disease) - Dimethomorph 50% WP @ 0.1% + Mancozeb75% @ 0.2% (after 7 days) of second spray with 28.50% DS as against of 100 % in control T7 (Fig. 7). In another experiment nine treatments were evaluated for developing spray schedule. The treatment consisted of Mancozeb 75% WP @ 0.2% (Before appearance of the disease) followed by Ametoctradin 27% + Dimethomorph 20.27% SC @ 0.2% (at onset of the disease) and one more spray of Cymoxanil 8+ mancozeb 64% WP @ 0.3% (after 7 days of second spray) recorded lowest diseases severity (29.67 % DS) followed by (T1) Mancozeb 75% WP @ 0.2% (before the appearance of the disease) followed by Fluopicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3% (at onset of the disease) and one more spray of Cymoxanil8+ mancozeb 64% WP @ 0.3% (after 7 days of second spray) with 32.00% DS as against of 97.67% in control (T9) (Fig. 8).

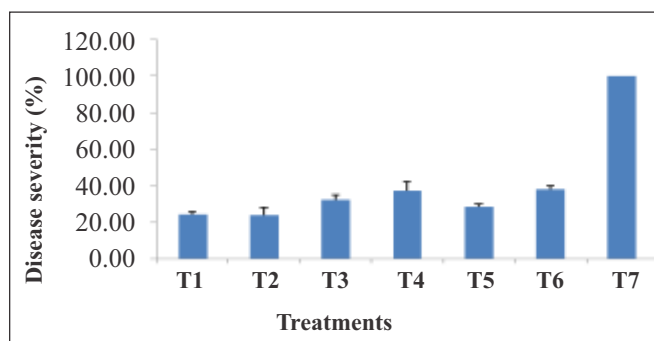


Fig. 7: Development of spray schedules (using one spray of contact fungicide and two sprays of same systemic/ translaminar fungicides) for management of late blight of potato

Economized water volume and concentration of fungicide (Dr Mehi Lal & Subhash)

In this experiment, mancozeb 75% WP was evaluated at three doses for three consecutive years (2017-18 to 19-20) for assessing effect of water volume and fungicide concentration on late blight management. The results revealed that mancozeb @ 0.5% (2.5 kg/ha in 500L water) had least disease severity (17.00%), followed by mancozeb @ 0.4% (2.0 kg/ha in 500L water, 20.50%) and mancozeb @ 0.3% (1.5 kg/ha in 500L water, 21.67%) as against of

96.67.00% in control (Fig. 9). These treatments were statistically at par with each other. However, differed significantly with 0.2% (2.0 kg/ha in 1000L water) and 0.25% (2.5 kg/ha in 1000L water). It can be concluded that concentration of fungicides have much more importance along with proper coverage of the foliage. In general, water volume of 500L/ha is sufficient with battery operated knapsack sprayer. However, if crop foliage is dense and late blight is moderate to severe, spray volume would be required more than 500L per ha along with optimum concentration of fungicides, for the effective management of late blight of potato.

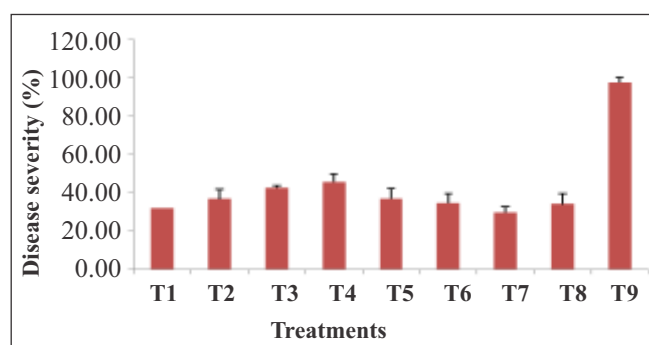


Fig. 8: Development of spray schedules (using one spray of contact fungicide and two sprays of different systemic/translaminar fungicides) for management of late blight of potato

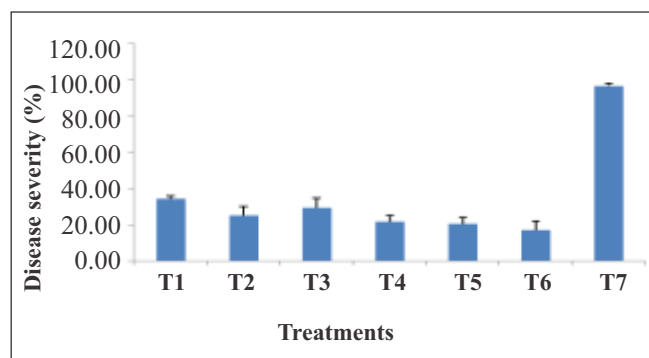


Fig. 9: Effect of water volume and concentration of fungicide on management of late blight of potato

[T1: Mancozeb 75% WP @ 0.2% (2.0Kg/1000L), T2: Mancozeb 75% WP @ 0.25% (2.5Kg/1000L), T3: Mancozeb 75% WP @ 0.2% (1.0Kg/500L), T4: Mancozeb 75% WP @ 0.3% (1.5Kg/500L), T5: Mancozeb 75% WP @ 0.4% (2.0Kg/500L), T6: Mancozeb 75% WP @ 0.5% (2.5Kg/500L), T7: Control]

Use of Huw San TR 25 as disinfectant for seed borne pathogens (Drs Mehi Lal, Sanjeev Sharma & Vinay Sagar)

Eight treatments consisted with disinfectant and boric acid along with two controls were evaluated for three years (2018-19, 2019-20 and 2020-21) as tuber treatment before storage against tuber borne pathogens. No significant differences were observed for dry rot incidence (3.5-4.0%) in boric acid and

disinfectant treated (3.0-4.0%) tubers as against of control (5.0%). Similar trend was observed for soft rot as 1.5 % incidence was recorded in both boric acid and disinfectant treated tubers against 3.0 % in control. It was also observed that incidence of the dry rot (3.0%) and soft rot (1.5%) was less in spray treatment than the dip treatment of disinfectant. Moreover, germination was not affected by disinfectant. However, under field condition efficacy of dip treatment of disinfectant was more against black scurf than spray treatment. Current year experiment is under progress.

Evaluation of chlorine dioxide for the management of soil and tuber borne diseases of potato (Mohd Abas Shah, Vinay Sagar & Sanjeev Sharma)

Last year, tuber spray treatment with chlorine dioxide (0.03%) was evaluated for the management of soil and tuber borne diseases. This year, the chemical was evaluated as soil application (as in-furrow treatment and as soil drench at earthing up) was evaluated separately against the common scab disease of potato. The chlorine dioxide solution was applied at the rate of 0.01, 0.02 and 0.03% alongside boric acid @ 3% and untreated control. The tuber treatments did not affect the germination percentage and tuber yield. With in-furrow application at planting, the intensity of common scab reduced to 12.19% with chlorine dioxide @ 0.03% in comparison to 16.99% with boric acid @ 3%, and 19.46% in un-treated control. In case of drenching treatments at earthing up, the intensity of common scab reduced to 14.86% with chlorine dioxide @ 0.03% in comparison to 17.64 with boric acid @ 3%, and 19.46% in untreated control. Therefore, the effect of chlorine dioxide treatments did not vary with the method or time of application.

Screening of potato varieties for resistance to *Ralstonia solanacearum* under controlled conditions (Vinay Sagar, Sanjeev Sharma & Vinay Bhardwaj)

The 08 out of 21 clones of “Phulwani Local” which showed resistance to *R. solanacearum* in initial screening test in 2019 were again screened this year in a pot experiment and found susceptible as all wilted completely within 21 days after inoculation with the test pathogen. Besides, 113 varieties/ reference

collections of potato (using Kufri Jyoti as susceptible check) received from Crop Improvement Division were tested for resistance to *R. solanacearum* through *in-vitro* bioassay method – a simple, quick and efficient method standardized at ICAR-CPRI, Shimla (Fig. 10). Among these, only three cultures namely “Badami”, “Champaran Lal” and “Assomia Alu” showed some degree of resistance and survived up to 14, 10 and 10 days, respectively, while all others wilted within 06 to 08 day after inoculation at $28 \pm 1^\circ\text{C}$.



Fig. 10: *In-vitro* evaluation of potato germplasm for resistance to *Ralstonia solanacearum*

Biotechnological Approaches

Spraying of dsRNA nano clay formulation targeting *Phytophthora infestans* under containment facility (Sundaresha S & Sanjeev Sharma)

In previous studies we have demonstrated the efficacy of dsRNA molecules against *P. infestans* culture bioassay, detached leaf assay and topical application methods. This year the application was extended to field assay under containment facility. Use of nano clay was assumed to be involved in the effective delivery, protection and boosting the action of RNAi in potato plants. A significant difference in the growth, sporulation count, disease severity and reduced expression of the genes and confocal microscopy imaging authenticates the effects of SIGS on late blight disease progression (Fig. 11). Our research demonstrated that topical dsRNA nano clay spray under the open-air environment could be an alternative to chemical fungicides and transgenic approaches as a novel plant protection strategy for late blight in an environment friendly manner.



Fig. 11: Confocal microscope images of potato leaf tissue after spraying of cy3 labelled dsRNA a) Leaf cross section showing uptake of dsRNA in the leaf tissue (Adaxial leaf surface) b) Cross section of leaf tissue showing cy3 fluorescence compared to c) Control leaf section showing minimal autofluorescence for only trichomes

PAP2- RNAi Kufri Jyoti lines revealed extreme resistance to *Ralstonia solanacearum* under *in vivo* conditions (Sundaresha S, Vinay Sagar & Sanjeev Sharma)

In earlier experiments, the function of *PAP2* gene was validated through VIGS in bacterial wilt susceptible 'Kufri Jyoti' potato cultivar and exhibited a significant decrease in disease symptoms, increased ROS accumulation, and increased expression of *PR-4* gene. After this proof of concept of VIGS validation, eighty RNAi lines for *PAP2* were developed and subjected to bacterial wilt assay using root inoculation method. These lines were screened up to third clonal generation. The response of the RNAi lines compared to control plants was assessed after 10 and 20 days of post inoculation of the pathogen. RNAi lines showed high resistance (0 scale) compared to 100% wilt symptoms in control (Fig.12a and 12b). The three lines of the event remained highly resistant till last observation made at 35 days after inoculation of *R. solanacearum*. Based on symptoms development, the lines were categorised as resistant, moderately resistant and highly susceptible. The integration, expression and

inheritance of three promising lines displayed enhanced resistance to wilt disease. Avirulent colony assay and bacterial ooze test were used to authenticate the silencing of *PAP2* in inhibiting the colonization and bacterial load with respect to the wilt disease development.



Fig. 12b: Bacterial wilt response of RNAi lines at 35 days after inoculation



Fig. 12a: Bacterial wilt response of RNAi lines at 20 days after inoculation

Chaetomium globosum mediated synthesis of nano silver and evaluation of its antifungal properties (Rahul K Tiwari, Aarti Bairwa, Sanjeev Sharma, Vinay Sagar, Ravinder Kumar & Kailash C Naga)

A protocol was developed for synthesizing nanosilver using fungal mycelia as synthesizing substrate. *Chaetomium globosum* (GenBank Accession No. MN228658) was mass multiplied in potato dextrose broth by culturing at 26 °C for 7 days incubation with continuous shaking. The developed mycelia balls were filtered through whatman filter, washed with distilled water, and incubated in water for 2 days at 26 °C in an incubator shaker. A 10 ml of 1 mM AgNO₃ solution was prepared and mixed with 90 ml of fungal filtrate. This solution was kept at 26 °C for 4 days with continuous stirring and repeated samples were taken for the spectroscopy and particle size analysis and *in vitro* assay. Spectrophotometric study revealed that

the maximum *UV-vis* absorbance of the biosynthesized silver nano particles (AgNPs) was 420–450 nm as measured by *UV-Vis* spectrophotometer. TEM analysis revealed the production of spherical AgNPs with a particle size of 18–44 nm (Fig. 13a). All results had clearly shown the

synthesis of silver nanoparticles. The synthesized nano silver was tested against *Fusarium sambucinum* (Dry rot in potato) *in vitro* where it exhibited maximum inhibition of mycelial growth (Fig. 13b). In future this can be a very promising sustainable antifungal product against potato pathogen.

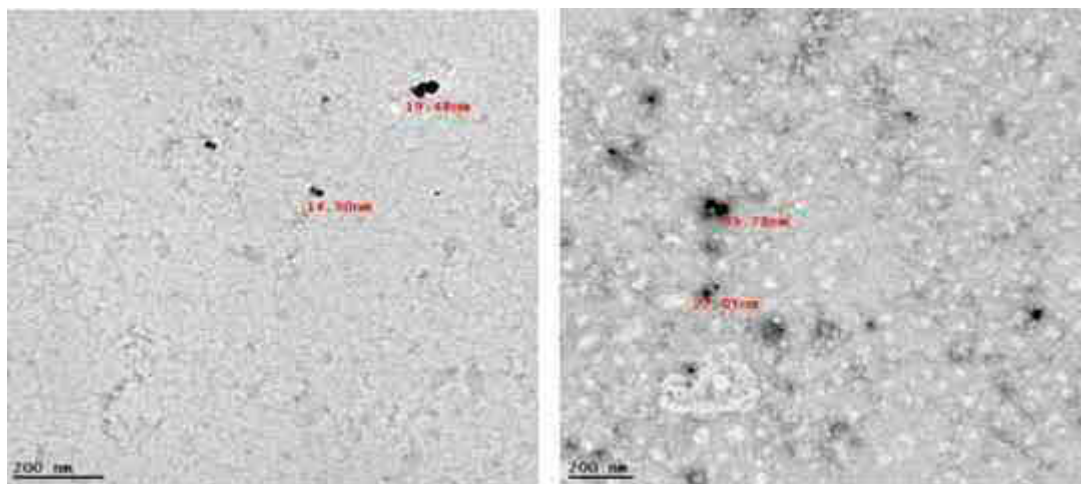


Fig. 13a: TEM images of spherical AgNPs of *Chaetomium globosum*



Fig. 13b: Bio-efficacy of *Chaetomium globosum* nano silver against dry rot pathogen

Post entry quarantine testing of imported germ-plasm (Vinay Sagar, Sanjeev Sharma, Ravinder Kumar & Vinay Bhardwaj)

A total of 34 *in-vitro* cultures of potato imported by Crop Improvement Division (15 cultures), M/ Utkal Tubers India Pvt Ltd (15 cultures), M/s Pepsico India Holdings Pvt Ltd (03 cultures), M/s Merino Industries Pvt. Ltd. (01 culture), and 02 TPS lines of potato imported by M/s Sungro Seed Pvt Ltd were tested for post entry quarantined pathogens.

Project 2: Diagnostic and Management of Viral Diseases of Potato

Development of Diagnostics Assays

A simple and convenient step to obtain high-pure RNA from potato tuber sprout and periderm (Gaurav Verma, Baswaraj Raigond, Kaliash Naga, & Sanjeev Sharma)

The extraction of high quality ribonucleic acid (RNA)

is a crucial step for the detection of pathogen and analysis of gene expression profiles using various isothermal amplification methods, RT-PCR, real-time PCR (RT-qPCR) and next generation sequencing (NGS). In plants there is no universal protocol for RNA extraction, since optimizations are required depending on the species, tissues and developmental stages. Given the economic importance to the potato tubers, which are used as a means of propagation, it is desirable to detect the pathogen directly from its tissues as well as in the sprouts. These tissues are rich in polysaccharides and most methods for RNA extraction are not suitable to handle the excess polysaccharides. Here, we compare the current methods for RNA extraction applicable to potato tubers tissues and sprouts. Initially, the extraction using the TRIzol reagent, CTAB, RNeasy Plant mini kit and Spectrum Plant RNA kit was not appropriate for RNA extraction from periderm and sprouts. The ratio between A260/A230 which

provides clues for polysaccharides and other related metabolites contamination resulted consistently < 2.0. On the other hand, total RNA extracted from potato leaf, the A260/A230 values were at about > 2.0 and the concentration was higher as compared to tuber (Table 3). The lower A260/A230 values will affect the downstream detection sensitivity, specificity and can also totally inhibit the PCR reaction. To avoid the polysaccharides contamination during the RNA extraction, we modified the method by the addition of high salt buffer which can efficiently reduce the chances of co-precipitation of polysaccharides with RNA. With the application of a simple step in the protocol we found that the A260/A230 values (Table

3) as well as RNA quality (Fig. 14) was increased significantly. Our comparison of methods and protocol modifications provide insight into the most appropriate method for high-throughput application that produces RNA of high quality, and quantity than the current methods.

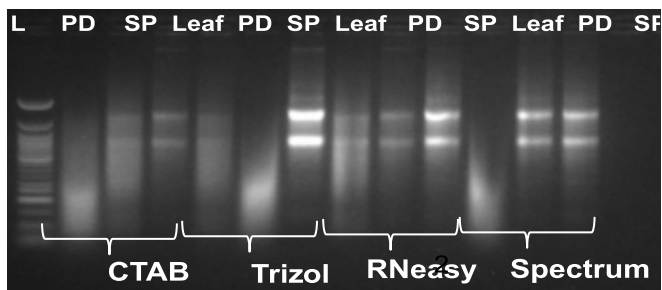


Fig. 14: Assessing RNA quality on gel electrophoresis

Table 3: Comparison of total RNA purity isolated from *Solanum tuberosum* L. sprouts, periderm and leaf tissues using the modified RNA method

RNA extraction method	A260/A230 ratio from different tissues of Potato				
	Sprouts (SP)		Periderm (PD)		Leaf
	Standard protocol	Modified	Standard protocol	Modified	Standard protocol
CTAB	1.00	1.98	1.00	1.89	2.00
TRIzol reagent	1.20	2.05	1.29	2.19	2.26
RNeasy Plant mini kit	1.19	2.19	1.20	2.25	2.30
Spectrum Plant RNA kit	1.5	2.40	1.01	2.35	2.32

Optimization of isothermal-based RT-LAMP assay for robust and rapid detection of PSTVd directly from potato tuber sprouts and periderm (Gaurav Verma, Baswaraj Raigond, Kaliash Naga, & Sanjeev Sharma)

Rapid and accurate diagnosis of virus and viroid is a key for effective disease control. Molecular based detection procedures with high specificity and sensitivity are available including PCR and isothermal assays. Till now such methods are not been optimized for detection of potato virus and viroid directly from tissues of the tuber. This procedure will increase our diagnostic capacity; to rapidly detect the pathogen in tubers otherwise a grow-out test is recommended which take around two months to complete the whole process. Here the major challenge is to isolate quality RNA from the periderm and sprouts due to the presence of secondary metabolites which largely hinder the downstream detection methods. Therefore, we applied our modified method for quality RNA extraction from the periderm and sprout

and, optimize the RT-LAMP assay for the detection of PSTVd. For optimization of RT-LAMP reaction we evaluated different components i.e. MgSO₄, dNTPs, Bst polymerase concentration and cDNA synthesis method. We found that MgSO₄, dNTPs and Bst polymerase at a concentration of 6 mM, 1.6 mM and 3.2U, respectively provided consistent RT-LAMP results for PSTVd (Fig. 15A). In addition, an increase in incubation temperature up to 50°C is optimum for a higher yield of targeted template (cDNA) in the reaction (Fig. 15B). Thereby, it increases the sensitivity and specificity of downstream detection assay from sprout and periderm. To estimate the reliability of RT-LAMP assay for detection of PSTVd in tubers, we tested total RNA from sprouts and periderm of PSTVd infected potato tubers. We detected PSTVd with RT-PCR and RT-LAMP in both sprouts and periderm tissues of tuber (Fig.15B&C). However, the PSTVd detection using periderm had weaker band intensity based on gel electrophoresis, when compared to the intensity

observed with the sprout sample (Fig. 15 D&E). This may be due to low titer of PSTVd in tuber periderm. Moreover, the band intensities of sprout and leaf samples are equivalent when observed on gel electrophoresis (Fig. 15D). Therefore, this technique shows greater potential for routine diagnosis method instead of the grow-out assay.

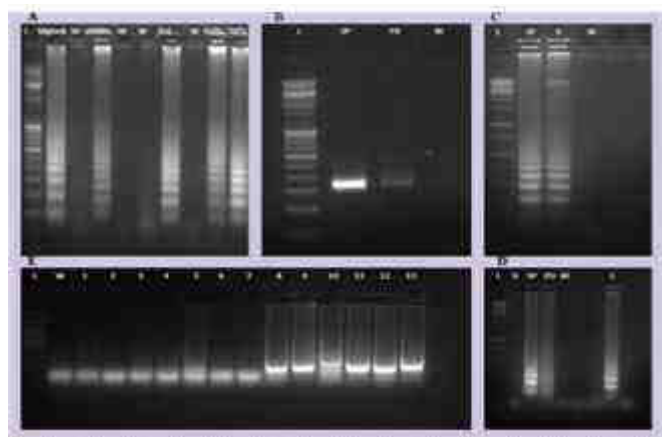


Fig. 15: RT-LAMP detection of PSTVd directly from Potato tuber sprouts and periderm

Development of one step reverse transcriptase-recombinase polymerase amplification (one step RT-RPA) assays for rapid detection of Potato virus X and Potato virus S (Ravinder Kumar, Rahul Kumar Tiwari, Sundaresha S & Sanjeev Sharma)

Recombinase polymerase amplification (RPA) is a quick, specific, sensitive molecular tool carried out at a constant temperature for pathogen detection. In the present study, one step reverse transcriptase-recombinase polymerase amplification (RPA) assays were developed for accurate detection of potato virus X and potato virus S in potato leaves as well as in potato tubers. These assays were combined with a simplified extraction method of the RNA and therefore established a rapid RPA procedure, which can allow real time detection in less than 40 min. Specificity of the reaction was determined by the lack of cross-reactivity with other common potato viruses. Three sets of novel primers that recognize the coat protein gene sequence of each PVS and PVX were designed from a consensus region among different isolates within the highly conserved coat protein sequence and one step RT-RPA assay was optimized using different concentrations of primers, magnesium acetate, incubation time and temperature. One best primer was selected for each virus and a magnesium acetate concentration of 14 mM, 30 min of incubation time and a temperature of 37–42°C was

found optimum for detection of the potato virus S and potato virus X in RPA assays. Comparison of sensitivity of detection revealed that RT-RPA could detect the PVX up to 10^{-5} dilution of the total RNA while PCR could detect the virus up to 10^{-3} dilution indicating that RPA is 100 times more sensitive than PCR (Fig.16). RPA was further simplified using crude extract as template which could detect the virus up to 10^{-4} dilution.

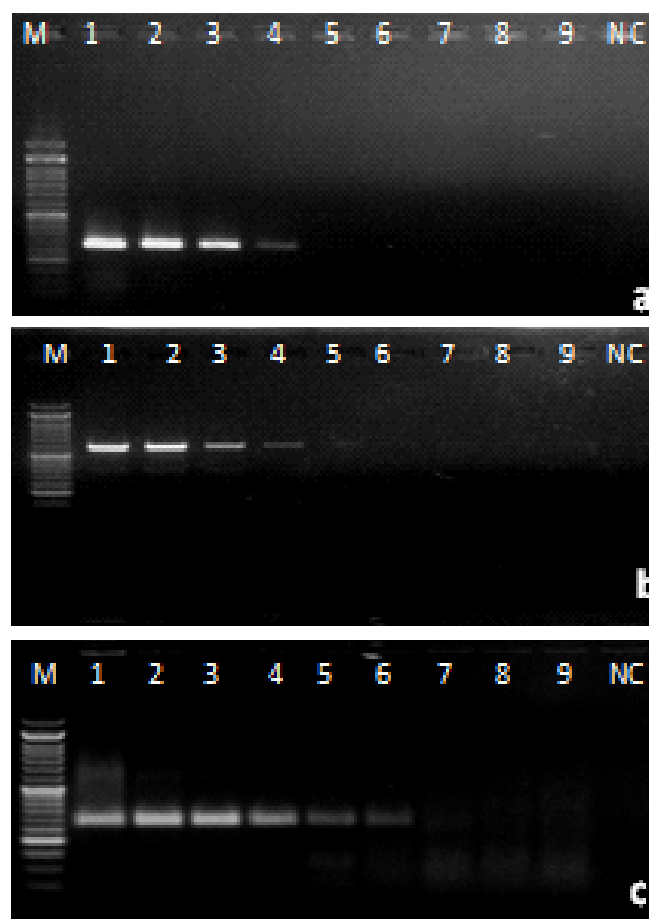


Fig. 16: Comparison of sensitivity of detection of PVX. a. One step RT-PCR (existing PCR primers), b. one step RT-PCR (RT-RPA primers), c. one step RT-RPA with crude extracted RNA (RT-RPA primers). Lane 1–9 loaded with RT-RPA/RT-PCR products obtained with template RNA dilutions from 10^0 – 10^{-9} , Lane M is loaded with 50 bp DNA ladder

RT-RPA assays were validated using field samples of potato representing different varieties and geographical regions by crude RNA extract and cDNA. Our study showed that RT-RPA can be successfully adopted as a substitute to PCR for detection of PVX and PVS infecting potato. In addition, the assay was sensitive enough to allow the detection of PVS and PVX when using crude extract from peridermal tuber tissues. The present study offers an alternative procedure to conventional

nucleic acid-based assays for successful and rapid detection in low viral titer samples and now eliminates the need of additional purification step of the products prior visualization and works with low quality RNA materials (Fig. 17).

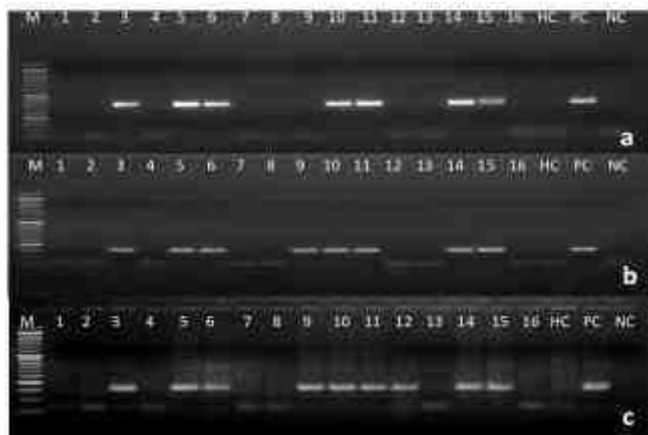


Fig. 17: Validation of RT-PCR assay and RT-RPA for specific detection of PVS a. One step RT-PCR (existing PCR primers), b. one step RT-PCR (RT-RPA primers), c. one step RT-RPA with crude extracted RNA (RT-RPA primers). Lane 1–16 loaded with RT-RPA/RT-PCR products obtained with template RNA dilutions from field potato samples, Lane M is loaded with 50 bp DNA ladder, Lane HC-healthy control, Lane PC-Positive control, Lane NC-Negative control

Development of isothermal based RT-LAMP assay for detection of PVY in potato tubers (Baswaraj Raigond, Gaurav Verma & Tarvinder Kochhar)

The optimized LAMP assay was used for the detection of PVY in potato tubers. The total RNA was isolated directly from the periderm of the potato tubers using RNA isolation kit followed by cDNA synthesis. The cDNA was then used as template to carry out RT-LAMP assay for detection of PVY. The amplified products were visualized by loading the product on 2.0% agarose gel (Fig. 18). The results showed a smear of ladder like amplicons which indicates that the assay needs further improvements.



Fig. 18: RT-LAMP assay for detection of PVY from potato tubers

Management of viral diseases of potato Transgenic approach

Multiplication and screening of selected transgenic lines resistant to ToLCNDV-potato under controlled conditions (Ravinder Kumar, Sundaresha S & Sanjeev Sharma)

Forty tubers each of two promising transgenic lines GTLC2-127 and KPLC2-53 were planted in containment facility for phenotypic observations. The tubers from these plants were harvested for further multiplication and studied tuber characters. GTLC2-90, GTLC2-127, KPLC2-13, KPLC2-37, KPLC2-53 and KPLC2-54 transgenic resistance lines were also maintained and multiplied under tissue culture. Out of these, two promising transgenic lines GTLC2-127 and KPLC2-53 were screened through agro inoculation technique and the results showed that transgenic lines did not show ToLCNDV- potato symptoms as against control plants (Fig. 19).



Fig. 19: Screening of KPLC2-53 transgenic line through agro inoculation technique. Transgenic line (a) and non transgenic line (b)

Maintenance and screening of developed transgenic lines against Potato virus Y (Baswaraj Raigond, Sundresha S & Tarvinder Kochhar)

The transgenic lines i.e., KPYS-13, KPYS-20 along with non-transgenic line of potato variety Kufri Pukhraj against *Potato virus Y* (PVY) are being maintained in tissue culture facility of the Division of

Plant Protection by regular sub culturing. These transgenic lines along with a non-transgenic healthy control were planted in pots and raised under glass house conditions (Fig. 20). These lines were regularly observed for their general growth where the lines i.e., KPYS-13 and KPYS- 20 along with non-transgenic control showed good germination and growth. Later on, to screen the lines for their resistance against PVY, they were challenge inoculated with the pure culture of PVY inoculum. After challenge inoculation, the lines were observed for visual symptoms and found

that the transgenic lines appeared to be healthy in contrast to non-transgenic lines. The same was confirmed by carrying out DAS-ELISA where, the transgenic lines were found negative to PVY but not the non-transgenic line. But, at the later stage, we recorded mild mosaic, necrotic lines/ patches on stem near nodes, leaf hanging followed by necrosis (Fig.20). Moreover, the tubers harvested were less in number and not regular shape. Hence, the above findings need to be confirmed again.



Fig. 20: Transgenic lines maintained in tissue culture facility. Screening of transgenic potato lines of KPYS-13, KPYS-20 along with a healthy non-transgenic control against *Potato virus Y* under glass house conditions

Nontoxic biomolecules based approach

Evaluation of potato tubers dipped in melatonin solution for attenuation of PLRV symptoms (Rahul Tiwari, Ravinder Kumar, Kailash Naga, Sanjeev Sharma & Milan K Lal)

An indoleamine molecule, melatonin (MEL, N-acetyl 5 methoxytryptamine) has been well documented to strengthen plants against a wide range of abiotic and biotic stresses. The exogenous application of MEL is reported to enhance the production of salicylic acid (SA), nitric oxide (NO) or reactive oxygen species in plants infected with the viral pathogens. In our study we evaluated the different concentrations (100 uM, 200 uM, 300 uM and 400 uM) of exogenous

melatonin for symptomatic expression of *Potato leaf roll virus* (PLRV) on potato plants. The potato tubers infected with PLRV were kept for sprouting and once the sprouts of 2-centimeter length were visible, those sprouts on individual tubers were pinpricked for enhanced melatonin absorption. Five PLRV infected tubers were dipped in 100 milliliter working solution of each melatonin concentration along with healthy and non-treated control tubers. The tubers were dipped in melatonin solution for two hours followed by overnight drying in laminar cabinet. The melatonin treated tubers and uninoculated tubers were planted in virus pure culture facility at ICAR-CPRI in a randomized complete block design. The periodic symptom observation on the treated plants

revealed that the morphological features of the plants were improved after melatonin treatment (Fig. 21), but it is difficult of categorize the efficacy of melatonin on attenuation of PLRV symptoms. Hence, real time PCR based quantification studies are going on for confirmation of melatonin mediated virus suppression.



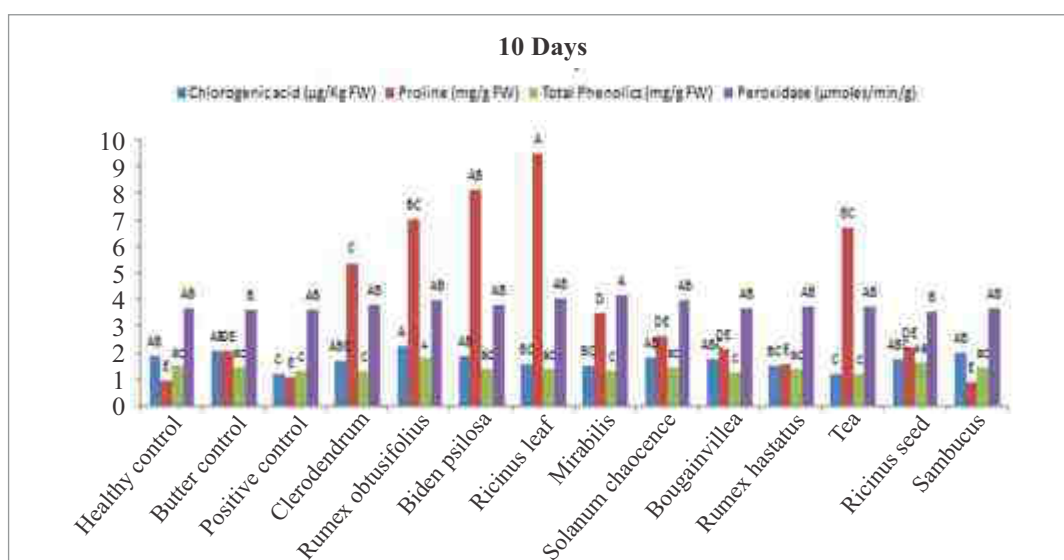
Fig. 21: Evaluation of potato tubers dipped in melatonin solution

Management of Plant Viruses through Plant Based Antiviral Proteins

Identification of suitable plant based anti-viral compounds for management of *Potato virus Y* (Baswaraj Raigond, Pinky Raigond & Tarvinder Kochhar)

A trial was conducted under glasshouse conditions where healthy potato plants (in replicates) were raised followed by application of total soluble proteins extracted from the botanicals onto newly emerged potato leaves. After 24 hours the plants were challenge inoculated with pure inoculum of PVY by maintaining controls. The plants were observed for expression of visual symptom where, it was observed that the treated plants appeared healthy for initial one week followed by mild mosaic patches but later the upper leaves or upcoming leaves were found healthy i.e., after 20 days of treatment. Plants treated as positive and buffer controls (inoculated with PVY)

showed mild mosaic and necrotic spots in contrast to healthy controls (un-inoculated). After 10 and 20 day of treatment, the plants were analyzed for non-enzymatic and enzymatic antioxidants like proline, chlorogenic acid, total phenolics and peroxidase which are reported to be involved in defense related pathways. The data obtained were analyzed statistically using MSTAT 4.0C software and the significance of means was compared using the Tukey's HSD test ($p < 0.05$). The combined results of all the techniques revealed best response in *Sambucus*, followed by *Camellia sinensis*, *Bougainvillea*, *Mirabilis*, *Solanum chaocence*, *Ricinus* seed and *Biden pilosa* (Fig. 22). Further, these plants were found to be negative in DAS-ELISA and no virus particles were seen in TEM. Whereas the positive control was found to be positive in DAS-ELISA and filamentous particles of PVY were observed visible in TEM. The results indicate that the proteins isolated from above mentioned plant species activated the plant defense response against PVY.



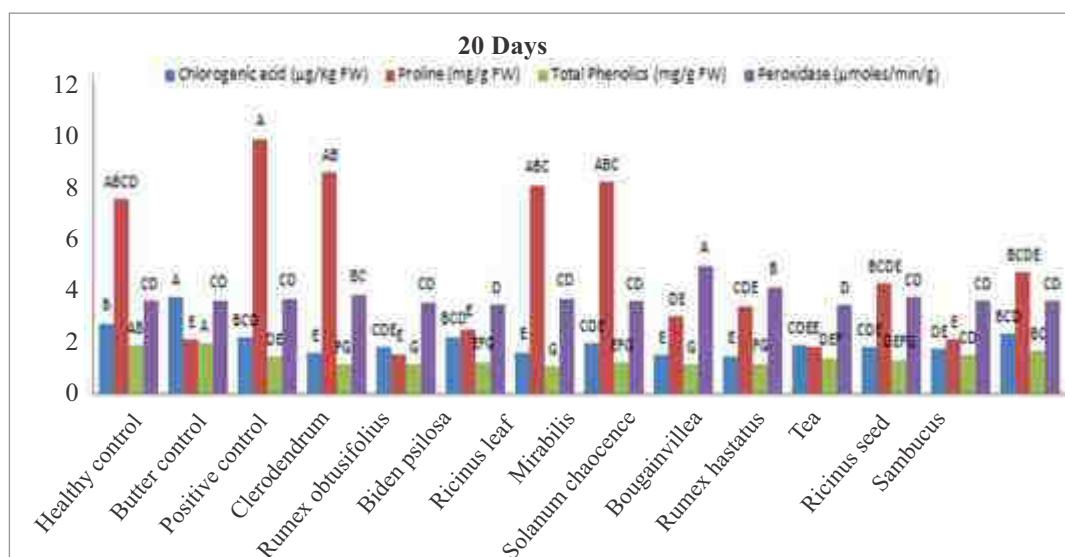


Fig. 22: Management of PVY by plant based antiviral proteins. Visual Symptoms, biochemical analysis and Transmission electron microscopic examination

Virus vector relationship/ interactions studies

Effect of Acquisition Access Period and Inoculation Access Period on transmission of ToLCNDV-potato by *Bemisia tabaci* (Asia II5) (Kailash Chandra Naga, Ravinder Kumar, Rahul Kumar Tiwari & Subhash S)

To observe the effects of different Acquisition Access Period (AAP) on the rate of virus transmission, *B. tabaci* was allowed to feed for 05, 15, 30 minutes and 01, 03, 06, 12 and 24 hrs on the *ToLCNDV*-potato affected potato plants separately. After the prescribed AAP, the *B. tabaci* were transferred on the 6 days old healthy potato plants at the rate of 15 whiteflies for a constant 24hrs Inoculation Access Period. To determine the influence of different Inoculation Access Period (IAP) on transmission of virus, *B. tabaci* were allowed for 24hrs as AAP on *ToLCNDV*-potato

affected potato plants. The viruliferous whiteflies were then transferred to 6 days old healthy potato plants at the rate of 15 whiteflies per plant, separately and allowed IAP for 5, 15, 30 min and 1, 3, 6, 12 and 24hrs. Whiteflies were then killed by insecticide spraying and seedlings were kept in insect proof cages for symptom development. The plants were tested for the virus by polymerase chain reaction using coat protein specific (5' TAAGGTGCAGTCC TTTGAATCT3' and 5'CTCCTCGGGTAACAT CACTAAC3') primers. The whitefly was capable of transmitting the virus with a minimum time of 30 minutes of each AAP and IAP and the transmission of virus increased with the increase in the AAP and IAPs. The whitefly, *B. tabaci* was capable of transmitting virus with 100% efficiencies with minimum period of 12 and 6 hrs of AAP and IAP, respectively (Table 4).

Table 4: Acquisition and inoculation access period required for transmission of ToLCNDV

Acquisition Access Period			Inoculation Access Period		
AAP periods	Infected/ Inoculated	Transmission (%)	IAP periods	Infected/ Inoculated	Transmission (%)
5 min	0/10	0	5	0/10	0
15 min	0/10	0	15	0/10	0
30 min	1/10	10	30	1/10	10
1 hr	3/10	30	1	4/10	40
3 hr	5/10	50	3	7/10	70
6 hr	8/10	80	6	10/10	100
12 hr	10/10	100	12	10/10	100
24 hr	10/10	100	24	10/10	100

Collection and detection of viruses from potato leaf samples and insect vectors *(Murlidhar Sadawarti, Subhash Katare, Baswaraj Raigond & Gaurav Verma)*

Twenty five virus infected potato leaf samples and five suspected stem necrosis samples were collected from Gwalior region and sent to Headquarters for further analysis. These samples were processed and isolated the RNA followed by cDNA synthesis. Further, PCR amplification for detection of specific virus is in progress. With respect to insect vectors, whiteflies, aphids and thrips were collected from Gwalior region and sent to Headquarters. The samples are being processed for detection of viruses in the collected vectors.

Testing of mericlones/ varieties against potato virus *(Baswaraj Raigond, Ravinder Kumar, Gaurav Verma & Tarvinder Kochhar)*

A total of 139 samples received from Crop Improvement division were tested by PCR/ RT-PCR and ELISA for various viruses. The details of the samples are 03 Hybrids i.e., MP/14-169, MP/15-667, MP/15-698 for all possible viruses; 21 mericlones of two varieties i.e., Phulwa splashed, Kufri Sahyadri (OS/01-497) for PAMV, PVS, PALCV; 18 potato cultures, containing 09 transgenic lines with Ama gene, 08 transgenic lines for low cold sweetening and one indigenous variety, for all possible viruses; 38 mericlones of three varieties/ hybrid i.e., K. Pushkar, Badami, MP/ 6-39 for PVX, PAMV, PVS, PVY, PVA; 22 potato cultures for all possible viruses; 3 indigenous cultures i.e., JG-1, Harpora, Manipur selection-1 for all possible viruses; 05 Potato cultures, KJ-5, KBD-9, KP-1, KP-2, MFIRINV-76 for all possible viruses and 21 mericlones of two varieties for PAMV, PALCV, and PVS.

Transmission Electron microscopic (TEM) examination of virus infected potato leaf samples and other TEM related activities *(Baswaraj Raigond & Tarvinder Kochhar)*

Ten potato leaf samples suspected for the infection of ToLCNDV-potato were examined under TEM by following a simple leaf dip method. The TEM examination revealed particles of twin structures

measuring around 37-38 nm (Fig. 23). Pure cultures of viruses being maintained in “Virus Pure Culture Facility” were also examined for the purity of the culture. Besides, potato plants treated with RIPs were also examined for the presence of *Potato virus Y* and samples were also examined for the association of viruses and characterization.

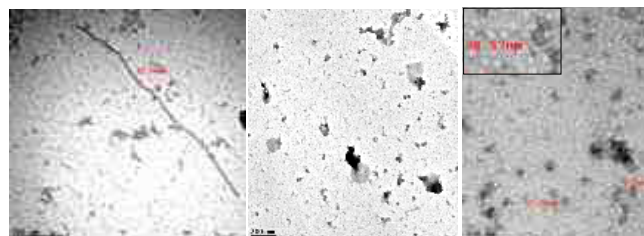


Fig. 23: Electron microscopic (TEM) examination of potato leaf samples

Testing of viruses under National Certification System for Tissue Culture Raised Plants NCS-TCP through DAS-ELISA/ PCR *(Ravinder Kumar, Sundaresha S & Sanjeev Sharma)*

Three thousand six hundred and ninety five samples for batch certification and mother culture of potato received from 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) and M/s Mahindra HZPC Pvt. Ltd., Mohali 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 7.47 lakh plants. Besides, 200 samples 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 2.0 lakhs plants under NCS-TCP. Apart from this, nearly 900 samples from M/s PepsiCo India Holdings Pvt. Ltd. Hoshiarpur (Punjab), M/s Technico Agri Science Pvt Ltd. Baddi, Solan (HP), M/s Mahindra HZPC Pvt. Ltd., Mohali and M/s Merino Industries Ltd., Hapur, were also tested for different viruses through DAS-ELISA/ PCR under non-ATL.

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

PROGRAMME: POST-HARVEST MANAGEMENT AND NUTRITIONAL ENHANCEMENT OF POTATOES

This programme aims to refine post-harvest handling and storage techniques to reduce post-harvest 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, acceptable to the Indian consumers and can also utilize the non-marketable potatoes. All these issues were dealt during the reported period and the results are being summarized here.

Sprout suppression with naturally occurring volatile compounds

Based on the previous years of laboratory scale trials, identified mixture of naturally occurring volatile oil was evaluated for their sprout suppression efficacy in potato tubers under controlled bulk storage conditions (10-12°C, RH 95%). Appropriately diluted mixture of nine naturally occurring volatile oils was applied on five different potato varieties namely Kufri Chandramukhi (KCM), Kufri Surya, Kufri Jyoti, Kufri Chipsona-1 & Lady Rosetta (LR) and stored at controlled conditions. It was found that in all varieties, after treatment there was complete sprout suppression up to 180 days of storage whereas, in control (untreated) potatoes 100% sprouting was recorded after 30 days of storage with higher sprout weight and sprouting index. Although after 180 days of storage partial sprouting was observed in KCM, and LR but the tubers were firm and sprouts length was limited to 1-1.5 cm. In all the varieties, shrivelling was less than 10% and skin colour of the treated tubers remains unaffected throughout the storage. It was observed that treatment was effective even after 250 days of storage (Fig.1). These findings suggests that these mixtures of different naturally occurring oils have the potential to replace the isopropyl N-3-chlorophenyl carbamate (CIPC) in future.

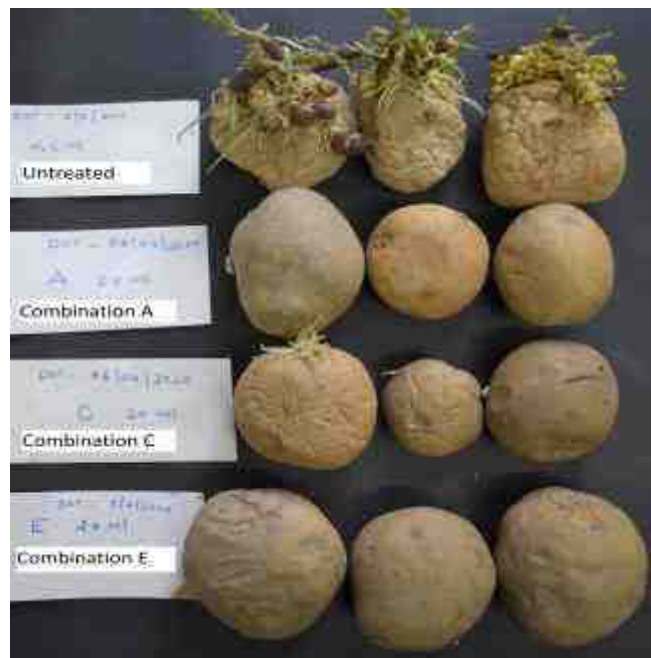


Fig.1: Sprout suppression in potatoes (K. Chandramukhi) up to 250 days with different volatile oil mixtures

HPLC method developed for estimation of anthocyanins

Anthocyanins are present in low concentrations in pale-yellow fleshed potatoes and in higher concentrations in potatoes with red and purple flesh color. Red fleshed potatoes contain pelargonidin, whereas purple fleshed potatoes contain malvidin, petunidin, peonidin and delphinine. The most common method used for estimation of anthocyanins is through spectrophotometer by which concentration of pelargonidin and malvidin can be estimated. However, to get more precise results a new method was developed on HPLC which can be used to estimate anthocyanidins from raw and boiled potatoes and can also be used to estimate their bioaccessibility (Fig. 2). In the present method, limit of detection and quantification are quite low that indicate that the method can estimate even the lower concentration of these compounds from potatoes. The samples viz. MSP 16-375 (purple fleshed), MSP 15-60 (Red tinged flesh at periphery), MSP 16-300 (purple fleshed), MSP 17-89 (Red fleshed), MSP 16-

272 (dark yellow fleshed), K. Neelkanth (yellow fleshed), K. Pukhraj (yellow fleshed) and K. Bahar (cream fleshed) were used to assess anthocyanins from raw potatoes and their bioaccessibility from boiled potatoes. The results showed that the raw tubers of MSP 16-300 contained maximum concentration of petunidin (7.7 mg/100g FW) and pelargonidin (221 mg/100g FW), whereas cyanin (11 mg/100g FW) and malvidin (35 mg/100g FW) were present in high concentration in MSP 16-375 (Fig. 3). In general boiling reduced the concentration of these compounds in all the tested samples. *In vitro* bioaccessibility studies have shown that most of these

anthocyanidins decreased in gastric and intestinal phase with maximum decrease at intestinal phase. Negligible concentration of these anthocyanidins was reported at the intestinal phase. The decrease in petunidin varied from 71% to 100% at intestinal stage. The decrease in pelargonidin, cyanin and malvidin was more than 90% at intestinal stage compared to their concentration in boiled potatoes. The results showed that this method is superior to spectrophotometric method due to estimation of more number of anthocyanidins and better yield of compounds.

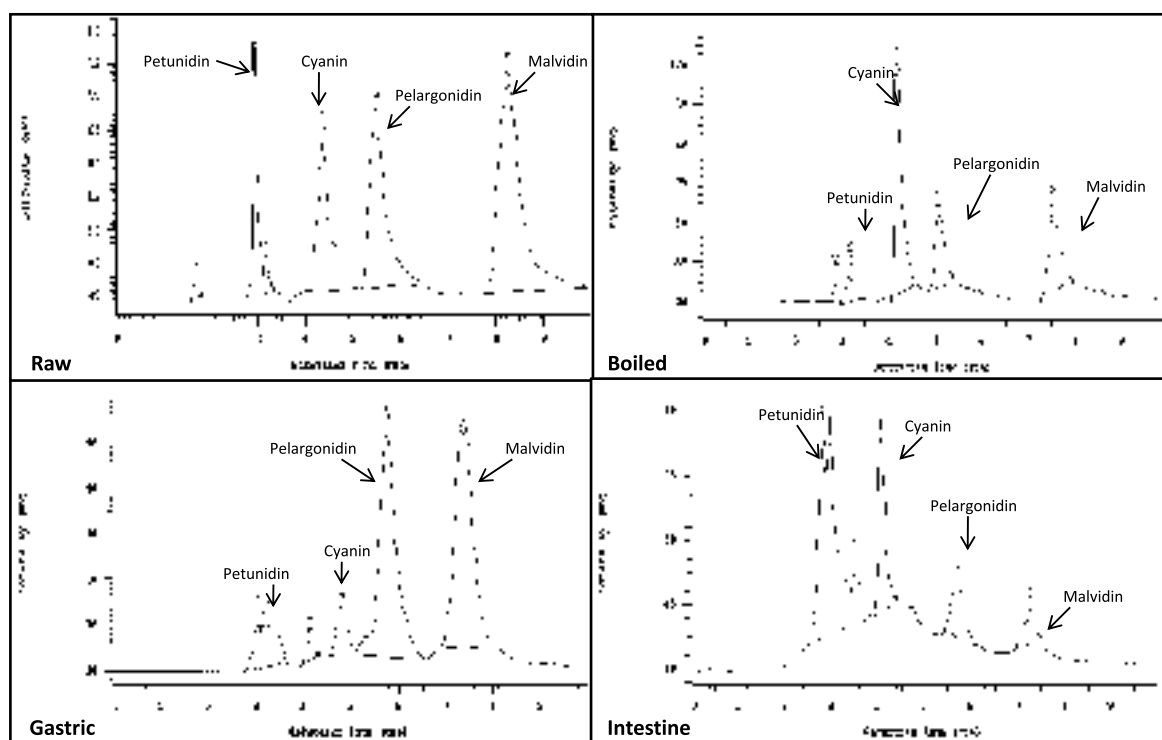


Fig. 2: HPLC chromatogram of anthocyanidins in raw, boiled potatoes, boiled potatoes-gastric phase and boiled potatoes-intestinal phase of MSP 16-375

Development of alternative method for estimation of glucose and sucrose using YSI analyser

An improvised method using extraction procedures was calibrated on YSI analyser 2900 D instrument for time, sample and labour saving. The normal method of glucose and sucrose analysis using YSI analyser involves weighing 200 grams of washed, peeled potatoes, extraction of juice and three times dilutions with buffer. In the modified method only 10 g of

chopped potato sample are required and extraction is done with Isopropyl alcohol (80 %, 50 ml) with refluxing twice (2 hours each time). The advantage of modified method is that it can be used when the sample size is too small, time taken for analysis is less with low labour involvement in extracting juice, washing of juicer after every sample, etc. The observations recorded using two methods were found to be at par in efficiency (Table 1).

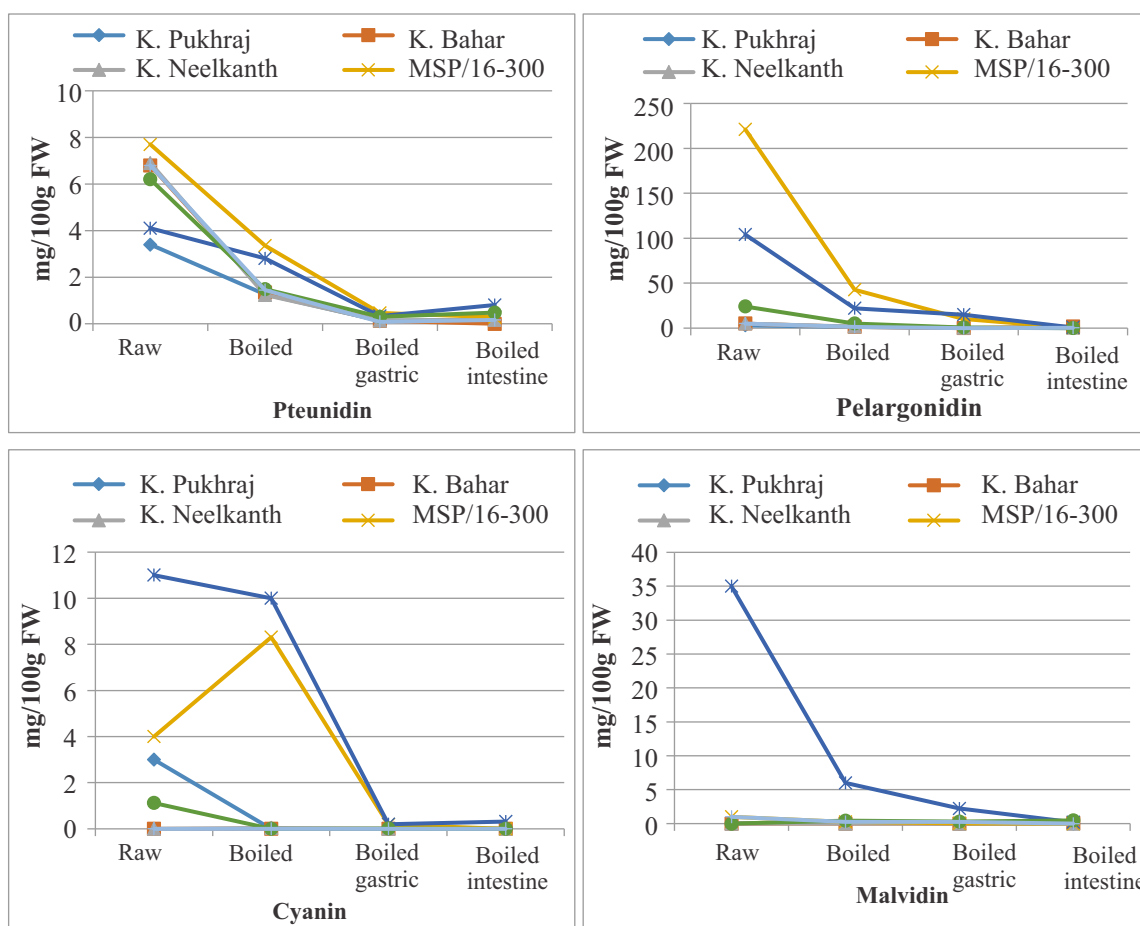


Fig. 3: Concentration of anthocyanidins in raw and boiled potatoes and *in-vitro* bioaccessibility of anthocyanidins of boiled potatoes

Table 1: Analysis efficiency of modified method compared to normal method

Glucose (mg/100g FW)		Sucrose (mg/100g FW)	
YSI 2900D Series	YSI 2900 D through modified method	YSI 2900D Series	YSI 2900 D through modified method
Kufri Chipsona -3			
1	15.5	16	173.13
2	20.78	22	166.25
3	18.56	17	179.35

Identification and distribution of carotenoids biosynthesis pathway genes in potato genome

Carotenoids, the second most abundant naturally occurring pigments on earth; are C40 lipophilic isoprenoids and synthesized in all photosynthetic organisms. Carotenoids have numerous health-promoting properties. Some carotenoids are precursors of vitamin A and prevent human age-related macular degeneration, and some are potent antioxidant and are considered to prevent prostate cancer and cardiovascular disease. In humans, carotenoids also serve as antioxidants and reduce age-related macular degeneration of the eye, the leading cause of blindness in the elderly worldwide. Potatoes

contain carotenoids, though in lesser amount. Thus, there is a scope for improving levels of various carotenoids in potato. Because of the high per capita consumption, potato will have more than significant impact on human health and nutrition. Keeping this in view, genome-wide identification of all the genes involved in carotenoids biosynthesis were carried out *in silico* using potato genome sequence available in public domain. These genes included : geranylgeranyl pyrophosphate synthase (GGPS); phytoene synthase (PSY); phytoene desaturase (PDS); f-carotene desaturase (ZDS); carotenoid isomerase (CRTISO); lycopene ϵ -cyclase (LCY- ϵ); lycopene β -cyclase (LCY- β); ϵ -ring hydroxylase (CHY- ϵ); β -carotene

hydroxylase (CHY- β); violaxanthin de-epoxidase (VDE); zeaxanthin epoxidase (ZEP); neoxanthin synthase (NXS); carotenoid cleavage dioxygenase (CCD); 9-cisepoxycarotenoids dioxygenase (NCED). Only one gene of ZDS, CRTISO and LCY- ϵ was found on chromosome 1, 10 and 12, respectively (Fig. 4). GGPS (chromosomes 4 & 11), LCY- β (chromosomes 4 & 10), CHY- β (chromosomes 3 & 6) had two genes each. VDE (chromosome 4), NXS (chromosomes 2, 3 & 6) and NCED (chromosome 5, 7 & 8) showed presence of 3, 4 and 5 genes, respectively. CCD (chromosome 1 & 7 & 8) and PSY (chromosomes 2, 3, 4, 8 & 12) had six genes each in potato genome (Fig. 4). ZEP gene could not be found on any chromosome. Similarly,

CHY- ϵ was not found in potato genome. These carotenoid biosynthesis genes differed in terms of number of introns, length of open reading frame, molecular weight and isoelectric points of deduced proteins, etc. Further, ZEP was cloned full length (Fig. 5). The complete ORF of cloned ZEP was 2010 nucleotides long and encoding a protein having 669 amino acids (NCBI acc no. MK852682). It exhibited variations at 13 amino acid positions when compared with most identical isoform of ZEP available in the GenBank. Detailed and comparative structural-functional analysis of the genes of carotenoids biosynthesis pathway in potato may provide the tools to enhance the total / targeted carotenoid(s) in potato and thus improving the nutritional value.

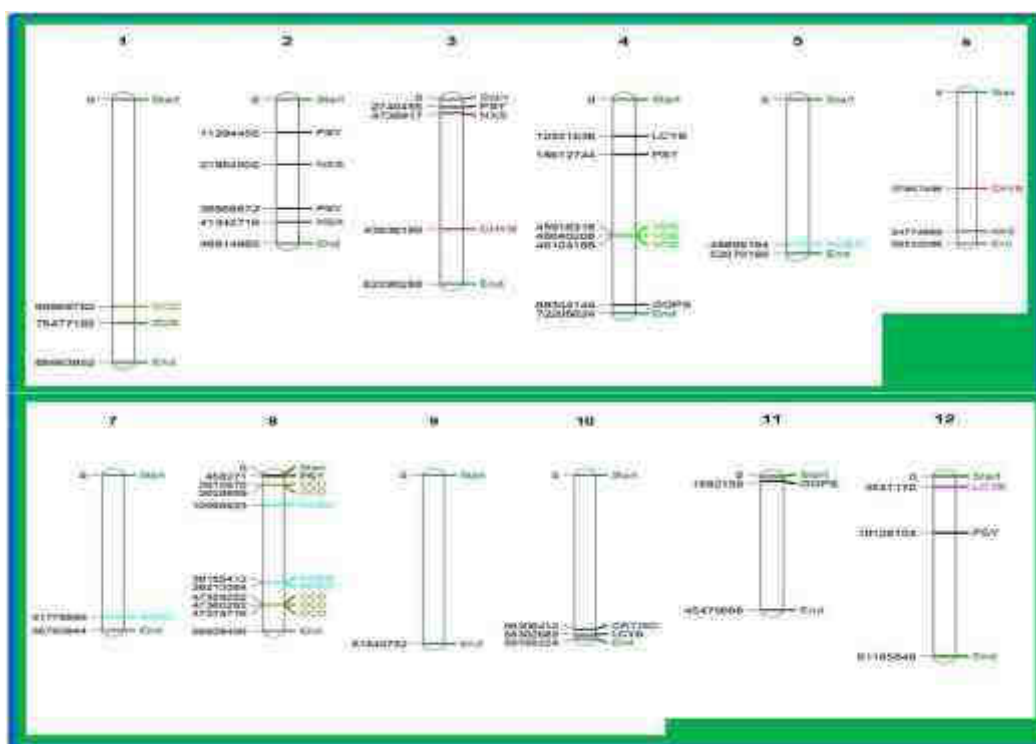


Fig. 4: Chromosomal location of carotenoids biosynthesis pathway genes of potato

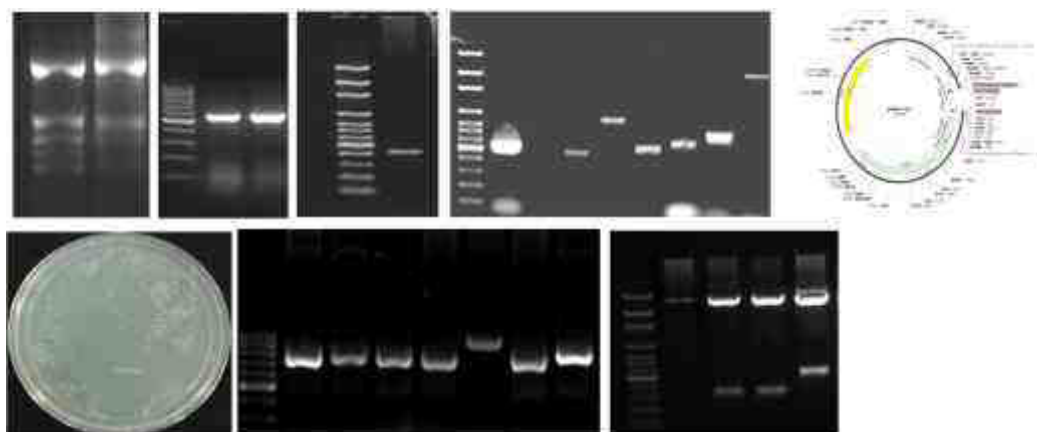


Fig. 5: Cloning and characterization of new isoform of Zeaxanthin epoxidase (ZEP) gene from Potato

Glycemic Index (GI) in Potato

Effect of storage and retrogradation on starch characteristics

Starchy foods like potato, rice, maize, wheat and other food products can be classified according to their digestibility in the human gut, which is characterized by the rate and duration of glycemic response. The term glycemic index (GI) used to classify foods based on their blood glucose-raising ability. The GI is defined as the response of blood glucose measured as an area under the curve (AUC) in test food taken by a person which is expressed as a percentage of the AUC following consumption of reference food consumed by the same person under standard condition. There are three levels of GI viz., low (55), medium (56-69) and high (70). Potato is categorized under high GI food as its average GI value is above 70. This calls for an effort to develop low GI varieties and processing techniques to further reduce the GI of potato. The GI and the glycemic load (GL) was also affected by starch properties like resistant starch (RS), amylose content

(AC), available carbohydrate (ACHO) and total starch content (TSC).

Effect of storage and retrogradation on amylose content and available carbohydrate content

The AC varied from 18.43 to 22.32 % and 19.96 to 23.99 % in cooked and cooled potato tubers respectively (Fig. 6a). It was observed that AC increased significantly after cooling in all the storage treatments as compared to non-retrograded samples. When tubers were cooked there was a disruption in the granules of which form a gel. However, cooling increases the firmness in the gel and disrupted granule re-associate. The available carbohydrate (ACHO) content varied significantly from 10.52 (Kufri Pukhraj) to 14.59 (Kufri Girdhari) in cooked potato tubers (Fig. 6b). The cooking and cooling of potato tubers showed to have a significant reduction in ACHO content with maximum and minimum value ranged from 9.28 to 12.24 g per 100g dry weight in Kufri Pukhraj and Kufri Girdhari, respectively (Fig 6b).

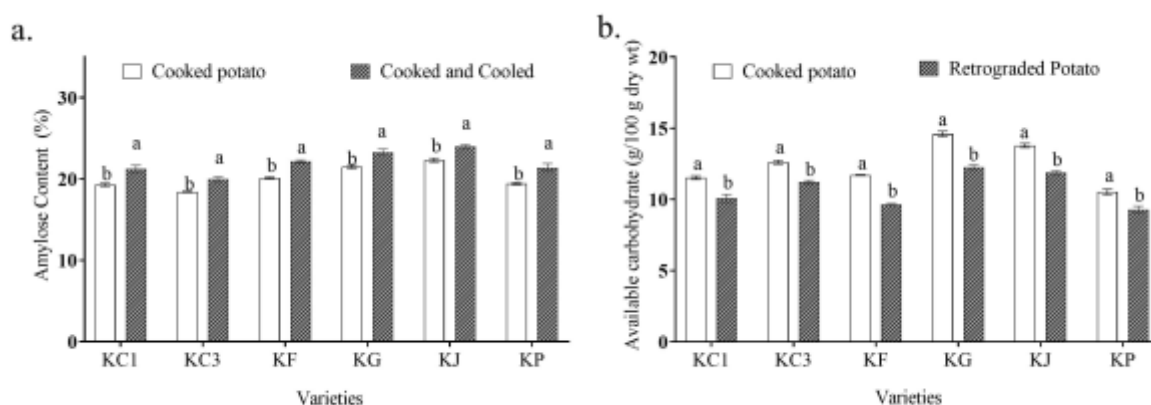


Fig. 6: Effect of storage on (a) amylose content and (b) available carbohydrate (ACHO) of six potato varieties

Effect of storage and retrogradation on total starch and resistant starch content

The total starch content in the cooked sample varied from minimum and maximum of 57.74% (Kufri Frysona) to 71.03% (Kufri Jyoti), respectively. There was a significant decrease in total starch content when the potato sample is kept at 4°C for 48 h. The total starch content after 48h of retrogradation was reported to range from 54.93 to 67.96 %, respectively in Kufri Frysona and Kufri Chispona 1 (Fig. 7). It was found that there was a significant decrease in total starch content in retrograded treatment in all the six

cultivars, except Kufri Chipsona 3, where total starch content was non-significant between treatment. The minimum decrease in total starch content observed when the potato was retrograded was 2.2% (Kufri Chipsona 3) and the maximum was 6.4 % (Kufri Frysona). The decrease in TSC during retrogradation was may be due to re-association and reformation of amylose and amylopectin into an ordered structure. It is to be noted that Kufri Chipsona 3 is a chipping potato variety whereas Kufri Frysona is extensively used for making French fries.

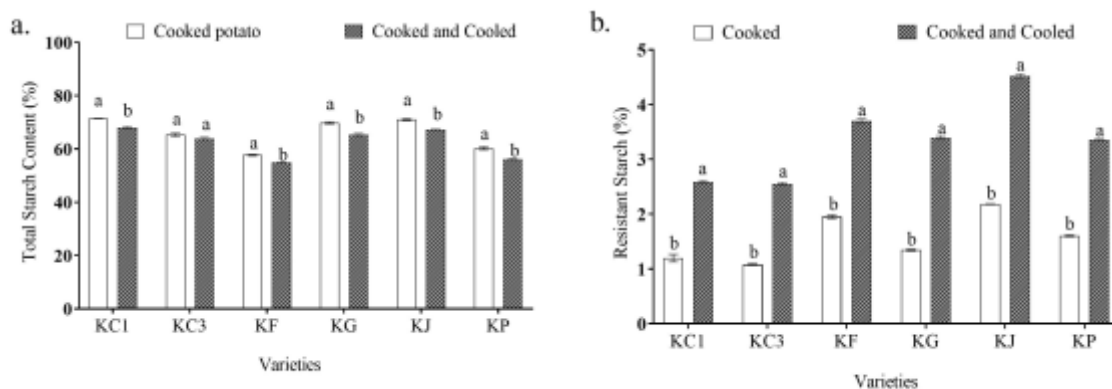


Fig. 7: Effect of storage on (a) total starch content and (b) resistant starch of six potato varieties

The RS content was found to increase in the boiled potatoes when cooled at 4°C, however, the maximum effect was observed after 48h. The RS content of potato varieties ranged from 1.08% to 2.18% in Kufri Chipsona 3 and Kufri Jyoti, respectively. Retrogradation at 4°C for 48 h showed to have an increase in resistant starch which ranged from 2.55 to 4.53 % in Kufri Chipsona 3 and Kufri Jyoti, respectively (Fig. 7b). It was found that there was a significant increase in RS, up to 152.59% in Kufri Girdhari after 48h of storage. During cooling, the gelatinized starch molecules begin to realign and RS formation is enhanced. RS may be recovered by boiling potatoes and cooling or retrogradation which significantly reduces GI.

Effect of storage and retrogradation on the glycemic index and glycemic load

Processing condition such as cooling can influence the glycemic impact of cooked potatoes through

retrogradation of starch polymers. The result showed that cooling/retrogradation had a significant GI lowering effect when cooked potatoes were stored for up to 48h (Fig. 8a). The maximum GI lowering effect was seen after 48 h of cooling. Our results showed that GI ranged from 72.87 to 83.08 in Kufri Jyoti and Kufri Chipsona 3, respectively. Potato samples cooked and kept for cooling at 4°C for 48 h, shown to have a lowering of GI. The minimum and maximum GI after retrogradation was reported in Kufri Jyoti and Kufri Chipsona 1 was about 62 and 69, respectively. The GI decreased significantly in all cultivars ($p < 0.05$) and the decrease was maximum (22%) and minimum (13.44%) in Kufri Chipsona 3 and Kufri Girdhari, respectively. Studies suggest that GI of potato was decreased significantly by 25% when cooled and again reheated for consumption. The retrogradation may change the starch structure under low temperature, which ultimately leads to a lowering of GI and GL.

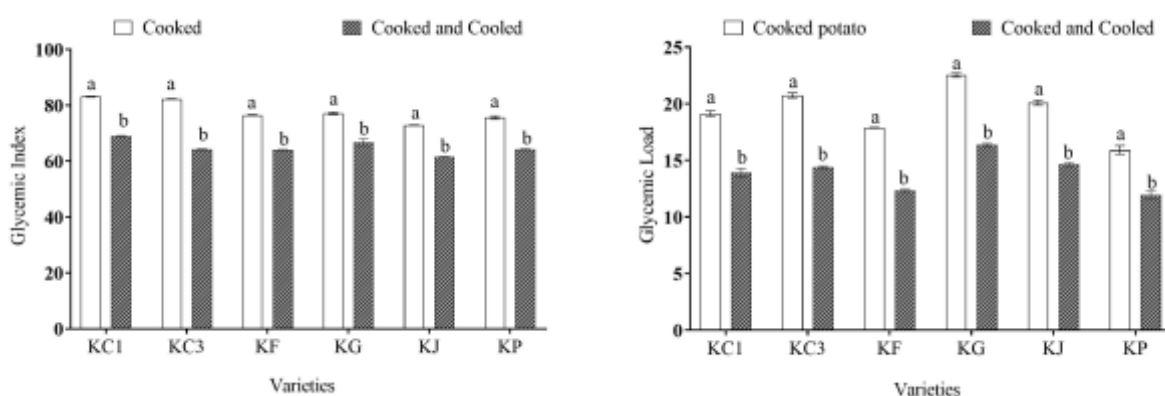


Fig. 8: Effect of storage on (a) glycemic index and (b) glycemic load of six potato varieties

Effect of guar gum addition on resistant starch and glycemic index

To increase the resistant starch (RS) and lower the glycemic index of cooked potatoes addition of guar gum at 0.5 and 1% concentration was tried to boiled and microwaved potatoes. In general resistant starch

was higher in microwaved tubers of all the varieties compared to boiled potatoes. Guar gum showed concentration dependent increase in RS content i.e RS content increased with the increasing concentration of guar gum. On average of varieties, addition of guar gum increased the RS content to 3-

4% and 6% at 0.5% and 1% concentration, respectively (Fig. 9). Total carbohydrates were higher in microwaved potatoes compared to boiled ones. Guar gum addition showed concentration dependent decrease in total carbohydrates. On an average 0.5% guar gum decreased the total carbohydrates to 16% and 1% guar gum decreased the carbohydrates to 29% in boiled potatoes. In case of microwaved potatoes with addition of 0.5% and 1% guar gum, decrease in carbohydrates was 21% and 32%, respectively (Fig. 9).

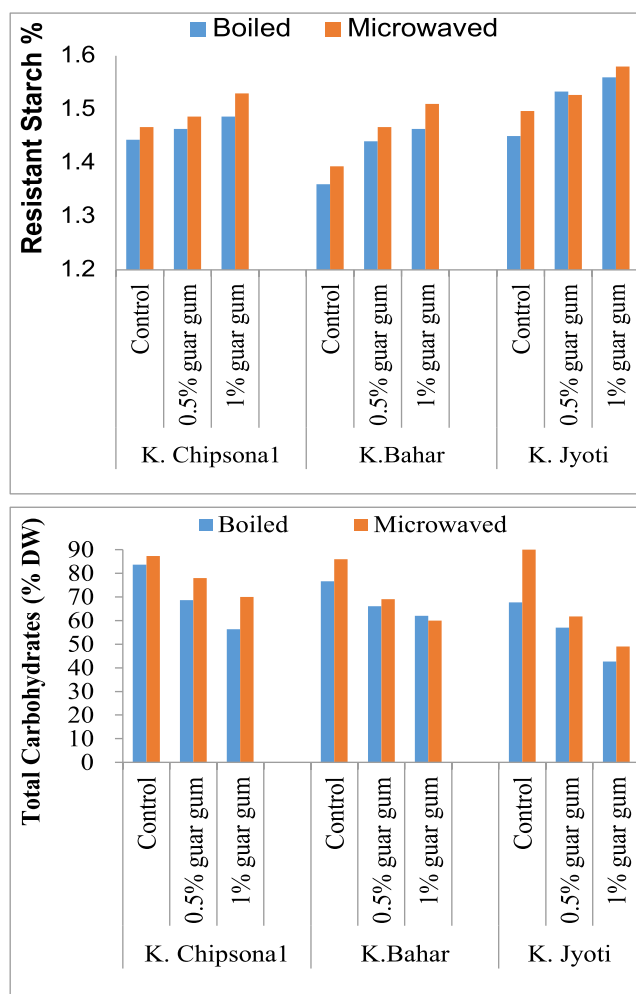


Fig. 9: Effect of guar gum addition on resistant starch content and total carbohydrates of cooked potatoes

Glycemic index (GI) is inversely proportional to RS content and directly proportional to total carbohydrates. Addition of guar gum reduced the GI of boiled and microwaved potatoes. GI was high in boiled and microwaved potatoes of varieties K. Chipsona 1, K. Bahar and K. Jyoti. Addition of guar gum showed concentration dependent decrease in GI. Addition of guar gum at 0.5% concentration to boiled potatoes though reduced the GI in all varieties, but the GI class remained the same i.e high GI. However,

addition of guar gum at 1% to boiled potatoes reduced the GI class from high (70 and above) to medium (56-69) in case of varieties K. Chipsona 1 and K. Bahar (Fig. 10). Microwaved potatoes exhibited lower GI compared to boiled potatoes. Guar gum addition at 1% concentration reduced the GI of microwaved potatoes from high to medium class in case of K. Chipsona 1. GI of microwaved potatoes of varieties K. Bahar and K. Jyoti also decreased with increasing concentration of guar gum, but GI class remained the same i.e medium for K. Bahar and high for K. Jyoti.

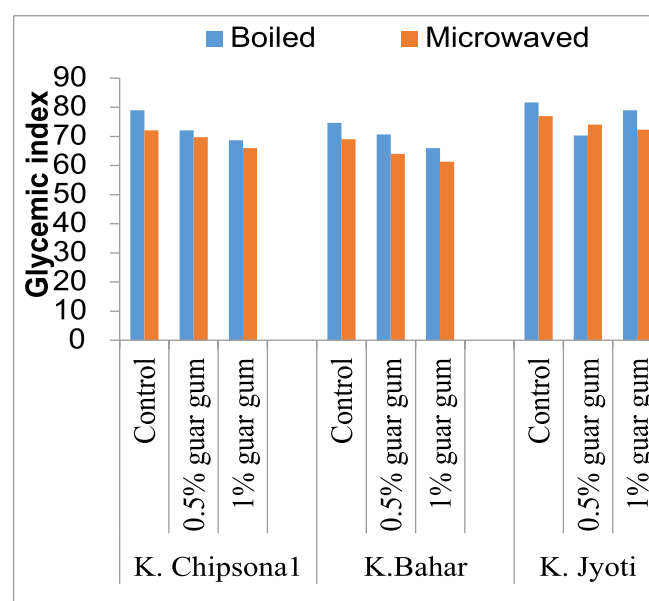


Fig. 10: Effect of guar gum addition on Glycemic index of cooked potatoes

Effect of addition of guar gum on in-vitro gastro intestinal digestion of carbohydrates

Addition of 0.5% guar gum led to significant increase in starch content indicating decrease in starch hydrolysis in both boiled and microwaved potatoes. Microwaved potato tubers contained more starch content than boiled potatoes. Similar trend was obtained in both cooking methods during digestion as minimum starch hydrolysis was observed in oral phase which proceeds in gastric phase and maximum starch hydrolysis noticed in intestinal phase. Starch content that was available at the intestinal phase was 0.16%, 0.18% and 0.16% in boiled tubers of K. Chipsona 1, K. Bahar and K. Jyoti, respectively. The addition of 0.5% guar gum inhibited the starch breakdown, hence more starch was present at intestinal phase and content was 0.53%, 0.62% and 0.69% in boiled tubers of K. Chipsona 1, K. Bahar and K. Jyoti, respectively. Starch breakdown in microwaved tubers

were little lesser than the boiled tubers in all the digestion phases. Starch was 0.19%, 0.22% and 0.23% in microwaved tubers of K. Chipsona 1, K. Bahar and K. Jyoti, respectively. Due to action of guar gum, the starch content in K. Chipsona 1, K. Bahar and K. Jyoti was reported to be 0.87%, 0.93% and

0.94%, respectively, at intestinal phase (Fig. 11). Addition of guar gum in boiled and microwaved potatoes increased starch content to 2 fold in oral phase, 3 fold in gastric phase and 4 fold in intestinal phase as compared to boiled/microwaved potato without guar gum (average of varieties).

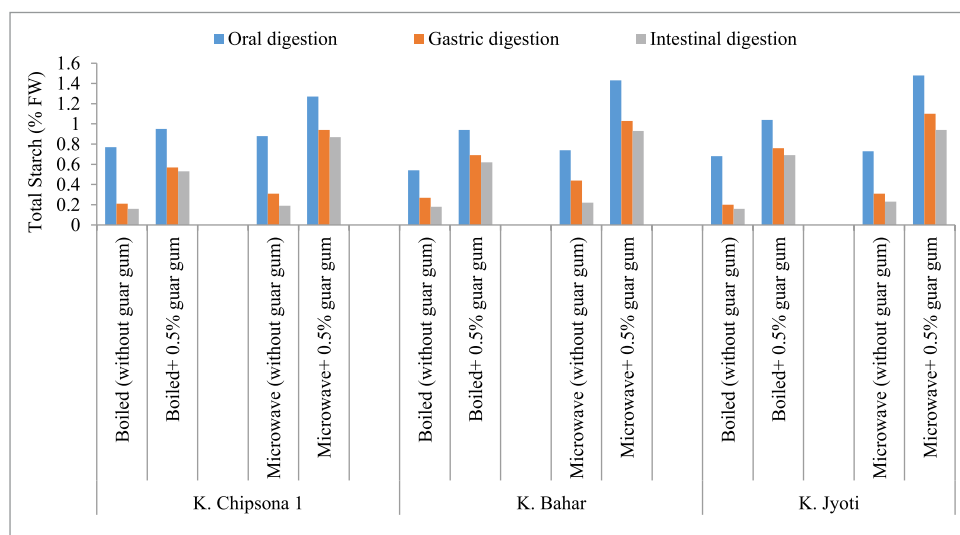


Fig. 11: Effect of addition of guar gum on *in-vitro* digestion of total starch in cooked potato

Novel Potato Products

Modified technique for production of granular cold water soluble potato starch (CWSPS)

The starch, inexpensive, renewable and biodegradable polymer, is biosynthesized as semi-crystalline granules comprising of two glucosidic macromolecular components: amylose and amylopectin. Although there are various applications for native starch, its industrial usage is limited due to some unfavorable

characteristics such as poor solubility in cold water, tendency to retrograde and high viscosity once it is gelatinized. Alcoholic-alkaline treatment of native potato starch results in granular cold water-soluble starch. The nature of structural alterations occurred in starch due to the treatment is however relatively vague. Potato starch was treated at various alcoholic-alkali conditions and subjected to light microscopy. Results showed that about 100% solubility of potato starch in cold water can be obtained (Fig. 12).



Fig. 12: Solubility of potato starch in cold water and Light microscope images of native potato starch (A) and cold water soluble potato starch (B)

Bioethanol production from potato peels waste (PPW)

In recent years, a significant increase in residue production of the potato processing industry has been noticed, primarily due to the increased demands for fast and convenience food. During the processing of the potato crops for the production of potato crisps

and chips, French fries or starch, important fractions (20–50%) of the raw product, mainly peels i.e. potato peels waste (PPW), are discharged as a by-product. These residues, generated by the abrasion peeling process, contain a large quantity of starch, cellulose, hemicellulose and lignin which could be potential

sources for the secondary production of high added value bio-products or biofuels, i.e bioethanol. The study focuses on the exploration of the potential use of potato peels waste (PPW) as feedstock for bioethanol production, saccharification and fermentation schemes. The saccharification of PPW was performed via thermal and enzymatic hydrolysis through the use of commercial enzymes such as cellulase, alpha-amylase, beta-amylase and glucoamylase. The results indicated that the enzymatic treatment by commercial enzymes led to higher saccharification efficiency (81.40%) and ethanol yield (0.49 g/g consumed sugars) corresponding to 96% of the maximum theoretical.

In order to overcome the structural and compositional barriers for converting non-soluble carbohydrates of PPW to ethanol, two extra steps towards the saccharification of biomass, which could take place either independently or in combination, are necessary i.e. a hydrolysis step, where enzymatic conversion of polymeric carbohydrates into soluble sugars takes place and a pretreatment step for enhancing the enzymatic hydrolysis. Table 2 describes the fermentation process by using various strains of Yeast at different time interval. The maximum ethanol yield was obtained by *Saccharomyces cerevisiae* MTCC 178 after 72 h was 84.19 g/L.

Table 2: Bioethanol yield at different time interval by different microbes

Microorganisms	Ethanol Yield (g/L)			
	24 h	36 h	48 h	72 h
<i>Saccharomyces cerevisiae</i> MTCC 170	37.30	49.33	77.20	81.71
<i>Saccharomyces cerevisiae</i> MTCC 171	45.00	59.07	82.40	87.16
<i>Saccharomyces cerevisiae</i> MTCC 173	28.63	43.67	67.50	76.57
<i>Saccharomyces cerevisiae</i> MTCC 174	36.97	50.56	75.70	80.50
<i>Saccharomyces cerevisiae</i> MTCC 177	31.30	43.77	76.29	79.11
<i>Saccharomyces cerevisiae</i> MTCC 178	39.30	49.633	79.200	84.19
LSD (P=0.05) Time = 2.225, Microorganism = 2.225, Time× Microorganism =NF				

Gluten-free potato Jalebi

Snacks have always been known to have a particular place in the regular human diet. India as a country known for its delicacies, has a whole long list of snacks, which are generally made from grains, cereals, or their by-products. *Jalebi* is one of the most popular sweet snacks of India, which is a fermented crispy sweet, deep-fried pretzel made from refined wheat flour/black gram flour/gram flour and eaten as snack food. Traditionally, *jalebi* is prepared by a fermented batter of refined wheat flour along with added Dahi (curd) as an indigenous source of lactic acid bacteria or yeast, salt and water. The thick leavened batter is squeezed and deposited as continuous spirals into hot edible oil. These fried spirals are removed from fat and submerged in hot sugar saffron-scented syrup, which saturates their hollow insides. But the presence of refined wheat flour makes traditional *jalebi* unfit for gluten intolerant persons due to the presence of gluten as an active component.

Another issue associated with the traditional *jalebi* is that it cannot be stored for longer times because *Jalebi* is preferred when served hot and crispy. To satisfy the *Jalebi* hunger of the gluten-intolerant population and

to bring something new for *jalebi* lovers, ICAR-CPRI has developed and standardized the process for potato-based gluten-free ready-to-reconstitute potato *jalebi* (Fig. 13) and Instant potato *Jalebi* premix. In ready-to-reconstitute type potato *jalebi*, before consumption, *jalebi* needs to be submerged in hot sugar syrup for 2 minutes. Moreover, potato *jalebi* has a shelf life of 3-4 months at ambient storage conditions without any loss in crispiness. The utilization of the whole potato also makes potato *Jalebi* rich in dietary fiber.

The potato *Jalebi* is independent of shape, size, dry matter, sugar, and variety of potatoes. Partially damaged or cold-stored potatoes can also be utilized. This technology can be easily adopted by industries involved in the production of ready to reconstitute food products, sweet shops and food industries involved in the production of snacks. As this product is ready-to-reconstitute type therefore can be easily sold at sweet shops, Kirana shops, malls, supermarkets, and departmental stores also. Technology is ready for commercialization. At present this technology is tested at a laboratory scale only.



Fig. 13: Gluten-free potato *jalebi*

Potato-Fruit-Butter cookies

Cookies are one of the most popular baked chewy or crunchy snacks and generally contains wheat flour as a major ingredient. The pleasure that people of all ages find in these bite-sized baked good is limitless. But the peoples suffering from gluten related allergies and intolerance are unable to share this pleasure. Although many gluten-free formulations are available but none

is from potatoes. In the past ICAR-CPRI has developed some gluten-free potato-millet based cookies but this time CPRI has developed a new variant of gluten-free potato cookies having goodness of mixture of candied fruits and rich taste of butter (Fig. 14). This variant will satisfy the craving of not only the gluten intolerant/allergic people, but also the people fond of potato, fruits and butter. Moreover, these cookies are good in dietary fiber and phytonutrients with the shelf life of up to 4 months.



Fig. 14: Potato-fruit-butter cookies



DIVISION OF SOCIAL SCIENCES

PROGRAMME: TRANSFER OF POTATO TECHNOLOGIES TO STAKEHOLDERS AND ASSESSMENT OF THEIR IMPACTS

Analysis of Varietal Replacement Rate and Constraints to adoption of quality seeds and improved varieties in Punjab

The varietal replacement rate in Punjab was estimated by interviewing 90 farmers (45 each from Jalandhar and Moga districts). The varietal replacement rate indicates the average number of years in which an old variety is replaced by a new variety and was estimated using a formula developed by Brennan and Byerlee (1991). The formula for calculating the weighted average age (WAA) is

The weighted average age of improved varieties was found to be about 38 years, which is very high, indicating that the varietal replacement rate in the study area is very slow, taking into consideration that almost every year, ICAR-CPRI and other agricultural institutes/SAUs developed at least one variety. Thus, potato growers are losing the genetic gains (which may

Table 1: Varietal Replacement Rate of improved potato varieties in Punjab

Varieties	Year of release	Age	Area (Ha)	WAA
K. Jyoti	1968	52	334.88	25.66
K. Pukhraj	1998	22	251.11	8.14
K. Chipsona-3	1998	22	24.69	0.80
K. Khyati	2008	12	18.09	0.32
K. Lauvkar	1972	48	14.16	1.00
K. Badshah	1979	41	13.35	0.81
KCM	1968	52	12.14	0.93
K. Chipsona-1	1998	22	10.12	0.33
Total		271	678.54	37.99

be for increasing yield and other important traits like nutritional improvement, drought tolerance, disease and insect resistance, processing quality, good storability, etc.) from the breeding programs.

Garrett's Ranking Technique was used to rank the constraints. Garrett's formula for converting ranks into percent was given by

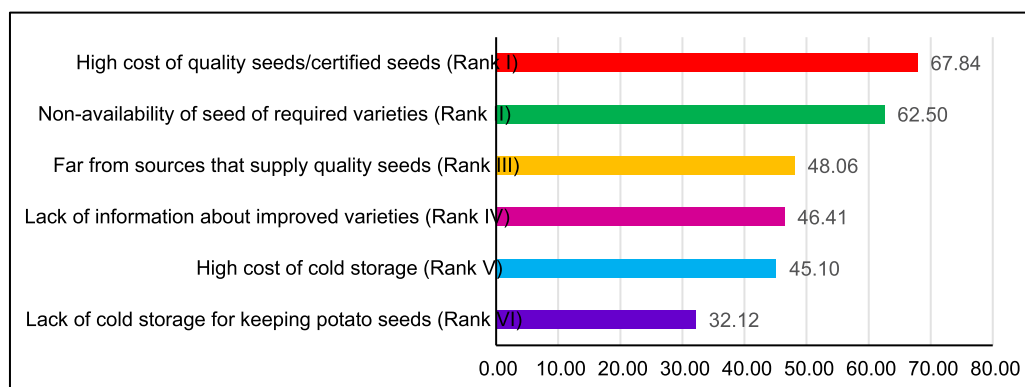


Fig.1: Garrett's mean scores and ranking of constraints to adoption of quality seeds and improved varieties in Punjab

Table 2: Varietal Replacement Rate of improved potato varieties in Haryana

Varieties	Year of release	Age	Area (Ha)	WAA
K. Pukhraj	1998	22	210.23	20.82
K. Chipsona3	2006	14	11.93	0.75
Total		36	222.16	21.57

Analysis of Varietal Replacement Rate and constraints to adoption of quality seeds and improved varieties in Haryana

The constraints analysis using Garrett's Ranking Technique revealed that the first major constraint ranked by potato growers was high cost of

quality/certified seed (with mean Garrett score of 54.25). This was followed by non-availability of seeds of required varieties (score=53.88, rank II), lack of information about improved varieties (51.63, rank III), high storage charges for keeping potato seeds (51.55, rank IV), far from sources of quality seeds (Score=48.77, rank=V) and lack of cold storages

(score=40.27, rank VI). The findings may be useful for state governments, policy makers and researchers in formulating plans, policies and researches related to

the dissemination and adoption of quality seeds of improved varieties in the study areas and in other potato growing regions.

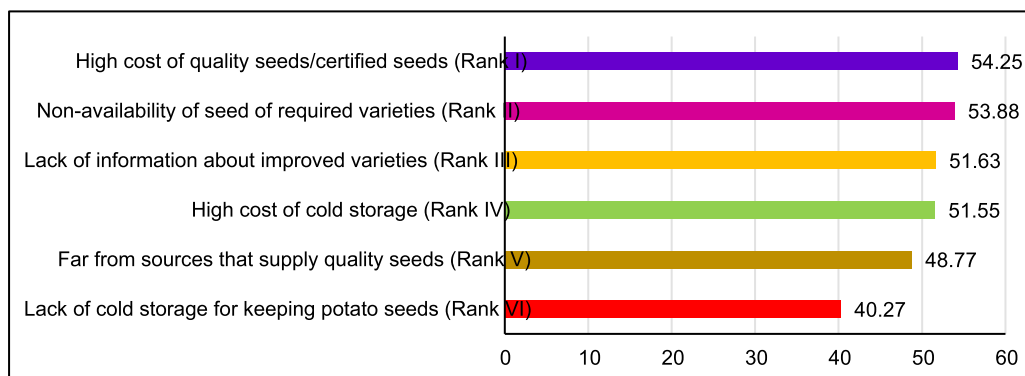


Fig. 2: Garrett's mean scores and ranking of constraints in adoption of quality seeds and improved varieties in Haryana

Transfer of Technologies

Two training programmes of three days duration on “*Aloo ki Unnat Kheti*” were organised by the institute in the month of February on 4-6 and 17-19 for 21 potato growers of Aravali district of Gujarat and 23 farmers from Siliguri (West Bengal). The training programmes were sponsored by DDH (Gujarat Horticulture Mission) Aravali (Gujarat) and Project Director (ATMA) Siliguri (West Bengal), respectively. The objective of the trainings was to enhance the knowledge and skill of the trainees regarding production of quality potato through new techniques and practices. Training methodologies like lecture cum discussion, practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the trainings to the participants.

Scientists from ICAR-CPRI, Shimla participated in the live phone-in programmes during January to December, 2020. The details of the topic and the expert is as under



Month	Topic	Name of the Expert
Februray 2020	Potato harvesting, storage and marketing in the plain areas of HP	Dr. NK Pandey Dr. Brajesh Singh
June, 2020	Different potato varieties in Himachal Pradesh	Dr. NK Pandey
July, 2020	Potato storage and Marketing in the mid-hills of HP	Dr. Brajesh Singh Dr. NK Pandey
August, 2020	Disease and pest control of potato in high hills of HP	Dr. Ravinder Kumar Dr. Kailash Naga
September, 2020	Inter culture operations in potato in high hills of HP	Dr. Ashwani Kumar Sharma Dr. Vinod Kumar
October, 2020	Potato varieties for plains of Himachal and their sowing	Dr. Vinod Kumar Dr. Jagesh Tiwari
November, 2020	Intercultural operations and control of weeds in potato crop	Dr. Jagdev Sharma Dr. Paresch Chaukhende
December, 2020	Management of insect pest and disease in potato	Dr. Ravinder Kumar Dr. Baswaraj Raigond

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, MODIPURAM

Frontline demonstration at farmer's field on varietal production technology

In view to popularize the new potato varieties and improved cultivation practices developed by institute for potato crop, we have conducted 10 field demonstrations on new variety Kufri Neelkanth at 8 different krishi vigyan kinder and 2 Farmer Fields i.e Meerut, Hapur, Lakhimpur kheri, Gautambudhnagar, JP Nagar, Kanpur dehat, Hapur, Shamli and Bijnor districts of Uttar Pradesh and Udham Singh nagar in Uttranchal in an area 0.02 ha. Yield of variety Kufri Neelkanth was compared with the existing variety Kufri bahar. In Kufri neelkanth 9.8 % increase in yield was recorded over Kufri bahar in all 10 locations, when crop was harvested after 90-100 days. Average tuber yield recorded was 355.0 q/ha of variety Kufri neelkanth under recommended practices as compared to yield of Kufri bahar 268.0 q/ha under farmers practices.

Frontline demonstration at farmers field on improved potato varieties and seed production technology in under SCSP

This year 224 quintals breeder seed of improved varieties like Kufri mohan, Kufri bahar, K. Frysona, K. Khayti, K. Garima, K Chipsona-4 and K. Surya was distributed to total 224 schedule caste farmers belong 10 districts of Uttar Pradesh and Udham Singh nagar in Uttranchal. The average yield of improved varieties were compared with the existing local variety. In Kufri Mohan 28.0 %, Kufri bahar 21.5 %, Kufri khyati 24.0 % K. Surya 19.5%, Kufri frysona 21.0 % and in chipsona-4, 18 % increase in average yield was recorded as compared to over yield of local varieties in all demonstrations when crop was harvested after 90 days- 110 days. Average tuber yield Kufri mohan (425q), Kufri bahar (350 q), K. Khayti (410 q), K. Garima (329.5 q), K Chipsona-4 (330.0 q), Kufri Frysona (324.5 q) and K. Surya (310 qt/ha) was recorded from various 10 districts under recommended practices. On an average 20.0 % increase in yield under recommended practices as compared to farmers practices.

Details of Frontline demonstration at farmers field on improved potato varieties and seed production technology in under SCSP during 2020-21

S.N.	District	Quantity of breeder seed distributed	Number of farmers	Number of villages covered	Number of block covered
1	Meerut	30	30	6	3
2	Hapur	24	24	4	2
3	Lakhimpur kheri	23	23	10	9
4	Gautambudh nagar	15	15	7	1
5	JP Nagar	18	18	10	3
6	Kanpur dehat	21	21	9	1
7	Shamli	20	20	11	3
8	Bijnor	25	25	7	4
9	Bulandshahar	15	15	8	4
10	Udham Singh nagar (UK)	30	30	5	2

Summary of visit

Exposure visits of officer trainees

Total 45 trainees from various ICAR Institute, state agriculture departments sponsored by various states visited Central Potato Research Institute RS, Modipuram (UP).

Exposure visits of farmers

Total 300 farmers sponsored by various states under different schemes and personal visit from various districts of U.P., Uttrakhand, Punjab, M.P., and Haryana visited Central Potato Research Institute RS, Modipuram (UP).

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, PATNA

A.	Training	1. One day Farmer's training (SC) at KVK Piprakothi, East Champaran of Bihar on 9 th January, 2020. Total 31 farmers participated in this occasion.
		2. Five days training cum orientation program under project: Development and promotion of 'Agan Ki Kyari' for better health and nutrition" at ICAR -CPRS, Patna on 23, 24, 28, 29 and 31 st January 2020. More than 300 Farmers and Aganbari Sevika participated in training cum orientation program.
		3. A farmers training consisting 42 farmers on potato cultivation and disease management was held on 23 rd December 20 at Gaunpura (Patna)
		4. A training and complain on potato seed production held on 25 th August 2020 at Janipur (Patna)
		5. Online training programme of the farmers from Reddy's foundation was conducted on 27 and 30-12-2020.
		6. Online tour training programme to the BAMETI, Patna farmers (copy attached)
B.	Exhibition / Kisan Mela	1. A stall arranged in Global Potato Conclave 2020 at Mahatma Mandir, Gandhinagar, Gujrat from 28 to 31 January, 20. Hon'ble Prime Minister Sh. Narendra Modi jee inaugurated the GPC-2020 by video conferencing.
		2. Three days Kisan Mela-20 at Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur from 16-18 February, 20.
		3. One day exhibition at ICAR -RCER, Patna on the occasion of 20 th Foundation day of ICAR RCER, Patna on 22.2.20.
		4. Three days Bihar Kisan Mela-20 at Bihar Agricultural University, Sabour, Bhagalpur from 23-25 February, 2020.
C.	FLD Programme Demonstration	1. 200 qtl. of potato varieties eg. Kufri Sindhuri and Kufri Khyati was given to the 200 Scheduled Caste farmers for FLD district Siwan, Noorsarai, Nalanda and Gaunpura (Patna).
		2. Four varieties eg. Kufri Khyati, Kufri Ganga, Kufri Lalit and Kufri Kesarhas been given to the farmers of three villages Namidih of Vaishali and Karmalichak Jalla & Gaunpura of Patna district under Mera Gaun Mera Gaurav programme for conducting demonstration.
D.	Exposer visit and delivering lectures on potato cultivation	1. Two Exposers visit of 48 farmers deployed by BAMETI (Patna) was Conducted on 28 th and 31 st December 2020
		2. Two exposers visit of 112 farmers from Gorakhpur and Maharajganj districts of U.P was conducted on 9 th and 14 th December.



EXTENSION ACTIVITIES AT ICAR-CPRI, RS, JALANDHAR

S/N	Training Program	Date	Coordinator/ Co-coordinator	Beneficiaries		Remarks
				Male	Female	
1.	Awareness program on Agri-Business Opportunities for UG students at Central Institute of Hand tools, Ministry of MSME, Jalandhar	19.02.20	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Arvind Jaiswal - Sh Yogesh Gupta	76	04	Students
2.	Awareness Program on Systems for Rooftop/Kitchen Gardening.	17.07.2020 18.07.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Sugani Devi	22	03	Scientists/Govt. Officers
3.	Training program on CPRI-In-Vitro Plant Hardening Technology and Use of HD Technique in Aeroponics for Department of Horticulture (Centre of Excellence for Potato), Punjab	14.08.2020	Coordinator – Er. Sukhwinder Singh	02	01	Scientists/Govt. Officers
4.	Technology commercialization program on Potato based Gluten-free cookies for M/s Goodrich Cereals, Karnal Haryana.	18.08. 2020	Coordinator – Er. Sukhwinder Singh Resource person - Dr Arvind Jaiswal - Sh Yogesh Gupta	01	-	Representative from Goodrich Cereals, Karnal
5.	Online training program on “Seed Potato Production using Net-House Technology”.	20.08.2020 to 27.08.2020	Chairman – Dr Raj Kumar Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Dr Raj Kumar - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Sugani Devi - Dr RP Kaur - Dr M Abas Shah	28	-	Potato Stake Holders/Farmers

6	Webinar/Training program on Net-House technology for seed potato production (Hindi).	01.09.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh	94	-	Farmers/Potato stake holders of Punjab, UP, MP
7.	Webinar/Training program on Net-House: A technology for seed potato production (Punjabi).	11.09.2020		78	-	Farmers/Potato stake holders of Punjab
8.	Webinar/Training program on Net-House cultivation of seed potato production.	15.09.2020		48	-	Farmers/Potato stake holders of Gujrat
9.	Webinar on Organic Potato production (incubation program)	25.09.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Dr Sanjay Rawal - Dr Arvind Jaiswal	03	-	Potato growers
10.	Training program on Aeroponics technology of potato seed production. (PTC Shamgarh, Haryana)	16.10.2020	Coordinator – Er. Sukhwinder Singh Resource person - Er. Sukhwinder Singh	02	01	Govt. officers
11.	Awareness webinar programme on Agri-Business Opportunities in seed potato production at CT college Jalandhar	16.10.2020.	Resource person - Er. Sukhwinder Singh - Sh Yogesh Gupta	90	-	Students
12.	Online awareness programme on “new technologies for potato seed production”.	24.10.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh	63	-	Farmers/Potato stake holders of West Bengal
13.	One-day webinar on CPRI-VEGFAST Technology for commercial use.	18.11.2020		16	02	New Entrepreneurs
14.	Online training program on CPRI-VEGFAST Technology for self-use.	21.11.2020		48	15	End users/vegetable growers
15.	Technology commercialization and training on CPRI-VEGFAST technology for rooftop gardening.	23.11.2020 to 25.11.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Sugani Devi - Sh Yogesh Gupta	13	01	New Entrepreneurs from Patiala, Jalandhar, Amritsar, Kapurthala, Barnala

16.	Online awareness program on CPRI-VEGFAST Technology for self-use.	05.12.2020	Coordinator – Er. Sukhwinder Singh Resource person - Er. Sukhwinder Singh	30	08	End users/vegetable growers
17.	Technology commercialization and training program on “CPRI-VEGFAST technology for rooftop vegetable production”.	09.12.2020 to 11.12.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Sugani Devi - Sh Yogesh Gupta	14	03	New Entrepreneurs from Bathinda, Moga, Ludhiana, Jalandhar
18.	Training program on “Net house technology for potato seed production” in association with Natural Farmers Association.	21.12.2020	Resource person - Er. Sukhwinder Singh	18	-	Farmers/Potato Stake Holders
19.	Technology commercialization and training program on “CPRI-VEGFAST technology for rooftop vegetable production”.	26.12.2020 to 28.12.2020	Coordinator – Er. Sukhwinder Singh Co-coordinator - Dr Brajesh Nare - Dr Arvind Jaiswal Resource person - Er. Sukhwinder Singh - Dr Brajesh Nare - Dr Sugani Devi - Sh Yogesh Gupta	08	03	New Entrepreneurs from Jaipur, Nanital, New Delhi, Rajpura



Training Session with Department of Horticulture (Centre of Excellence for Potato), Punjab on CPRI-In Vitro Plant Hardening Technology and Use of HD Technique in Aeroponics.



Signed technology license agreement with M/s Goodrich Cereals for Potato based Gluten- free cookies on 18 August 2020

Webinar organised on CPRI VEGFAST technology on 21-11-2020



Training program on VEGFAST technology on 09-12-2020



EXTENSION ACTIVITIES AT ICAR-CPRI, RS, GWALIOR

Farmers' training programs organized at ICAR-CPRI, RS, Gwalior

Two Farmers' training programmes were organized under Scheduled Caste Component at ICAR-CPRI RS, Gwalior on "Advanced technologies for potato production" during 4-5 January and 18-19 January, 2020. In these training, Dr. S P Singh detailed about

the research activities of ICAR-CPRI, RS, Gwalior. In the first session, lectures on different crop activities for potato production were delivered. Besides this, farmers were provided information on different aspects like potato seed production technology, potato crop pests, disease management and potato storage. During the training, the farmers were taken to the field and laboratory of the station. 58 Farmers from Dabra, Gohad, Mehgaon, Bhind districts of Gwalior and Baah village from Uttar Pradesh

participated in the first training programme. 61 farmers from Behta, Chakraipur, Dikshit ka pura, Mahoori ka pura, Bhadrauli, Sirsauda, Aino, Gormin, Mehgaon, Gohad districts of Gwalior and from Baah Village of Uttar Pradesh participated in the second training programme. During the training, the propagation booklet and folder published on the potato production technique were released and distributed to the farmers. The reports of above training programs were also published in the institute's website and local newspapers.

Five days training programme sponsored by Agricultural Technology Management Agency on "Advanced technologies of Potato production and

management" was organized at ICAR-CPRI RS, Gwalior during 16-20 March, 2020.

In this training, Dr. S P Singh, in his address, detailed about production of breeder seed and research activities of the station. Subsequently, in the first session of the training, lectures were given on potato cultivation, potato irrigation and weed control and potato fertilizer management. During the training, detailed information was provided on the major pests and management of potato crop, necessary precautions during the use of agricultural chemicals and potato seed production techniques for production in Madhya Pradesh.

EXTENSION ACTIVITIES AT ICAR-CPRI, RS, OOTY

Exhibitions:

S. No.	Date	Beneficiary	Institution/Organization	No. of participants
1.	05.02.2020 to 08.02.2020	Farmers/Researchers	National Horticulture fair 2019 organised by ICAR -IIHR, Bengaluru, Karnataka	>1000
2.	28.2.2020	Students/ Researchers	Radio Astronomy Centre, TIFR, Muthorai, Ooty	>1000

Trainings:

S. No.	Date	Beneficiary	Institution/Organization	No. of participants
1.	06.01.2020	Students	Ramakrishna Mission Vivekananda College, Chennai, Tamil Nadu	10
2.	07.01.2020	Students	Ramakrishna Mission Vivekananda College, Chennai, Tamil Nadu	49
3.	20.01.2020	Students	Kerala Agricultural University, Thrissur, Kerala	15
4.	10.02.2020	Students	Alva's College (P.G Dept. of Botany), Moodubidire, Karnataka.	25
5.	05.03.2020	Students	J.K.K. Munirajah college of Agricultural Science, T.N Palayam, Erode (Final year B.Sc., Agri.), Tamil Nadu	81
6.	18.03.2020	Students	Alva's College (M.Sc., Biotechnology), Moodbidri, Karnataka.	25
7.	12.03.2020	Students	Annamalai University (II M.Sc., Agri.) - Faculty of Agriculture, Tamil Nadu	33
8.	16.03.2020	Students	Andavan Arts and Science College, Trichy, Tamil Nadu	46
9.	31.03.2020	Students	J.K.K. Munirajah college of Agricultural Science, T.N Palayam, Erode (Final year B.Sc., Agri.), Tamil Nadu	81

10.	24.03.2020	Farmers	Department of Horticulture -ATMA - Kodaikanal, Tamil Nadu	50
11.	21.10.2020	Students	Karunya Institute of Technology and Sciences (RAWE programme)	10
12.	28.10.2020	Students	Karunya Institute of Technology and Sciences (RAWE programme)	5
13.	18.12.2020	Students	Hindustan College, Coimbatore (RAWE programme)	2

OTHER EXTENSION ACTIVITIES

- On Farm Trials (OFT): OFTs were conducted during Summer season of 2020-2021 in farmer's field at three locations of Nilgiri district viz., Mulligur, Wellington and Needagula villages for popularization of newly released ICAR-CPRI varieties, Kufri Sahyadri (with combined resistance to late blight and potato cyst nematode) and Kufri Karan (with combined resistance to late blight, viruses and potato cyst nematode).
- Three villages viz., Kallakorai, Nedugula and Kallati were adopted under "MeraGaonMera Gaurav" and all the technical inputs related to potato production have been given during crop season.
- Scientist, ICAR-CPRI, RS, Ooty attended and delivered lectures on various aspects of potato cultivation to the state officials at monthly Zonal Workshops conducted by Dept. of Horticulture, The Nilgiris, Tamil Nadu, during 2020-21.

EXTENSION ACTIVITIES AT CPRS, SHILLONG (MEGHALAYA)

Demonstrations

A total of 15 Front line demonstration was conducted during 2021-21.

- Front Line Demonstration of "Improved potato cultivation method with high yielding varieties" was laid out in two districts of Meghalaya (Jaintia Hills and East Khasi Hills District) during 2020-2021. Improved potato cultivation method with high yielding varieties (K. Himalini and K. Girdhari) evaluated with conventional organic practices (*nur-bun method* of potato planting) was demonstrated in 04 farmers field.
- FLD of "Demonstration on cultivation of late blight disease resistant variety (K. Girdhari) under

conventional practices" was carried out at 10 farmers field in East Khasi Hills (EKH) District.

- FLD on "Improved low-cost storage technology" was conducted at 01 farmer's field with K. Himalini in EKH district.

Training conducted

One Day training (04 Days) on "Training & Orientation of Lead Farmers on Potato Seed Production" was conducted for four batches in which 72 farmers were trained. The training was conducted in collaboration with Meghalaya Basin development agency (MBMA).



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 84 documents were purchased, procured and added to library resources. The total collection at Shimla stands at 40018 documents comprised of 16473 books, 15780 back volume of journals, 2754 serials, 2262 annual reports, 586 theses, 251 standards, 51 maps/atlasses, 1663 reprints and 198 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 27998 books; journals back volumes and other documents i.e. AR/Reprints and Bulletins etc as per the details below (Table-1).

Table-1: Library Collection of CPRIC & CPRS

Regional Stations		Books	Back vols. of Journals	Other Documents (AR/Rpr/Bull)	Total	Current Journals subscribed (Indian)
1	CPRIC, Modipuram	4710	6014	2562	13286	06
2	CPRS, Jalandhar	3344	1591	463	5398	06
3	CPRS, Patna*	2098	1280		3378	09
4	CPRS, Gwalior	1187	4	75	1266	-
5	CPRS, Ooty	1674	580	564	2818	09
6	CPRS, Shillong	1540	-	168	1708	-
7	CPRS, Kufri	144	-	-	144	
TOTAL		14697	9469	3832	27998	30

Periodicals and Serials Management

A total of 121 current journals comprising of 16 foreign and 105 Indian is being subscribed at Shimla. Out of which 8 foreign and 93 Indian journals were subscribed on payment basis and rest 20 on exchange or gratis. However due to the COVID-19 pandemic the subscription of 1 Indian and 5 foreign journals could be renewed. In all 766 issues of such journals were received, marked and kept in library for use. Besides, 30 titles of different journals were subscribed

at CPRS libraries. 84 books were classified, catalogued, labeled, pasted and transcribed and entered in Library Automation Software for use. The library has the complete series of CABCD (till Dec. 2017 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, 5 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 web sites were visited and information and data were downloaded therefrom for scientists' use. 1047 Extension/Technical/Annual Reports/Station Annual Reports/Content Pages of Potato books available at CPRI library/Training Manuals/Newspaper clipping were scanned and uploaded in institute's website under the link "Institutional Repository of CPRI".

Readers and Reference Service

A total of 383 documents were circulated (borrowed and returned) for home studies and 1698 readers consulted 3127 documents within the library. Besides, 4 outside scientists and research scholars of various research organizations consulted the library resources. 1 new members were enrolled and 5 old members withdrew their library membership due to their transfer or retirement. At present 121 readers are active members of library including RAs/SRAs. Library received thousands of reference queries from the users of the library and responded to them satisfactorily. Besides, 234 job requests were received for 1,98,977 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

446 issues of journals (334 issues of national and 112 issues of international journals) were scanned for potato literature and 224 potato articles were found and recorded. Approximately, 84 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 4000 content pages of 870 potato books were scanned for integrating into institute's OPAC.

Resource Generation and utilization

The library has generated the revenue of Rs.7,764.00 which includes the amount charged on account of rendering CDROM searching & photocopying (Rs.6,164.00) and library discount on books (Rs.1600.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 2,40,456.00 was spent on purchase of library resources like books (Rs.14,045.00), and subscription of journals (Rs. 2,26,411.00) at HQ library Shimla.



PUBLICATIONS

Research articles published in Journals

1. Azizi AF, Sethi S, Joshi A, Singh AM, Raigond P, Singh MK, Yadav RK (2020). Biochemical and functional attributes of raw and boiled potato flesh and peel powders for suitability in food applications. *Journal of Food Science and Technology*. doi.org/10.1007/s13197-020-04424-3.
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Patent filed

1. Filed an Indian patent entitled “GLUTEN-FREE FLOUR COMPOSITION AND PRODUCTS THEREOF” for potato based gluten-free, ready-to-reconstitute jalebi (Application Number: 202111012301)

Technology transfer

1. Transferred the technology of Gluten-free potato cookies to M/s Goodrich Cereals, Karnal, Haryana on August 18, 2020.

Portal Developed

1. Shashi Rawat , RP Kaur, Shefali Sood, Vinod Kumar, SK Luthra, Vinay Bhardwaj, JK Tiwari & SK Chakrabarti. 2020. Potato Variety. ICAR-C P R I , S h i m l a w e b s i t e . (http://14.139.61.83/Potato_Variety/default.asp.)

INSTITUTE ACTIVITIES

Important Meetings, Events & Visitors

Global Potato Conclave organized at Gandhinagar, Gujarat

Indian Potato Association, Shimla in collaboration with Indian Council of Agricultural Research, New Delhi and ICAR-Central Potato Research Institute, Shimla organized Global Potato Conclave-2020 (GPC2020) at Mahatma Mandir, Gandhinagar, Gujarat during 28-31 January, 2020. The Conclave had three pillars, The Conference, Agri-Expo and Potato Field Day. The Conclave was inaugurated by the Hon'ble Prime Minister, Sh Narendra Modi ji in the presence of Chief Minister of Gujarat Sh. Vijay Rupani, Union Agriculture Minister Sh Narendra Singh Tomar, MOS for Agriculture Sh Parshottam Rupala, State Agriculture Minister Sh RC Faldu and other dignitaries.



The Conference and the Agri-Expo were held concurrently at Mahatma Mandir, Gujarat during 28-30 January 2020. The Conference was attended by over 400 delegates from India and abroad. More than 70 delegates from over 17 foreign nations also participated in the Conference. There were 14 Technical Sessions in the Conference which provided an opportunity for researchers to present their work and share their knowledge with national and

international scientists and academicians. Various issues related with trade and industries were also discussed during Panel Discussions.

In Agri-Expo, more than 70 companies exhibited their products. Which included farm implements, chemicals, processing units, storage solutions etc. Besides, seed companies also exhibited their varieties. The State Departments, SAUs, ICAR Institutes, several PSUs etc also participated in the Expo and demonstrated their products, technologies and research and extension activities being undertaken by them. About 1,500-2,000 visitors attended the Agri-Expo during three days.

The Potato Field Day was organised at Village Chandarala, Gandhinagar, which is about 25 km from Gandhinagar, on 31st January 2020. The live demo of the potato technologies and farm machineries were arranged in about 13 acres of land.

More than 10 companies participated in live demo which included demo of the potato varieties, drip and sprinkler irrigation systems, drone technology, potato planter and digger, potato grading machines, potato processing machines, aeroponic unit etc. Besides, in over 50 stalls, exhibitors demonstrated their products/technologies /implements etc. Over 3,000 farmers and other stakeholders attended this one day event.

CPRI celebrated its 72nd Foundation Day

ICAR-CPRI Shimla celebrated its 72nd Foundation Day on 9th September, 2020. Due to COVID-19 the foundation day was celebrated virtually. Dr. AK Singh, DDG (Hort. Sci.) ICAR, New Delhi was the chief guest of the event. On the occasion former directors of CPRI Dr. SK Chakrabarti, Dr. BP Singh, Dr. SK Pandey, Dr. SM Paul Khurana also joined in and shared their reminiscence at ICAR-CPRI. Dr. V Pandey, ADG (Hort. I) was also present as guests of honour. During the event Best Worker Awards were given to the staff of all categories of the institute.. Some institute publications were also released on the occasion. The programme was attended virtually by a number of farmers from nearby areas, students, ex-staff of the institute, scientists from other institutes, policy makers, entrepreneurs and other stake holders in agriculture and allied activities. They all were made aware about technologies of the institute.



Week-long celebrations before 150th Birth Anniversary of Mahatma Gandhi

To celebrate the two-year long commemoration of 150th Birth Anniversary celebration of Mahatma Gandhi, one-week program during Sept 26 – Oct 02, 2020 on Gandhian Philosophy was organised following social distancing and also through virtual mode. On September 26, Tribute to Mahatma Gandhi was paid by all the staff. On September 27, an Essay Writing Competition on the topic “Teachings of Mahatma Gandhi” and on September 28, painting competition with the theme: Mahatma Gandhi, was organised for the children of staff. On September 29, a Quiz competition on 'Life of Mahatma Gandhi' was organised in the Institute for the Staff. On October 01, Institute invited a special invitee: Dr. Girjesh

Shukla, Dean (Academics), HP National Law University Shimla for delivering a lecture on 'Philosophy of Mahatma Gandhi and Indian Constitution' to the staff of the Institute. Staff members from Institute's Regional Stations also joined the event through video conferencing. On October 02, concluding ceremony of week-long celebration of 150th Birth anniversary of Mahatma Gandhi was organised at the Institute. During this occasion, a Yoga session and Swachta Abhiyan/Cleaning campaign was organised at the Institute. Also, prize distribution ceremony was held in which the winners of the competitions were awarded mementos and certificates. The ceremony ended with remarks by the Director, CPRI Shimla.



Activities under Constitution-Day at ICAR-CPRI, Shimla (HP)

As per GOI/ICAR directions an awareness campaign focused on Citizen Duties including fundamental duties as enshrined in the Indian Constitution is to be conducted from 26th Nov., 2019 to 26th Nov., 2020, throughout the year. In this connection, a lecture on **“Constitutional amendments and their significance”** was delivered by Sh. Rajiv Rai, Advocate, High Court, Shimla (Invited Expert) with focus on main constitutional amendments viz. amendment no. 7, 24, 42, 44 & 86th organized on 23.1.2020. In continuation to the yearlong programmes in the month of February a talk on **“Constitution and citizen duties, Land legislation and Reform”** was delivered on 28.02.2020 in which more than 70 officials representing scientific/ technical/ administrative/supporting staff of the institute participated. The talk was delivered by Sh. Sandeep Singh Dudi, Administrative Officer, ICAR-CPRI, Shimla. He thoroughly elaborated various parts of constitution with special emphasised upon the act related to Land legislation and the reforms that has taken place in the constitution. The talk was highly interactive and the listeners also participated enthusiastically.



"Potato Day" celebrated at Central Potato Research Institute

"Potato Day" was organized on 15 February 2020 by ICAR-Central Potato Research Institute at its Regional station, Modipuram. On this occasion, a farmers' seminar was organized to increase the knowledge of the potato growers, in which the experts of the institute gave information about advanced techniques of potato production- like advanced varieties, crop production activities, plant protection, storage etc. and farmer's problems were resolved. On

this occasion, the officials of State Bank of India, the associate of the event, gave information about the agricultural schemes of the bank to the farmers and responded to their queries. Agriculture / potato quiz was also organized for the farmers present on the occasion, based on the answers given; the winning farmers were selected for the award. A small exhibition to showcase potatoes and other techniques for the enlightenment of farmers was also organized on this occasion.

The chief guests of the event was Dr. S K Chakrabarti, Director of the Institute, Joint Director of the Station welcomed all the distinguished guests and farmers. In his presidential address, Director advised farmers to take up farming, especially potato, at a commercial level, so that farmers can increase their income by lowering input cost and high quality production to meet the challenges. On this occasion, farmers who made significant contributions in the field of potato production were honoured and the winners of the quiz were also awarded.

26th Regional Committee Meeting for region-1 held through Video Conferencing

ICAR-CPRI, Shimla organised 26th Regional Committee-I meeting virtually of the Indian Council of Agricultural Research on 30th June, 2020 through video conferencing. The committee covered two states i.e. Himachal Pradesh and Uttarakhand and two union territories i.e. Jammu & Kashmir and Ladakh. The regional Committees meet biennially to discuss and review the current status of agricultural research, education and extension to critically examine various problems faced by the region either in the execution of the approved programmes or in tackling the emergent problems and identify gaps for research by





Agricultural Universities or in transfer of known technologies by extension agencies. The committee provides a good forum for a meaningful dialogue amongst research and development agencies and also to bridge the gap between research and extension in the fields of agriculture, horticulture, animal husbandry, fisheries and agro-forestry. It helps in forging an effective liaison and coordination amongst ICAR Institutes, State Agriculture Universities and Departments of Agriculture, Horticulture, Animal Husbandry and Fisheries of the respective state governments/ UTs. This year almost 170 participants took part in this meeting. The meeting was chaired by Dr. T. Mohapatra, DG, ICAR and Secretary, DARE, Govt. of India. On this occasion Hon'ble Minister of State for Agriculture and Farmers Welfare, Govt. of India Sh. Parshottam Rupala and Sh. Kailash Choudhary were present. The chief guest of the meeting Sh. Narendra Singh Tomar Hon'ble Minister of Agriculture and Farmers Welfare, Govt. of India in his presidential address stressed upon organic farming and value addition for enhancing farmers' income. Sh Subodh Uniyal and Sh. Ram Lal Markanda the Ministers of Agriculture of Uttarakhand and Himachal Pradesh respectively also elaborated about the farmer's situation, their problems and ways for enhancing farmer's income. The Vice Chancellors, Directors Research, Scientists from Himachal Pradesh, Uttarakhand, Jammu & Kashmir and Ladakh, Member ICAR General Body, Farmers from all four states/UTs were also present in the meeting. Several recommendations emerged out after thorough discussion. Publications related to package of practices for respective states were also released during this meeting. Virtual plantation at ICAR-CPRI, Shimla was also organised. The meeting ended with a vote of thanks to the chair person.

International Day of Yoga (IDY) Celebration at ICAR-CPRI, Shimla

International Day of Yoga (IDY) was celebrated by all staff members of Institute along with their family members on 21st of June 2020 from their respective homes due to COVID-19 pandemic in the country. Two experienced Yoga teachers (Art of Living), Ms. Dhara Saraswati Ji and Shri Abhay Sharma Ji were invited to conduct the yoga session. The Aasans, Pranayam and Dhyana of Yoga were demonstrated online by the teachers and performed by all staff members, research scholars and all participants of the ongoing training at the institute. The yoga teachers also explained the beneficial effects of all the demonstrated Aasans, Pranayam and Dhyana techniques. Various online resources pertaining to IDY available on the Ministry of AYUSH website were utilized by several staff members for performing the Yoga. In total, around 400 persons of the Institute participated in the IDY-2020 celebrations.

Institute Management Committee meeting held at Shimla

Institute Management Committee held at ICAR-CPRI, Shimla on 7th December, 2020. Dr. Manoj Kumar, Director, ICAR-CPRI, Shimla chaired the meeting. Dr. Naresh Kr. Badhan, Director (Ag.) HP Govt., Dr. Kallol Pramanick, Head, IARI Regional Station, Shimla, Sh. Rajesh Kr. Garg and Sh. Devender Thakur Koonpuri, Farmer members attended the meeting at the Institute whereas other three external members viz. Dr. Arjun Kr. Saini, DG, Horticulture, Haryana,; Sh. Jagdish Chander, FAO, IIWBR, Karnal and Dr. Vijay Mahajan, Pr. Scientist, Directorate of Onion & Garlic Research, Pune attended the meeting through virtual platform. Dr. Brajesh Singh, Head; Sh. Raj Kumar, SF&AO and Sh. Sandeep Singh Dudi, AO, ICAR-CPRI, Shimla attended this meeting as Special Invitees to provide vital inputs to the IMC. Dr. Manoj Kumar welcomed all the invitees of this meeting and in his address, he stressed upon taking all such measures and initiatives in consideration which can lead to benefit of the Institute and its staff. In this meeting, various issues were discussed like Confirmation of the proceedings of the Institute Management Committee meeting held on 24th March., 2020 at CPRI, Shimla and action taken report, Replacement of two more medical practitioners to act as AMA's for the medical treatment in respect of employees of ICAR-CPRI, Shimla for the

year 2020-21, Allotment of vacant Type 1 quarters to RA/SRF/JRF etc hired under various projects, Reservation of Type 5 quarter for CAO in accordance to ICAR House allotment rules, approval for change of usage of 12 Nos. (Type-I&II) old residential quarters at CPRIC, Modipuram & to utilize them for other purposes such as seed storage etc. and discussion was held on outstanding audit paras. The meeting ended with vote of thanks by Dr. Pankaj Kumar, CAO & Member Secretary, ICAR-CPRI, Shimla.



Research Advisory Committee Meeting

The 26th meeting of the Research Advisory Committee (RAC) was held at the ICAR-Central Potato Research Institute, Shimla on 23rd July 2020 (through virtual mode) under the Chairmanship of Prof. KV Peter, Ex-Vice Chancellor, Kerala Agricultural University, Trissur. Special Invitee Dr. AK Singh, DDG (HS), ICAR, New Delhi, Members: Dr. PS Naik, Former Director, ICAR-IIVR, Varanasi; Dr. U.S Singh, CIP, New Delhi; Dr. Madan Pal, Principal Scientist, IARI, New Delhi; Dr. P.S BIRTHAL, Principal Scientist, NIAEPR, New Delhi; Dr. VK Pandey, ADG (HS-I) (Acting); Dr. Manoj Kumar, Director (Acting), ICAR-CPRI, Shimla; Dr. VK Dua, Member-Secretary, RAC, ICAR-CPRI, Shimla and IMC Non-official member Sh. Rajesh Kumar Garg, participated in the meeting. All the scientists from the headquarters and regional stations also joined the meeting through video conferencing. After the deliberations & discussions on all the ongoing



programmes, recommendations were made for each ongoing research programme which have also been approved by the Council

Institute Research Committee Meeting

The Institute Research Committee Meeting (IRC), 2020 was held at through virtual mode due to pandemic situation during 25th to 28th August, 2020 under the Chairmanship of Dr. Dr. Manoj Kumar, Director (Acting), ICAR-CPRI, Shimla. Dr. Vikramaditya Pandey ADG (Hort Sci.-I) and Dr. BK Pandey, ADG (Hort Sci.-II) also attended the meeting as a special invitee. This meeting was attended by most of the scientists from the headquarters and regional stations. The basic objective of this meeting was to review the research achievements under different ongoing programmes. Overall achievements of the Division were presented by respective Divisional Heads. Scientists also made individual presentations regarding the research achievements and proposed work plan for the next year. Ten new programmes were initiated from April 2020. On the basis of detailed deliberations, many decisions were made and which are being implemented.



Vigilance awareness week 2020 Observed

Vigilance awareness week was observed at ICAR-CPRI, Shimla and its regional stations from 27th October to 02nd November, 2020. On the first day i.e. 27th October, the entire staff of the institute took oath of integrity and pledged to fight against corruption. During the week a number of competitions were organized for the staff of the institutions in which the staff members took part with great enthusiasm. On 28th October an essay competition was organized, on 29th October a debate competition was organised and on 31st October a quiz competition was organised. All these competition had a common theme of corruption eradication and a vigil on offensive activities. On 2nd November the week long observation came to an end with the concluding

ceremony which was presided over by Sh. Vijay Sharma, DSP, State Vigilance & Anti-Corruption Bureau, HP. In his address he emphasized upon being vigilant all the time on the workplace and be aware of laws, rules and compliance mechanism in the conduct of our official work. On this occasion Dr. Manoj Kumar, Director and Dr. Pankaj Kumar, CAO also addressed the staff and conveyed that we shall practice ethical work and commit to good governance based on transparency and fairness. Dr. NK Pandey, Institute Vigilance Officer, CPRI in his address told the staff to be vigilant and uphold high standards of honesty and integrity. The winners of the competitions held during the said week were awarded with certificates and mementoes for their efforts.



Swachta Abhiyan 2020 (Swachhta hi Seva) pakhwara celebrated at ICAR-CPRI, Shimla

Swachhta Pakhwara was celebrated in the institute during 16 to 31 December. It started with an oath taking ceremony on 16th December regarding keeping our surrounding clean be it our home, workplace or neighbourhood thereby contributing in the cleanliness in the entire nation. Along with regular cleanliness drives during the period certain special actions were also undertaken like on 22nd December a plantation drive was undertaken in which the staff of the institute planted flowers and other plants in the garden of the institute. On 23rd October a lecture on

the importance of cleanliness was delivered to the supporting staff who generally contributes more and holds the responsibility of cleaning by Sh. SS Dudi, AO. Also a feedback was taken from them. Altogether it was an interactive session.

As a part of the concluding of Swachhta Pakhwara celebration of the institute, a one full day cleanliness drive was organised at the institute and its regional stations on 30th December. On this occasion Smt. Satya Kaundal, Mayor MC, Shimla was the chief guest along with Sh. Puran Chand, Councillor of Kanlog ward was guest of honour. The celebration started with cleaning of the institute and its nearby areas as well as the roads connecting the institute. They also contributed in the cleanliness and also visited the lower lab area of the institute for inspection purpose. She praised the staff for the upkeep of the institute. The function ended with a speech of the director towards maintaining cleanliness in the daily routine.



TRAINING AND CAPACITY BUILDING

Training and capacity building programmes/ conference/ seminar/ symposium/ workshop etc attended by Scientific, Technical and Administrative staffs of ICAR-CPRI, Shimla in 2020.

National Trainings

Sl. No	Name of Employee	Training Programme	Date & Venue
1.	Sh. Sandeep Dahiya, AAO, CPRI, RS, Modipuram and Sh. Krishan Lal, Assistant, ICAR-CPRI, Shimla	Off Campus Training Programme on Administrative & Finance Management for Section Officers/ AAO/AFAO/JAO/ Assistants of Headquarters/ Institutes	05-11 February, 2020 at ICAR-CIFT, Cochin
2.	Sh. Milan Kumar Lal, Dr. Nishant Chourasia and Sh. Subhash S., Scientists, ICAR-CPRI, Shimla	Short training course on “Flow cytogenetics and molecular techniques for improvement of horticultural crops	10-19 February, 2020 at ICAR-CPRI, Shimla
3.	Dr. Kapil Kumar Sharma, ACTO, ICAR-CPRI, Shimla	Training programme on “Filed Diagnosis and Management of Plant Parasitic Nematodes”	09-13 March, 2020 at NIPHM, Hyderabad
4.	Dr. Preeti Singh, Scientist, ICAR-CPRI, Shimla	Training course on “Sequencing methods and applications for microbial identification”	17-21 March, 2020 at ICAR-NBAIM, Mau
5.	Dr. Devendra Kumar, PS, ICAR -CPRI, RS, Modipuram	Online Training programme on “Stress Management”	07 – 10 July, 2020
6.	Ms. Vandana Parmar, T -1, Sh. Rakesh Kumar, T-1, ICAR-CPRI, Shimla	Online Training programme on “Laboratory quality system management and internal audit as per ISO/IEC 17025:2017”	27 – 31 July, 2020
7.	Dr. Mohammad Abbas Shah, Scientist, ICAR-CPRI, RS, Jalandhar Dr. Subhash Katore, Scientist, ICAR – CPRI, RS, Gwalior	Online training programme on “Im pact of climate change on pests”	07 – 11 September, 2020
8.	Dr. Ratna Preeti Kaur, Scientist, CPRI, RS, Jalandhar, Dr. Sushil Changan, Scientist and Dr. Kumar Nishant Chourasia, Scientist, ICAR - CPRI, Shimla	Online Training programme on “Advanced Bio-informatics tools and its application in agriculture”	14 – 19 September, 2020
9.	Dr. Baswaraj Raigond, Scientist, ICAR – CPRI, Shimla	Online short term course on “Intellectual Property Rights”	19 – 20 November, 2020
10.	Dr. Anil Kumar Choudhary , Scientist, ICAR – CPRI, Shimla	Online Training programme on “Right to Information”	19 – 20 November, 2020 at ISTM, New Delhi

Sl. No	Name of Employee	Training Programme	Date & Venue
11.	Dr. Sushil Changan, Scientist, ICAR – CPRI, Shimla	Online Training programme on “Analysis of experimental data using SAS”	09 – 17 November, 2020
12.	Dr. Shashi Rawat, PS, ICAR – CPRI, Shimla	Online Training course on “Cyber Security”	16 December, 2020
13.	Dr. Vinay Bhardwaj, PS, ICAR-CPRI, Shimla, Er. Sukhwinder Singh, Scientist, ICAR -CPRI, RS, Jalandhar and Dr. Rajender Singh, RA, ICAR – CPRI, Shimla	Virtual workshop – cum – training on “Intellectual Property Rights in Agricultural Research & Education in India”	12 – 28 September, 2020 at New Delhi
14.	Dr. Tanuja Buckseth	Online Training Programme “ Analysis of Experiemtal Data using R” .	5-11 August, 2020 at ICAR-NAARM

Other Trainings

1.	Sushil Sudhakar Chagan, Kumar Nishant Chourasia, Rahul Kumar Tiwari, Ratna Preeti Kaur	Advanced Bioinformatics Tools and its Applications in Agriculture	September 14-19, 2020
2.	Anuj Bhatnagar, RK Singh	Role of Technology in Community Level Disaster Mitigation	February 01-05, 2021
3.	SP Singh	Integrated Nutrient Management and Nutrient Budgeting through Advanced Models to improve crop productivity	January 18-22, 2021
4.	Sarla Yadav	Online Hands -on Advanced Bio Image Analysis Course by C-CAMP	October 26,28 & 30, 2020
5.	Subhash Katore, Mohammad Abbas Shah	Impact of Climate change on pests	September 07-11, 2020
6.	Shashi Rawat	Cyber Security	December 16, 2020
7.	Vandana Parmar, Rakesh Kumar	Laboratory Quality System Management and Internal Audit as per ISO/IEC 17025:2017	July 27-31, 2020
8.	Ram Dayal, Deep Ram, Neem Chand, Anil Kumar Dube, Parmesh Dutt, Sabarius Nongrum, Ram Dass Rai, Munna Lal, Jaswinder Singh, Narendra Mayer, Pawan Kumar, Alakh Narain, Pravesh Kumar Yadav, Ved Singh, Madan Pal, Shubash Chand, Pawan Kumar Malik, Arjun Dass, Nisha Verma, Vivek Kumar, Sanjay Kumar, Siddharth Saroha, Sanjeev Kumar Meena, Rishav Kumar, Vineeta Sharma, Sumit Kumar, Rohit Verma, Sonam, Rahul, Virendra Kumar, Vinod Kumar Meena, Ajaya Kumar, Bijendra Singh, V. Rajendran, UPPaudel,	2-days Online Training on Use of IT Technology & related aspects	January 28-29, 2021

Sl. No	Name of Employee	Training Programme	Date & Venue
	Kedar Singh, RK Samadhiya, Praveen Kumar, Tara Chand, Mohan Lal, YP Singh, Ram Jeevan, Chet Ram, Sheesh Ram Thakur, Avnish Kumar Attrey, Jagdish Chand, Hari Kishore, Naresh Kumar Thakur, Vijay Kumar, Ravinder Kumar, Liaq Ram, Surinder Pal, Roop Lal, Mansha Ram, Satpal Singh, Alekh Narain, Ashok Kumar, Sneh Lata Pawan Kumar, Mohit Oberoi, Bimla Salhotra, Rajesh Kumar, Jaspal Singh Suraj Singh, Sunil Kumar, Rajesh Chauhan, Pratish Kumar Patel Omvir Singh, Subash Chand, Yogendra Pal Singh, Lal Babu Dass,		
10.	Santosh Kumar, Kapil Kumar Sharma	Sub Masters Training programme for Farm Act 2020	October 27, 2020
11.	Sachin Kanwar	Handling Parliamentary Matters	January 28-29, 2021
12.	Raj Kumar	Training on Accrual Accounting	January 12-14, 2021
13.	Rakesh	Noting & Drafting	March 15-17, 2021
14.	Saran, Munni Devi, Roop Singh Jia Lal, Raj Kumar, Murari, Mukesh, Ram Phal, Rajpal, Sudesh Pal, Mani Ram, Som Pal, Amirrudin, Jagtey, Rajbir Singh, Gyanendra Kumar, Jagai Ram, Tejbir Singh	Office Procedure and Etiquettes	March 23-24, 2020
15.	Komal, Satnam, Passo, Ram Lubhaya, Paramjit Singh, Jagat Ram, Sukhwinder Dass, Raw Swarup, Ram nath, Jagan Nath, Rashpal Devi	Office Procedure and Etiquettes	December 21-22, 2020

AWARDS AND HONOURS

Sr. No.	Name of the the Person	Category	Year
1.	Dr Sanjeev Sharma and Dr. Baswaraj Raigond, ICAR-CPRI, Shimla	Scientific	2020
2.	Sh. KP Singh, ICAR-CPRI, RS, Modipuram and Sh. Dev Raj and Sh. Roop Lal (Jointly), ICAR-CPRI, Shimla	Technical	2020
3.	Sh. Amar Chand and Sh. CP Sharma, ICAR-CPRI, Shimla	Administrative	2020
4.	Sh. Murari, ICAR-CPRI, RS, Modipuram and Sh. Ramphal, ICAR-CPRI, RS, Modipuram and Sh. Saran (Jointly), ICAR-CPRI, Shimla	Supporting	2020

- Awarded ICAR- Lal Bahadur Shastri Outstanding Young Scientist Award – 2019 (for Crop & Hort. Sci.) to Dr. Jagesh Kumar Tiwari, Senior Scientist, Division of Crop Improvement, ICAR-CPRI, Shimla.
- Dr. Brajesh Singh was awarded Fellowship of National Academy of Agricultural Sciences (NAAS), New Delhi for the year 2021.
- Dr. Brajesh Singh bagged JJ Chinoy Gold Medal Award (2020) in Plant Physiology from Indian Society for Plant Physiology, New Delhi.
- Received best oral presentation award by Aarti Bairwa et al. (2020). Loop-mediated isothermal amplification (LAMP) for rapid and precise detection of the golden nematode of potato, *Globodera rostochiensis* directly from soil. *In*: International Web-Conference on “New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development (NTAEBSID- 2020)” on 21st-22nd June, 2020.
- Awarded Young Scientist Woman Award to Aarti Bairwa by Agro Environmental Development Society (AEDS), Rampur, UP on June 21-22, 2020 on the occasion of International Web-Conference.
- Received best poster presentation award by Rahman FA et al. (2020). Studies on development of single row potato digger for hill terrain farming. *In*: Global Potato Conclave, Roadmap for better world, held at Mahatma Mandir, Gandhinagar, Gujarat, India on 28th-31st January 2020. Pp:96-97.
- Received best poster presentation award by Rahul Kumar Tiwari et al. (2020). Standardization of protocol for *Chaetomium globosum* mediated synthesis nano silver and evaluation of its antifungal properties. *In*: Global Potato Conclave, Roadmap for better world, held at Mahatma Mandir, Gandhinagar, Gujarat, India on 28th-31st January 2020. p:116.
- Received best oral presentation award by Berliner, J. et al. (2020). Mapping of nematode in Nilgiris using GIS technique. *In*: IPS South Zone Virtual Symposium on Advances in Crop Health Management, Organized by Organized by Indian Phytopathological Society (South Zone Chapter) and ICAR-Indian Agricultural Research Institute Regional Station, Wellington, TN, during 1st-2nd December 2020.
- Received best poster presentation award by Baswaraj Raigond et al. (2020). Development of RT-LAMP assay: a novel diagnostic technique for detection of Groundnut bud *necrosis* virus causing potato stem necrosis disease. *In*: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
- Received best oral presentation award by Ravinder Kumar et al. (2020). Development of one-step RT-LAMP for visual detection of Potato virus M. *In*: International conference on 'Multidisciplinary approaches for plant disease management in achieving sustainability in agriculture' organised by Department of Plant

- Pathology, College of Horticulture, Bengaluru, University of Horticultural Sciences, Bagalkot, India during 6-9th October, 2020.
11. Drs. Sanjeev Sharma and Ravinder Kumar received certificate of appreciation from Indian Potato Association, Shimla for their invaluable contribution in organization of Global Potato Conclave 2020 held at Gandhinagar, Gujarat (India).
 12. Received best poster presentation award by Ashwani Kumar Sharma et al. (2020). Studies on production behavior of aerial vs. normal aeroponic tubers under protected conditions. In: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
 13. Received best poster presentation award by Ashwani Kumar Sharma et al. (2020). Optimization of inter and intra row spacing and canopy management for production of seed size tubers in potato. In: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
 14. Received best oral presentation award by Tanuja Buckseth et al. (2020). Evaluation of the performances of newly released potato varieties under aeroponics. In: International Web Conference: Perspective on Agricultural and Applied Sciences in COVID-19 Scenario (PAAS-2020, October 4-6).
 15. Dr SK Luthra et al. were awarded best paper award of Indian Potato Association medal for "Breeding for coloured flesh potatoes: Molecular, agronomical and nutritional profiling" published in Potato Journal (2018, Volume 45). Global Potato Conclave, Roadmap for a Better World, 28-31 Jan. 2020, Gandhinagar, Gujarat.
 16. Received best poster presentation award by Sundaresha S et al. (2020). CRISPR editing of potato phytoene desaturase (PDS) gene as a proof of concept for genome editing in potato. In: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
 17. Received best oral presentation award by Salej Sood et al. (2020). Genomic selection for enhanced genetic gain in potato breeding. In: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
 18. Dr Vinay Bhardwaj acted as Course Co-ordinator for ICAR sponsored short course entitled, 'Flow Cytogenetics and Molecular Techniques for Improvement of Horticulture Crops organised w.e.f. 10-19th Feb, 2020 at ICAR-CPRI Shimla.
 19. Drs. Manoj Kumar, Brajesh Singh, Jagdev Sharma, Sanjeev Sharma, Vinay Bhardwaj, Ravinder Kumar acted as organizing Secretary, Global Potato Conclave, Roadmap for a Better World, 28-31 Jan. 2020, Mahatma Mandir, Gandhinagar, Gujarat.
 20. Received best poster presentation award by Angmo D et al. (2020). Potato (*Solanum tuberosum* L.) clones exhibited differences for frost tolerance associated leaf morpho-anatomical traits. In: Global Potato Conclave-2020 Roadmap for a Better World during 28-31st January, 2020 at Mahatma Mandir, Gandhinagar, Gujarat which was organized by Indian Potato Association (IPA).
 21. Dr. Tanjua Buckseth received Young Women Scientist Award on the occasion of International web conference on New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development (NTAEBSID-2020) organized by Agro Environmental Developmental Society (AEDS) during 21-22 June, 2020.
 22. Dr. Tanuja Buckseth received Young Scientist Award from Agriculture & Environmental Technology Development Society (AETDS) during International Web Conference (4-6 October, 2020)



STAFF POSITION

NAME OF STAFF AT ICAR-CPRI, SHIMLA & ITS REGIONAL STATIONS AS ON 31.12.2020

SCIENTIFIC

AICRP-Potato Unit

1. Dr. Vinod Kumar, Principal Scientist

Division of Crop Improvement & Seed Technology

2. Dr. Rajesh Kumar Singh, Principal Scientist & Head

3. Dr. Vinay Bhardwaj, Principal Scientist

4. Dr. Jagesh Kumar Tiwari, Senior Scientist

5. Dr. Salej Sood, Scientist

6. Dr. (Mrs.) Tanuja Buckseth, Scientist

7. Sh. Hemant Balasaheb Kardile, Scientist

8. Sh. VU Patil, Scientist

9. Dr. Kumar Nishant Chourasia, Scientist

Division of Crop Production

10. Dr. Vijay Kumar Dua, Principal Scientist & Officiating Head

11. Dr. Jagdev Sharma, Principal Scientist

12. Dr. Anil Kumar Choudhary, Senior Scientist

13. Sh. Paresh Baldeorao Chaukhande, Scientist

Division of Social Sciences

14. Dr. NK Pandey, Principal Scientist & Officiating Head

15. Sh. Pynbianglang Kharumunid, Scientist

Division of Plant Protection

16. Dr. Sanjeev Sharma, Principal Scientist and Officiating Head

17. Dr. Vinay Sagar, Principal Scientist

18. Dr. Baswaraj Raigond, Senior Scientist

19. Dr. Sundaresha S., Scientist

20. Dr. Ravinder Kumar, Scientist

21. Dr. Gaurav Verma, Scientist

22. Dr. (Ms.) Aarti Bairwa, Scientist

23. Dr. Kailash Chandra Naga, Scientist

24. Sh. Rahul Kumar Tiwari, Scientist

Division of CPB & PHT

25. Dr. Brajesh Singh, Principal Scientist & Officiating Head

26. Dr. Som Dutt, Principal Scientist

27. Dr. (Mrs.) Pinky Raigond, Scientist

28. Dr. Changan Sushil Sudhakar, Scientist

29. Dr. Dharmendra Kumar, Scientist

30. Sh. Milan Kumar Lal, Scientist

AKMU

31. Dr. Shashi Rawat, Principal Scientist & Incharge

ICAR-CPRI, Kufri-Fagu Unit

32. Dr. Ashwani Kumar Sharma, Principal Scientist & Incharge

33. Dr. (Ms.) Dalamu, Scientist

ICAR-CPRI, RS, Modipuram

34. Dr. Manoj Kumar, Principal Scientist & Joint Director

35. Dr. Devendra Kumar, Principal Scientist

36. Dr. SK Luthra, Principal Scientist

37. Dr. Name Singh, Principal Scientist

38. Dr. Vinay Singh, Principal Scientist

39. Dr. Anuj Bhatnagar, Principal Scientist

40. Dr. Sanjay Rawal, Principal Scientist

41. Dr. Dhruv Kumar, Principal Scientist

42. Dr. Vijai Kishore Gupta, Principal Scientist

43. Dr. (Mrs.) Babita Chaudhary, Principal Scientist

44. Dr. Mehi Lal, Senior Scientist

45. Dr. (Ms.) Bandana, Scientist

46. Dr. (Ms.) Pooja Praful Mankar, Scientist

47. Dr. Subhash. S, Scientist

ICAR-CPRI, RS, Jalandhar

48. Dr. Raj Kumar, Principal Scientist & Officiating Head

49. Dr. Anil Sharma, Principal Scientist

50. Er. Sukhwinder Singh, Scientist (SG)

51. Er. Sunil Gulati, Scientist (SG)

52. Dr.(Ms) Ratna Preeti Kaur, Scientist

53. Dr. Prince Kumar, Scientist

54. Dr. (Mrs.) Sugani Devi, Scientist

55. Er. Brajesh Nare, Scientist

56. Dr. Arvind Kumar Jaiswal, Scientist
57. Dr. Sunayan Saha, Scientist
58. Dr. Mohd. Abas Shah, Scientist

ICAR-CPRI, RS, Gwalior

59. Dr. Shiv Pratap Singh, Principal Scientist & Officiating Head
60. Dr. Murlidhar .J. Sadawarti, Scientist
61. Dr. Subhash Katare, Principal Scientist

ICAR-CPRI, RS, Shillong

62. Dr. Ngursangzuala Sailo, Scientist & Officiating Head
63. Ms. Clarissa Challam, Scientist
64. Sh. Bappi Dass, Scientist
65. Dr.(Mrs.) P Janani, Scientist

ICAR-CPRI, RS, Muthorai (Ooty)

66. Dr. EP Venkatsalam, Principal Scientist & Incharge
67. Mrs. Divya K. Lekshmanan, Scientist
68. Dr. Mhatre Priyank Hanuman, Scientist

ICAR-CPRI, RS, Patna

69. Dr. Shambhu Kumar, Principal Scientist & Officiating Head
70. Dr. Raj Kumar Singh, Senior Scientist
71. Dr. (Mrs.) Sarala Yadav, Scientist

TECHNICAL

ICAR-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. Parvesh Jassal, ACTO
9. Sh. Kameshwar Sen, ACTO
10. Sh. Avinish Kumar Atrey, ACTO
11. Sh. Chander Mohan Singh Bist, ACTO
12. Sh. Yogesh, CTO
13. Sh. Harvinder Singh (Overseer Civil), STO
14. Smt. Shruti Gupta, STO
15. Sh. Vinod Kumar, STO

16. Sh. Tilak Raj, STO
17. Sh. Dharam Prakash Gautam, TO
18. Sh. Kana Singh Chauhan, STO
19. Sh. Sheesh Ram Thakur, TO
20. Sh. Sushil Singh, TO (Driver)
21. Sh. Naresh Kumar Sharma, TO
22. Sh. Naresh Chand, TO
23. Smt. Manjeet Syal, STA
24. Smt. Madhu Bala, STA
25. Smt. Asha Thakur, TO
26. Sh. Hari Kishore, STA
27. Sh. Ram Singh, STA
28. Sh. Dharminder Kumar Gupta, TO
29. Sh. Rajinder Kumar, TO
30. Sh. Rakesh Kumar Patyal, TO
31. Sh. Roop Lal, STA (Driver)
32. Sh. Ravinder Kumar, STA
33. Sh. Naresh Kumar, STA
34. Sh. Ranjesh Bhardwaj, STA
35. Sh. Deep Ram, STA
36. Sh. Ashok Kumar, STA (Driver)
37. Sh. Rakesh Kumar, STA
38. Smt. Jatinder Kaur Arora, STA
39. Sh. Jagdish Chand (Welder), TA
40. Sh. Jagdish Chand (Carpenter), ST (T-I-3)
41. Sh. Dev Raj, ST
42. Sh. Ram Dayal, ST
43. Sh. Parmesh Dutt, ST
44. Sh. Anil Kumar Dube, ST
45. Sh. Neem Chand, ST
46. Sh. Laiq Ram, ST
47. Sh. Surinder Pal, ST
48. Sh. Mansha Ram, Technician
49. Sh. Arjun Dass, Technician
50. Sh. Sh. Vivek Kumar, Technician
51. Sh. Rahul, Technician
52. Sh. Sanjay Kumar, Technician
53. Sh. Rakesh Kumar, Technician
54. Smt. Sonam, Technician
55. Miss Vandana Parma, Technician
56. Miss Vineeta Sharma, Technician

ICAR-CPRI, Kufri -Fagu Unit

57. Sh. Kapil Kumar Sharma, ACTO
58. Sh. Santosh Kumar, ACTO
59. Sh. Kedar Singh, TO
60. Sh. Ajit Singh, STA
61. Sh. Ram jivan, STA
62. Sh. Mohan Lal, SA

ICAR-CPRI, RS, Modipuram station

63. Sh. Mahipal Singh Bharti , CTO
64. Sh. Harvir Singh, CTO
65. Dr. Ashok Kumar, CTO
66. Sh. Krishan Pal Singh, CTO
67. Sh. Ompal, ACTO
68. Smt. Kusum Singh, ACTO
69. Sh. Harvir Singh, STO
70. Sh. Murari Lal, ACTO
71. Sh. Omvir Singh, STO
72. Sh. Subhash Chand, ACTO
73. Smt. Vineet Sharma, ACTO
74. Sh. Avinash Chaudhary, ACTO
75. Sh. Dinesh Singh, ACTO
76. Sh. Pushpendra Kumar, STO
77. Dr. Sanat Kumar, STO
78. Sh. Udai Vir Singh, STO
79. Sh. Ved Singh, STO
80. Sh. Krishan Pal Singh, TA
81. Sh. Udhha Prasad Paudel, TA
82. Sh. Sayed Danish Abbas Rizvi, STA
83. Sh. Pawan Kumar Malik, TO
84. Sh. Mahesh Pal Singh, TA (T-I-3)Driver
85. Sh. Vipin Kumar, TA (Driver)
86. Sh. Madan Pal, ST
87. Sh. Satpal Singh, ST
88. Sh. Siddharth Saroha, Technician
89. Sh. Rohit Verma, Technician
90. Sh. Ajay Kumar, Technician

ICAR-CPRI, RS, Jalandhar

91. Sh. Munna Lal, ACTO
92. Sh. Jaswinder Singh, ACTO
93. Sh. Yogesh Kumar Gupta, ACTO
94. Sh. Akhilesh Kumar Singh, ACTO
95. Sh. Parveen Kumar, TO

96. Sh. Som Dutt Randev, STA (Driver)
97. Sh. Narinder Mayer, TO
98. Sh. Kulwinder Singh, TO
99. Sh. Anil Kumar Chandel, STA
100. Sh. Pardeep Kumar Upadhaya, TO
101. Sh. Vijay Kumar, STA
102. Sh. Pawan Kumar, STA
103. Sh. Virender Kumar, Technician

ICAR-CPRI, RS, Gwalior

104. Dr. Yogendra Pal Singh, ACTO
105. Dr. Sanjay Kumar Sharma, STO
106. Sh. Shyam Kumar Gupta , STO
107. Sh. Rajender Kumar Samadhiya, STO
108. Sh. Surendar Singh, TO
109. Sh. Radha Kishan, TA (T-I-3)Driver
110. Sh. Nihal Singh, TA
111. Smt. Nisha Verma Hindi Translator (TA)
112. Sh. Tara Chand, ST
113. Sh. Chet Ram, ST
114. Sh. Vinod Kumar Meena, Technician

ICAR-CPRI, RS, Patna

115. Sh. Arun Kumar Singh, CTO
116. Sh. Arjun Kumar Sharma, STO
117. Sh. Rakesh Srivastava, TO
118. Sh. Anil Kumar, TO
119. Sh. Alekh Narain, TO
120. Sh. Narendra Kumar, ST
121. Sh. Lal Babu Dass, STA (Driver)
122. Sh. Sunil Kumar Singh, ST
123. Sh. Pravesh Kumar Yadav, ST
124. Sh. Rishav Kumar, Technician
125. Sh. Pratish Kumar Patel, Technician
126. Sh. Sanjeev Kumar Meena, Technician

ICAR-CPRI, RS, Shillong

127. Sh. Ram Das Rai, TA (T-I-3)Driver
128. Sh. Phishalis Roy Khongbuh, TA
129. Sh. Sabarius Nongrum, ST
130. Sh. Sumit Kumar, Technician

ICAR-CPRI, RS, Muthorai

131. Sh. V. Rajendran, TO
132. Sh. R Lakshmanan, STA
133. Sh. B. Suresh, ST

ADMINISTRATIVE ICAR-CPRI, Shimla

1. Dr. Pankaj Kumar, CAO
2. Sh. Sandeep Singh Dudi, AO
3. Sh. Raj Kumar, SFAO
4. Sh. Chander Prakash, AFAO
5. Dr. Ashish Dhangar, AFAO (on lien)
6. Sh. Joginder Singh Thakur, AAO
7. Sh. Chanda Ram, AAO
8. Smt. Poonam Sood, AAO
9. Smt. Meena Verma, AAO
10. Smt. Babli Bhawani, AAO
11. Sh. Krishan Lal, Assistant
12. Ms. Rita Walia, Assistant
13. Sh. Amar Chand, Assistant
14. Smt. Urmila Verma, Assistant
15. Smt. Sunita Thakur, Assistant
16. Sh. Om Parkash, Assistant
17. Smt. Shyam Lata Beakta, Assistant
18. Sh. Deep Ram, Assistant
19. Sh. Pawan Kumar, Assistant
20. Sh. Sachin Kanwar, UDC
21. Sh. Hans Raj, UDC
22. Smt. Nirmala Chauhan, UDC
23. Sh. Kamal Chand Verma, UDC
24. Sh. Ashwani Gupta, UDC
25. Sh. Tej Singh, UDC
26. Smt. Geeta Devi, UDC
27. Smt. Sonia Chauhan, UDC
28. Smt. Punam Jyoti, UDC
29. Sh. Mohinder Singh, UDC
30. Sh. Narender Paul, UDC
31. Sh. Raghubir Singh, UDC
32. Sh. Gokal Ram, UDC
33. Sh. Ashish Kalyan, UDC
34. Sh. Rakesh Negi, UDC
35. Sh. Kundan Lal, LDC
36. Sh. Nand Lal, LDC
37. Sh. Gurjeet Singh, PS
38. Sh. Ram Chand, PS

39. Smt. Shashi Bala Thakur, PS
40. Sh. Suresh Kumar, PA
41. Sh. Girish Thakur, PA
42. Sh. Mohit Oberoi, SG-III

ICAR-CPRI, Kufri-Fagu Unit

43. Smt. Chandni Bhagta, Assistant

ICAR-CPRI, RS, Jalandhar

44. Miss. Prawartika Das, AAO
45. Sh. Sukhpal Sharma, Assistant
46. Ms. Sandhya Srivastava, Assistant
47. Sh. Rakesh, Assistant
48. Smt. Daishey Tuli, UDC
49. Sh. Daljit Singh, UDC
50. Sh. Naresh Kumar, UDC
51. Sh. Suresh Kumar Verma, PA

ICAR-CPRI, RS, Modipuram

52. Sh. Jaspal Singh, AO
53. Sh. Sandeep, AAO
54. Smt. Sneha Lata, UDC
55. Smt. Seema Verma, UDC
56. Sh. Ashok Kumar, UDC
57. Sh. Pradyuman Kumar Saraswat, UDC
58. Sh. Suraj Singh, LDC
59. Sh. Rajesh Kumar, PS
60. Sh. Tejbir Singh, LDC

ICAR-CPRI, RS, Patna

61. Sh. Jagbir Singh, Asstt. Admn. Officer
62. Sh. Sanjib Kumar, Assistant.
63. Sh. RK Gupta, UDC
64. Sh. Rajesh Chauhan, LDC
65. Sh. Pawan Kumar, SG-III

ICAR-CPRI, RS, Gwalior

66. Sh. Surender Singh, Assistant
67. Sh. Sunil Kumar, LDC

ICAR-CPRI, RS, Muthorai

68. Smt. IC Dharmapaul, AAO
69. Smt. M. Rani, Assistant

ICAR-CPRI, RS, Shillong

NIL

SKILLED SUPPORT STAFF

ICAR-CPRI, Shimla

1. Sh. Charan Dass , SSS
2. Sh. Kanhiya Prasad ,SSS
3. Sh. Subhash Chand, SSS
4. Sh. Mansa Ram, SSS
5. Sh. Babu Ram, SSS
6. Sh. Rajinder Kumar, SSS
7. Sh. Kulwant Singh, SSS
8. Sh. Sanjeevan Kumar, SSS
9. Sh. Ashok Kumar , SSS
10. Sh. Narender Kumar , SSS
11. Smt. Kajal , SSS
12. Sh. Padam Dev , SSS
13. Sh. Roshan Lal, SSS
14. Smt. Manjit , SSS
15. Sh. Amar Nath , SSS
16. Sh. Rajinder Singh, SSS
17. Sh. Padam Chand, SSS
18. Smt. Kiran, SSS

ICAR-CPRI, Kufri-Fagu Unit

19. Sh. Hira Singh , SSS
20. Sh. Saran, SSS
21. Smt. Muni Devi, SSS
22. Sh. Roop Singh, SSS
23. Sh. Jia Lal, SSS
24. Sh. Hira Singh, SSS

ICAR-CPRI, RS, Modipuram

25. Sh. Amiruddin, SSS
26. Sh. Jagtey, SSS
27. Sh. Som Pal, SSS
28. Sh. Mani Ram, SSS
29. Sh. Rajpal, SSS
30. Sh. Rajbir Singh, SSS
31. Sh. Raj Kumar, SSS
32. Sh. Sudesh Pal, SSS
33. Sh. Gyanendra Kumar, SSS
34. Sh. Ramphal, SSS
35. Sh. Mukesh, SSS
36. Sh. Murari, SSS

37. Sh. Rajpal Singh, SSS

ICAR-CPRI, RS, Jalandhar

38. Sh. Komal, SSS
39. Mrs. Passo, SSS
40. Smt. Rashpal Devi, SSS
41. Sh. Ram Lubhaya, SSS
42. Sh. Sukhwinder , SSS
43. Sh. Jagai Ram, SSS
44. Sh. Paramjit Singh, SSS
45. Sh. Ram Sarup, SSS
46. Sh. Joginder Pal, SSS
47. Sh. Jagan Nath, SSS

ICAR-CPRI, RS, Patna

48. Sh. Tapan Burman , SSS
49. Sh. Ram Kisun Ram, SSS
50. Sh. Teka Rai, SSS
51. Sh. Jagat Kumar, SSS
52. Sh. Bishun Rai, SSS
53. Sh. Akhilesh Singh, SSS

ICAR-CPRI ,RS, Gwalior

54. Sh. Ram Babu, SSS
55. Sh. Niranjan Singh, SSS
56. Sh. Ram Singh, SSS
57. Sh. Jagdish, SSS
58. Sh. Shyam Singh, SSS
59. Sh. Parkash Tomar, SSS
60. Sh. Virendra Singh, SSS
61. Sh. Ranbir Singh, SSS
62. Sh. Kallu, SSS
63. Sh. Ashok Kumar, SSS
64. Smt. Vimla Devi, SSS
65. Sh. Jaswant Singh, SSS
66. Sh. Kedar, SSS
67. Sh. Parasu Ram, SSS
68. Sh. Punjab Singh, SSS
69. Sh. Ram Parkash, SSS
70. Sh. Bharat Singh, SSS
71. Sh. Mannu Singh, SSS
72. Sh. Lala Ram, SSS

- 73. Sh. Kali Charan, SSS
- 74. Sh. Tilak Singh, SSS
- 75. Sh. Net Ram, SSS
- 76. Sh. Mangal, SSS
- 77. Sh. Jandel Singh, SSS
- 78. Sh. Bhagirath, SSS
- 79. Sh. Ramdin, SSS
- 80. Sh. Sikander Singh, SSS

ICAR-CPRI, RS, Shillong

- 81. Smt.Theibet Thawmuit, SSS
- 82. Mrs. Tellinora, SSS

ICAR-CPRI, RS, Ooty

NIL

SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2020 (EXCLUDING 01 RMP POSITION)

Sl. No.	Discipline	HoD/HoRS			Principal Scientist (DR)			Senior Scientist (DR)			Scientist (including Sr. Sci.&PS promoted Through CAS)			Total		
		S	F	V	S	F	V	S	F	V	S	F	V	S	F	V
1.	AGRICULTURAL BIOTECHNOLOGY	-	-	-	-	-	-	1	-	1	3	3	-	4	3	1
2.	AGRONOMY	-	-	-	-	-	-	1	1	-	4	4	-	5	5	-
3.	AG. ENTOMOLOGY	-	-	-	-	-	-	2	2	-	5	3	2	7	5	2
4.	AG. ECONOMICS	-	-	-	-	-	-	1	-	1	1	-	1	2	-	2
5.	AG METEOROLOGY	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-
6.	AGRICULTURAL MICROBIOLOGY	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-
7.	COM. APPLN.& IT	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-
8.	AG. EXTENSION	-	-	-	-	-	-	1	-	1	1	1	-	2	1	1
9.	AG. ENGG.(FM&P)	-	-	-	-	-	-	-	-	-	3	3	-	3	3	-
10.	PL.BIOCHEMISTRY	-	-	-	-	-	-	1	1	-	2	2	-	3	3	-
11.	FOOD TECHNOLOGY	-	-	-	-	-	-	1	-	1	1	1	-	2	1	1
12.	VEG. SCIENCE	-	-	-	-	-	-	1	-	1	14	13	1	15	13	2
13.	NEMATOLOGY	-	-	-	-	-	-	-	-	-	2	2	-	2	2	-
14.	GENETICS AND PLANT BREEDING	-	-	-	-	-	-	2	2	-	8	7	1	10	9	1
15.	PL. PATHOLOGY	-	-	-	-	-	-	2	2	-	7	6	1	9	8	1
16.	PL. PHYSIOLOGY	-	-	-	-	-	-	1	-	1	5	4	1	6	4	2
17.	SOIL SCIENCE SOIL CHEM./ FERT. MICRO	-	-	-	-	-	-	1	1	-	2	1	1	3	2	1
18.	SEED SCIENCE AND TECHNOLOGY	-	-	-	-	-	-	1	1	-	3	3	-	4	4	-
1.	Joint Director, Modipuram	1*	1	-	-	-	-	-	-	-	-	-	-	1	1	-
2.	Head, Crop Improvement & Seed Technology	1*	1	-	-	-	-	-	-	-	-	-	-	1	1	-
3.	Head, Social Science	1*	1**	-	-	-	-	-	-	-	-	-	-	1	1	-
4.	Head, Crop Production	1*	1**	-	-	-	-	-	-	-	-	-	-	1	1	-
5.	Head, CPB&PHT	1*	1**	-	-	-	-	-	-	-	-	-	-	1	1	-
6.	Head, Plant Protection	1*	-	1	-	-	-	-	-	-	-	-	-	1	-	1
7.	Head, CPRS, Jalandhar	1*	-	1	-	-	-	-	-	-	-	-	-	1	-	1
TOTAL		7	5	2	-	-	-	16	10	6	64	56	8	87	71	16

*Independent to discipline.S-Cadre Strength F-In position V-Vacancy

**Extension as stop gap arrangement has been given upto April, 2021

SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2020

S.N.	Name of the Station	JD/HoD/HoRS			Sr. Scientist			Scientist			Total		
		S	F	V	S	F	V	S	F	V	S	F	V
1.	CPRI, Shimla including AICRP & CPRI Kufri Fagu Unit	05	04	01	07	04	03	30	25	05	42	33	09
2.	CPRS, Jalandhar	01	00	01	01	01	00	10	10	00	12	11	01
3.	CPRIIRC, Modipuram	01	01	00	04	03	01	10	10	00	15	14	01
4.	CPRS, Gwalior	00	00	00	03	01	02	03	02	01	06	03	03
5.	CPRS, Patna	00	00	00	01	01	00	04	02	02	05	03	02
6.	CPRS, Ooty	00	00	00	00	00	00	03	03	00	03	03	00
7.	CPRS, Shillong	00	00	00	00	00	00	04	04	00	04	04	00
TOTAL		07	05	02	16	10	06	64	56	08	87	71	16

*Excluding RMP

SCIENTIFIC CATEGORY

NEW JOINING

1. Dr. Anil Kumar Choudhary, Senior Scientist (Agronomy) joined at ICAR-CPRI, Shimla on 17.01.2020 (FN).

TRANSFERS (INTRA-INSTITUTE)

1. Dr. (Mrs.) Pooja Praful Mankar, Scientist (Vegetable Science), ICAR-CPRI, Shimla relieved on 20.06.2020 (AN) to join at ICAR-CPRI, RS, Modipuram.
2. Dr. Subhash S., Scientist (Agricultural Entomology), ICAR-CPRI, Shimla relieved on 20.06.2020 (AN) to join at ICAR-CPRI, RS, Modipuram.

TRANSFERS (INTER-INSTITUTE)

1. Ms. Preeti Singh, Scientist (Soil Science), ICAR-CPRI, Shimla relieved on 19.06.2020 (AN) to join at ICAR-IARI, Gorla Karma, Hazaribagh, Jharkhand.
2. Sh. Raj Kumar, Scientist (Vegetable Science), ICAR-CPRI, Shimla relieved on 07.08.2020 (AN) to join at ICAR-IARI, New Delhi.

3. Sh. Rahul Ramesh Rao Bakade, Scientist (Plant Pathology), ICAR-CPRI, RS, Patna relieved on 14.09.2020 (AN) to join at ICAR-IINRG, Namkum, Ranchi – 834010 (Jharkhand).

4. Dr. (Mrs.) Girimalla Vanishree, Scientist (Genetics & Plant Breeding), ICAR-CPRI, Shimla relieved on 30.09.2020 (AN) to join at ICAR-IIMR, Hyderabad.

PROMOTIONS

1. Dr. Subhash Katore, Senior Scientist (Agricultural Entomology, RGP Rs.9000/-) ICAR-CPRI, RS, Gwalior promoted to the next higher grade of Scientist (RGP Rs. 10,000/-) under CAS w.e.f. 10.07.2017 as Principal Scientist vide ICAR office order F. No. Pers.2-25/2017-AU dated 12.11.2020.

RETIREMENT

1. Dr. S. K. Chakrabarti, Director, ICAR-CPRI, Shimla retired from Council's service w.e.f. 31.03.2020 (AN).

SANCTIONED FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.12.2020, BASED ON REVISED CADRE STRENGTH

Functional Group	Hqrs.		Shillong		Jalandhar		Modipuram		Gwalior		Patna		Ooty		Kufri		Total	
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Field Farm Technician (FFT)																		
Cat. I Jr. Tech. Asstt. / Sr. Field Asstt. / Field Asstt.	29	33	5	3	8	7	1	10	4	4	12	09	4	3	8	4	83	73
							3											10
Cat. II Sr. Tech. Asstt. (T-4) Tech. Asstt. (T-3)	9	8	-	-	4	3	1	09	2	1	3	2	-	-	-	1	31	24
							3											07
Cat. III Farm Supdt. T-6	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	2	1
																		1
Lab. Technician -																		
Cat. I Computer (T-2)	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	3
Projector Operator, T-2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
																		0
Cat. II Lab. Tech. (T-4)/ Lab. Tech. (T-3)	3	2	-	-	1	-	1	1	1	2*	-	-	-	-	-	-	6	5
																		1
Cat. III Computer programmer T-6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0
																		1
Lib. Information / Documentation																		
Cat. II Lib. Asstt. (T-3)	1	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2
																		1
Asstt. Librarian (T-5)	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
																		0
Documentalist, T-3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
																		1
Tech. Asstt. (Stat.) (T-3)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
																		1

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
Photography																		
Cat. I																		
Photographer /	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Press & Editorial Staff Cat. II																		
Hindi Translator, T-3	1	-	-	-	-	-	1	1	-	1	-	-	-	-	-	2	2	0
Workshop & Engg. Staff																		
Cat. I																		
Blacksmith-cum-Carpenter	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Sr. Mechanic (T-2)	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	2	0
Fitter (T-1)	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1
Welder	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0
Mechanic cum Electrician	1	1	-	-	2	-	1	1	-	-	-	-	-	-	-	-	4	2
Operator Electrical	1	1	-	-	-	-	1	1	-	-	1	-	-	-	-	-	3	1
Driver	3	2	2	-	2	-	2	3	2	-	2	1	-	-	-	-	13	7
Tractor Driver	1	1	1	1	1	-	4	-	3	2	1	-	1	-	-	-	12	8
Cat. II																		
Foreman (T-4)	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1
Asstt. Foreman (T-3)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	0
Overseer (Civil) T-3	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0
Cat. III																		
Instrument Engineer, T-7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Total	61	56	08	04	22	13	42	28	13	11	19	12	05	03	08	06	178	133
																	45	

SANCTIONED FILLED AND VACANT POSTION OF TECHNICAL CATEGORY AS ON 31.03.2021

S.No.	Category	Sanctioned	Filled	Vacant
1	Category-I	125	95	30
2	Category-II	49	37	12
3	Category-III	04	01	03
	Total	178	133	45

PROMOTION

1. Sh. Yogesh, ACTO, ICAR-CPRI, Shimla promoted to CTO from 1.2.2019
2. Sh. Arjun Kumar Sharma, STO, ICAR-CPRI, RS, Patna promoted to ACTO from 8.6.2019
3. Sh. Akhilesh Kumar Singh, STO, ICAR-CPRI, RS, Jalandhar Promoted to ACTO from 24.7.2019
4. Sh. Avinash Chaudhry, STO, ICAR-CPRI, RS, Modipuram promoted to ACTO from 30.6.2019
5. Sh. Subhash Chand, STO, ICAR-CPRI, RS, Modipuram promoted to ACTO from 16.9.2018
6. Sh. Krishan Pal Singh, ACTO, ICAR-CPRI, RS, Modipuram promoted to CTO from 12.3.2019
7. Sh. Anil Kumar Chandel, TA, ICAR-CPRI, RS, Jalandhar promoted to STA (T-4) from 27.9.2019
8. Sh. Ram Jivan, TA, ICAR-CPRI, RS, Kufri promoted to STA (T-4) from 8.9.2019
9. Sh. Narinder Mayar, STA, ICAR-CPRI, RS, Jalandhar promoted to TO (T-5) from 24.9.2019
10. Dr. Veenit Sharma, STO, ICAR-CPRI, RS, Modipuram promoted to ACTO from 30.7.2019
11. Dr. YP Singh, STO, ICAR-CPRI, RS, Gwalior promoted to ACTO from 18.6.2019

12. Sh. Arjun Dass, Technician, ICAR-CPRI, Shimla promoted to ST from 31.3.2020
13. Sh. Mansha Ram, Technician, ICAR-CPRI, Shimla promoted to ST from 31.3.2020
14. Sh. Narendra Kumar, ST, ICAR-CPRI, RS, Patna promoted to TA, STA and TO from 3.12.2009, 3.12.2014 and 3.12.2019
15. Sh. Kulwinder Singh, STA, ICAR-CPRI, RS, Jalandhar promoted to TO from 4.3.2020
16. Sh. Parveen Kumar, STA, ICAR-CPRI, RS, Jalandhar promoted to TO from 7.3.2020

RETIREMENT

1. Sh. Jasvir Singh, ACTO, ICAR-CPRI, RS, Modipuram expired on 16.1.2020
2. Sh. Vijay Kumar Yadav, STO, ICAR-CPRI, RS, Modipuram retired on 29.2.2020
3. Sh. Bijendra Singh, ST, ICAR-CPRI, RS, Gwalior retired on 31.8.2020

RESIGNATION

1. Sh. Rajat, Tech. Trainee, ICAR-CPRI, RS, Kufri resigned on 23.7.2020

TRANSFERRED

1. Sh. Ajay Kumar, Tech. Trainee, ICAR-CPRI, RS, Patna transferred to ICAR-CPRI, RS, Modipuram.
2. Smt. Nisha Verma, Hindi Translator, ICAR-CPRI, Shimla transferred to Gwalior on 12.6.2020

ADMINISTRATIVE STAFF AS ON 31.12.2020

	Shimla			Shillong			Jalandhar			Modipuram			Gwalior			Patna			Ooty			Kufri			Total		
	S	F	V	S	F	V	S	F	V	S	F	V	S	F	V	S	F	V	S	F	V	S	F	V	S	F	V
CAO	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
SF&AO	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
AO	2	1	1	0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
AAO	5	5	0	0	0	0	1	1	0	2	1	1	1	0	1	1	1	0	0	1	1	0	0	0	10	9	1
AF&AO	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
AD(OL)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
PS	3	3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0
PA	7	3	4	0	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	10	5	5
Asstt.	20	9	11	2	0	2	1	3	-2	3	0	3	1	1	0	1	1	0	1	1	0	1	1	0	30	16	14
UDC	5	15	-10	1	0	1	3	3	0	3	4	-1	1	0	1	2	1	1	1	0	1	1	0	1	17	23	-6
LDC	14	2	12	1	0	1	2	0	2	3	2	1	1	1	0	2	1	1	1	0	1	0	0	0	24	6	18
Total	61	42	19	4	0	4	8	8	0	12	9	3	5	2	3	7	5	2	3	2	1	2	1	1	102	69	33

NEW JOINING

Nil

TRANSFERS

1. Sh. Sunil Kumar, LDC relieved from ICAR-CPRI, RS, Modipuram w.e.f. 18.09.2020 and joined at ICAR-CPRI, RS, Gwalior on 29.09.2020.
2. Sh. Pradyuman Kumar Saraswat, UDC relieved from ICAR-CPRI, RS, Gwalior w.e.f. 06.10.2020 and joined at ICAR-CPRI, RS, Modipuram on 09.10.2020.

Promotions

1. Sh. Ashish Kalyan, LDC, ICAR-CPRI, Shimla promoted to the post of UDC w.e.f. 06.06.2020.
2. Sh. Girish Thakur, Stenographer Grade-III, ICAR-CPRI, Shimla promoted to the post of Personal Assistant w.e.f. 26.06.2020.
3. Sh. Rakesh Negi, LDC, ICAR-CPRI, Shimla Promoted to the post of UDC w.e.f. 08.09.2020 through LDCE.
4. Sh. Naresh Kumar, LDC, ICAR-CPRI, RS, Jalandhar Promoted to the post of UDC w.e.f.

08.09.2020 through LDCE.

5. Sh. Pawan Kumar, UDC, ICAR-CPRI, Shimla Promoted to the post of Assistant w.e.f. 08.09.2020 through LDCE.

MACP

1. Sh. Chander Prakash, Asstt. Fin. & Accts. Officer, ICAR-CPRI, Shimla granted 1st MACP w.e.f. 24.5.2020.
2. Sh. Ashish Dhangar, Asstt. Fin. & Accts. Officer, ICAR-CPRI, Shimla granted 1st MACP w.e.f. 28.5.2020.
3. Sh. Gurjeet Singh, Private Secretary, ICAR-CPRI, Shimla granted 3rd MACP w.e.f. 09.11.2019.
4. Sh. Ashish Kalyan, UDC, ICAR-CPRI, Shimla granted 2nd MACP w.e.f. 26.7.2019.

RETIREMENT

1. Sh. Santosh Kumar, Assistant retired on 28.02.2020 from Council's Service.
2. Smt. Bimla Salhotra, UDC, ICAR-CPRI, RS, Jalandhar retired on 30.05.2020.

SANCTIONED/FILLED & VACANT POSITION OF SKILLED SUPPORT STAFF AS ON 31.12.2020

Name	Sanctioned	Filled	Vacant
Shimla/Kufri	30	24	06
Patna	07	06	01
Jalandhar	14	10	04
Modipuram	21	13	08
Shillong	04	02	02
Ooty	03	-	03
Gwalior	26	27	(-)1
Total:	105	82	23

* Sanctioned strength reduced to 105 by Council vide Office Order No.14-2/2017-E-1(R&P) dated 17.06.2019

** Reduced sanctioned strength is distributed vide Institute Office Order No.F.10-04/2019/E.I dated 16.3.2021

GRANT OF MACP BENEFIT

1. Smt. Theibet Thawmuit, SSS, ICAR-CPRI, RS, Shillong granted 3rd MACP w.e.f. 06.06.20 in Pay Matrix Level 4
2. Smt. Tellinora Kurkalang, SSS, ICAR-CPRI, RS, Shillong granted 3rd MACP w.e.f. 06.06.20 in Pay Matrix Level 4
3. Smt. Manjit, SSS, ICAR-CPRI, Shimla granted 2nd MACP w.e.f. 20.04.2020 in Pay Matrix Level 3
4. Sh. Amar Nath, SSS, ICAR-CPRI, Shimla granted 2nd MACP w.e.f. 20.04.2020 in Pay Matrix Level 3

RETIREMENTS

1. Sh. Kailash, SSS, ICAR-CPRI, RS, Gwalior retired from Council's service on 30.4.2020.
2. Sh. Shiv Singh, SSS, ICAR-CPRI, RS, Gwalior retired from Council's service on 30.4.2020.
3. Sh. Madan Lal, SSS, ICAR-CPRI, RS, Kufri retired from Council's service on 30.6.2020.

4. Sh. Ram Nath, SSS, ICAR-CPRI, RS, Jalandhar retired from Council's service on 31.8.2020.
5. Sh. Ramesh Kumar, SSS, ICAR-CPRI, Shimla retired from Council service on 30.9.2020.
6. Sh. Satnam Singh, SSS, ICAR-CPRI, RS, Jalandhar retired from Council service on 31.10.2020.
7. Smt. Sodha Devi, SSS, ICAR-CPRI, RS, Kufri retired from Council service on 30.11.2020.
8. Sh. Mohan Lal, SSS, ICAR-CPRI, RS, Gwalior retired from Council service on 31.12.2020.
9. Sh. K. Ramasamy, SSS, ICAR-CPRI, RS, Muthurai retired from Council service on 31.12.2020

PROMOTION

1. Sh. Tejbir Singh, SSS, ICAR-CPRI, RS, Modipuram promoted as LDC from 08.6.2020.

TRANSFER

1. Sh. Hira Singh, SSS, ICAR-CPRI, Shimla to CPRI-Kufri-Fagu Unit relieved on 23.11.2020 & joined on 24.11.2020 at ICAR-CPRI-Kufri-Fagu Unit

INSTITUTE BUDGET (2020-21)

ANNEXURE- 'A'

ICAR-CPRI

ANNUAL ACCOUNT 2020-21

ABSTRACT OF 'OTHER RECEIPTS' FOR THE YEAR 2020-21

S.NO	HEAD OF ACCOUNT	AMOUNT
1	Sale of farm produce	21158543.00
2	Sale of fish & poultry	0.00
3	Sale of land	0.00
4	Sale of building	0.00
5	Sale of vehicle, other machine tools	140100.00
6	Sale of livestock	0.00
7	Sale of publication and advertisement	0.00
8	Licence fee	619682.00
9	Interest earned on loans & advances	704831.00
10	Leave salary and pension contribution	0.00
11	Receipts from schemes	0.00
12	Analytical and testing fee	0.00
13	Pre-Shipment fee	0.00
14	Application fee from candidates	0.00
15	Diploma Charges	0.00
16	Receipts from services rendered	100.00
17	Unspent balance of Grants of previous years	0.00
18	Interest earned on short term deposits	1357833.00
19	Income generated from Internal Resource Generation Scheme	0.00
	a) Training	617337.00
	b) Consulancy	0.00
	c) Contract Research	0.00
	d) Sale of technology	0.00
	e) Other (Specify the source)	0.00
20	Revolving funds	113881245.00
21	Recoveries of Loans & Advances	621940.00
22	Miscellaneous Receipts	669952.00
	TOTAL : OTHER RECEIPTS	139771563.00

Details of Institute Govt. Grant expenditure for the year 2019-20

S. No.	Head	Allocation Govt. Grant 2020-21	Allocation Internal Resource + Additional amount provided by HQ out of Council's share(2020-21)	TOTAL ALLOCATION 2020-21	Expenditure (Govt. Grant) 2020-21			Expenditure(R evenue Generation)20 20-21	TOTAL EXPENDITURE 2020-21
1	2	3	4	5 (3 + 4)	6			7	8 (6 + 7)
					NEH	TSP	Other than NEH & TSP		
1	Works								
	A. Land								
	B. Building								
	i. Office building	730000.00	0.00	730000.00	0.00		729051.00	0.00	729051.00
	ii. Residential building	0.00	0.00	0.00	0.00			0.00	0.00
	iii. Minor Works	0.00	0.00	0.00	0.00			0.00	0.00
2	Equipments	1685000.00	0.00	1685000.00	0.00		1682880.00	0.00	1682880.00
3	Information Technology	0.00	0.00	0.00	0.00			0.00	0.00
4	Library Books and Journals	283000.00	0.00	283000.00	0.00		282991.00	0.00	282991.00
5	Vehicles & Vessels	0.00	0.00	0.00	0.00			0.00	0.00
6	Livestock	0.00	0.00	0.00	0.00			0.00	0.00
7	Furniture & fixtures	0.00	0.00	0.00	0.00			0.00	0.00
8	Others	0.00	0.00	0.00	0.00			0.00	0.00
	Total - CAPITAL (Grants for creation of Capital Assets)	2698000.00	0.00	2698000.00	0.00		2694922.00	0.00	2694922.00

S. No.	Head	Allocation Govt. Grant 2020-21	Allocation Internal Resource + Additional amount provided by HQ out of Council's share(2020-21)	TOTAL ALLOCATION 2020-21	Expenditure (Govt. Grant) 2020-21	Expenditure (Revenue Generation) 2020-21	TOTAL EXPENDITURE 2020-21
1	Establishment Expenses (Salaries)						0.00
	i. Establishment Charges	377000000.00	0.00	377000000.00	376998128.00	0.00	376998128.00
	ii. Wages	0.00	0.00	0.00		0.00	0.00
	iii. Overtime Allowance	0.00	0.00	0.00		0.00	0.00
	Total - Establishment Expenses	377000000.00	0.00	377000000.00	376998128.00	0.00	376998128.00
1	(Grant in Aid - Salaries) Pension & Other Retirement Benefits	280000000.00	0.00	280000000.00	279991741.00	0.00	279991741.00
2	T.A.	2550000		2550000	2520338.00		2520338.00
	A. Domestic TA / Transfer TA	0.00	0.00	0.00		0.00	0.00
	B. Foreign TA	0.00	0.00	0.00		0.00	0.00
	Total - Traveling Allowance	2550000.00	0.00	2550000.00	2520338.00	0.00	2520338.00
3	Research & Operational Expenses						0.00
	A. Research Expenses	8100000.00	0.00	8100000.00	8060712.00	0.00	8060712.00
	B. Operational Expenses	11800000.00		11800000.00	994894.00	0.00	11785359.00
	Total - Research & Operational Expenses	19900000.00	0.00	19900000.00	17351966.00	0.00	19846071.00
4	Administrative Expenses						0.00
	A. Infrastructure	15500000.00	0.00	15500000.00	13432789.00	0.00	13432789.00
	B. Communication	5000000.00	0.00	5000000.00	485426.00	0.00	485426.00
	C. Repair & Maintenance			0.00	0.00		0.00

S. No.	Head	Allocation Govt. Grant 2020-21	Allocation Internal Resource + Additional amount provided by HQ out of Council's share(2020-21)	TOTAL ALLOCATION 2020-21	Expenditure (Govt. Grant) 2020-21	Expenditure (Revenue Generation) 2020-21	TOTAL EXPENDITURE 2020-21
	i. Equipments, Vehicles & Others	3000000.00	0.00	3000000.00	0.00	0.00	3060451.00
	ii. Office building	1300000.00	0.00	1300000.00	0.00	0.00	852650.00
	iii. Residential building	3000000.00	0.00	3000000.00	0.00	0.00	3403445.00
	iv. Minor Works	50000.00	0.00	50000.00	0.00	0.00	43905.00
	D. Others (excluding TA)	26600000.00	0.00	26600000.00	0.00	0.00	28721529.00
	Total - Administrative Expenses	49950000.00	0.00	49950000.00	0.00	0.00	50000195.00
5	Miscellaneous Expenses						0.00
	A. HRD	70000.00	0.00	70000.00	0.00	0.00	69060.00
	B. Other Items (Fellowships, Scholarships etc.)	0.00	0.00	0.00	0.00	0.00	0.00
	C. Publicity & Exhibitions	30000.00	0.00	30000.00	0.00	0.00	29500.00
	D. Guest House - Maintenance	0.00	0.00	0.00	0.00	0.00	0.00
	E. Other Miscellaneous	2000000.00	0.00	2000000.00	0.00	0.00	1989915.00
	Total - Miscellaneous Expenses	2100000.00	0.00	2100000.00	0.00	0.00	2088475.00
	Total - Grants in Aid - General	354500000.00	0.00	354500000.00	1499211.00	994894.00	351952715.00
	Grand Total (Capital + Establishment + General)	734198000.00	0.00	734198000.00	1499211.00	994894.00	734139870.00
6	Loans and Advances	0.00	0.00	0.00	0.00	0.00	0.00



ICAR-CENTRAL POTATO RESEARCH INSTITUTE
Shimla-171 001, Himachal Pradesh



Phone: 0177-2625073, Fax: 0177-2624460, E-mail: director.cpri@icar.gov.in, Website: <https://cpri.icar.gov.in>