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ICAR-CENTRAL POTATO RESEARCH INSTITUTE
SHIMLA-171001, HIMACHAL PRADESH



Annual Report 2022

ICAR-CENTRAL POTATO RESEARCH INSTITUTE
SHIMLA-171001, HIMACHAL PRADESH

ICAR-CPRI Annual Report-2022

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PREFACE

It is my great pleasure to present the Annual Report 2022 of ICAR-Central Potato Research Institute (CPRI), Shimla. Since its inception in 1949, the institute developed suitable varieties and technologies that virtually transformed the temperate potato crop to sub-tropical one enabling its spread from hilly regions to the vast Indo-Gangetic plains as a rabi crop. As a result, India is now the second largest producer of potato contributing to ~12% of global production. As per the third advance estimate for 2021-22 (DAC&FW), India produced 53.38 million tonnes of potatoes from 2.20 million ha area with average productivity of 24.26 t/ha. This Annual Report presents a glimpse of research and development activities carried out at the institute during the year.

During 2022, three promising potato varieties, namely Kufri Chipsona-5, Kufri Bhaskar and Kufri Daksh were recommended for release in the 40th AICRP (Potato) group meeting. A total of 11 advanced-stage hybrids have been introduced in AICRP for multi-location testing. Two biofortified potato genetic stocks, namely, MSP/15-26 and MSP/15-51 were registered by ICAR-NBPGR, New Delhi. The institute has been making continuous efforts to enrich potato germplasm repository and presently it conserves more than 4700 accessions obtained from 30 countries. A total of 155 accessions were imported in *in-vitro* form from 3 countries, including 137 from CIP, Lima, Peru, 13 from the Netherlands, and 5 from France.

The hybridization program produced 9,03,156 true potato seeds from 521 crosses involving superior parents for yield, quality, and resistance/tolerance to biotic and abiotic stresses. Genome editing of potato cultivars Kufri Chipsona-1 and Kufri Sangam has been targeted for modifying starch composition for high amylose content with resistant starch properties. Multicistronic gRNA CRISPR cassette for two isoforms of starch branching enzymes viz., SBE 2genes (SBE 2.1 and SBE 2.2) was constructed through CRISPR RGEN tools.

A total production of 2801.83 tons of nucleus and breeder seed was achieved from 137.42 ha. Out of which, 2120.43 tons production from 102.44 ha was through conventional and 760.70 tons from 34.98 ha through hi-tech seed production systems, respectively. In total, 2229.45 tons of breeder seed was supplied to various government and private agencies. A total of 224 virus-free *in vitro* culture tubes of basic seed material of 31 varieties were supplied to 31 different seed-producing organizations in India, generating a revenue of Rs.11,20,000/-. Disposal of breeder seed has generated 11 crores during the year.

A simulation study carried out using INFOCROP-Potato model for two climatic scenarios; RCP 4.5 and RCP 6.0 of IPCC AR5 for three time slices (2030s, 2050s and 2080s) revealed that tuber yield is likely to reduce in all the three slices under both the RCPs and this can be countered by reducing the irrigation interval from 8 days to 5 days. Experiments were laid down to generate data for calibrating and validating AQUACROP simulation model for determining crop water productivity under changing climatic conditions. A catalogue (along with QR code) of suitable exportable potato varieties was developed. The refinement in rapid seed potato production technologies suggests that aeroponic minitubers of even 1.0 -1.5g size can be used commercially in G-1 stage.

Indo-Blightcast model predicted appearance of late blight accurately across agro-ecologies and accordingly agro-advisories were issued to various states for its management. A reverse transcriptase-recombinase polymerase amplification (RT-RPA) assay was developed for rapid detection of potato leafroll virus. The field surveys showed that, the root-knot nematode (RKN) was prevalent in Sabarkantha and Aravalli districts of Gujarat and found responsible for qualitative (bumps on the tubers making them unmarketable) as well as quantitative (reduced healthy tubers) reductions in potato yields. Potato cyst nematode (PCN) is responsible for about 31-69% decrease in tuber yield.

A new formulation of naturally occurring oil which can suppress the potato sprouting stored at 10-12°C up to 120 days was identified. Two novel value-added products, namely, potato-bengalgram-based *boondi* for sweet and *raita* and potato-based *boondi* snack were developed. Two hand tools were designed for marking on prepared soil ridges during minituber planting process. A battery-operated pull type spraying system was developed for spraying of agrochemicals with consideration of human safety.

A survey was conducted in Bihar for identifying the major constraints, suggestions and varietal replacement rate. A total of 845 FLDs were conducted in UP, MP, Bihar, Tamil Nadu and Meghalaya. The institute conducted 64 training programmes for farmers and other potato stakeholders. The institute organized 26 exhibitions, fairs, chat shows and *kisan goshthies*. More than 300 queries of potato growers were attended at Kisan Call Centre, CPRIRS, Modipuram. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 11 live phone-in programmes on *Doordarshan* and *Aakashvani*.

Four patents (vertical hydroponic system, S type VEGFAST trough, rectangular VEGFAST trough and potato flakes energy bar) were granted. The scientists of the institute published 95 research publications and 87 other publications. The scientists were conferred with several prestigious awards and recognitions.

I am extremely grateful to Dr. Himanshu Pathak, Secretary (DARE) & Director General, ICAR and Dr. Anand Kumar Singh, Deputy Director General (Horticultural Science), for constant support and encouragement. I would also thank the Chairperson and members of different committees (QRT, RAC, IRC, IMC, etc.) for giving direction to the R & D activities of the institute. I take this opportunity to congratulate the entire team of scientists and other staffs for carrying out all the research and development activities and bringing out the results in time. I extend my special thanks and congratulate the editorial team for bringing out this comprehensive annual report within the stipulated time.


(Brajesh Singh)
Director

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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 61 scientists, 121 technical staffs and 64 administrative staff & 62 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, NASF, NEC and UPCAR are also under operation. Production of Breeders' seed is being done by the Institute under a Revolving Fund Scheme and National Seed Programme.

STAFF & FINANCE

The institute has 437 sanctioned staff strength comprising of 87 scientific, 178 technical, 67 administrative and 105 supporting staff excluding RMP. The staff position as on 31.12.2022 was 308 including 61 scientific, 121 technical, 64 administrative and 62 supporting staff. In 2022-23, total allocation was ₹84,78,61,000/- and total expenditure was ₹84,78,51,778/-. The institute generated about ₹11 crore under Revolving Fund Scheme (RFS) by sale of breeder seed etc. During the year, 1 joined as inter-

institutional transfer & 3 Scientists promoted from Scientist to Scientist (SS), 2 Scientists (SS) were promoted from Scientist (SS) to Sr. Scientist, 4 Sr. Scientists were promoted from Sr. Scientist to Sr. Scientist (RGP 9000). 2 Principal Scientists retired & 2 Scientists expired. In technical category, 2 joined, 22 were promoted, 3 were transferred (inter) and 3 were transferred (intra), 2 were retired and one resigned. Under administrative category, 3 joined, 2 promoted, 2 transferred on selection basis, and 5 granted financial up-gradation under MACP Scheme. In skilled supporting staff, 1 promoted, 7 got grant of MACP benefit, 8 retired and 1 expired.

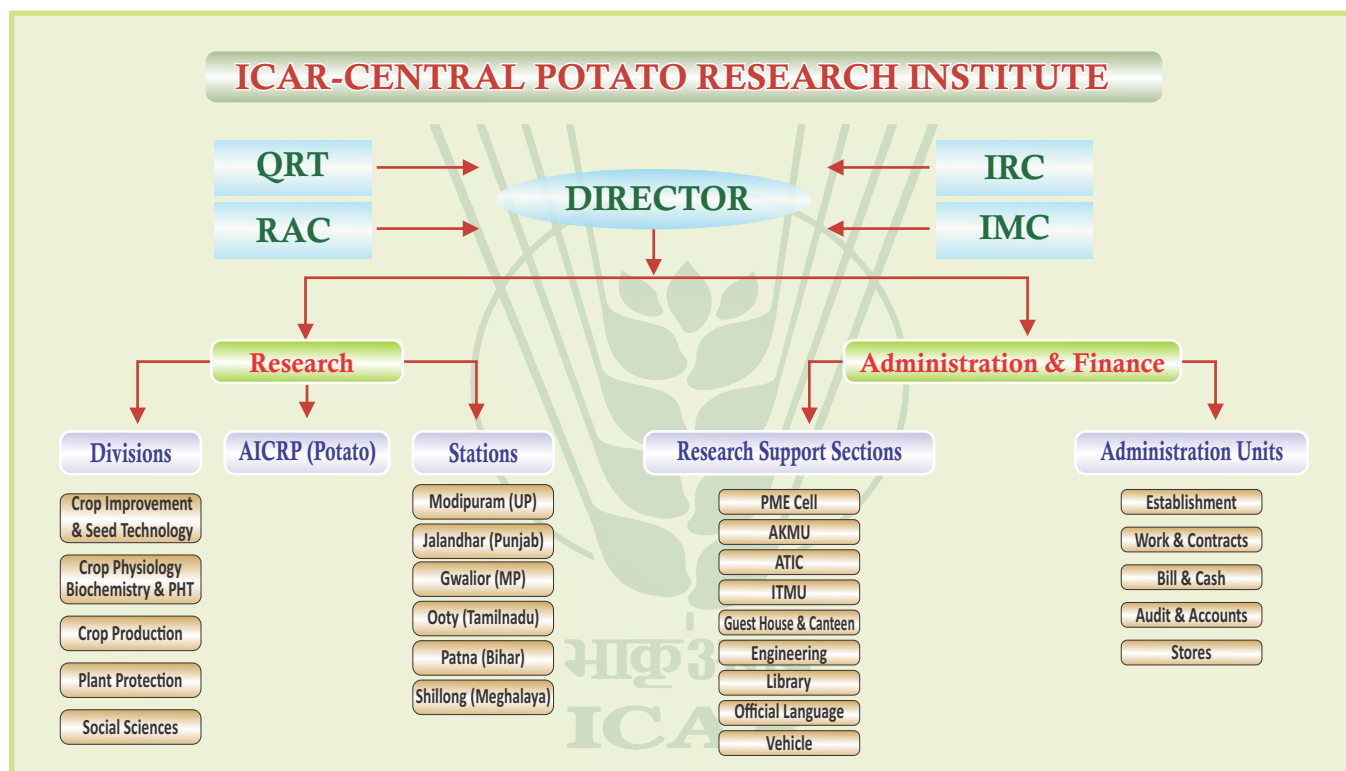
FACILITIES

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 514.84 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

Under germplasm project, a total of 155 accessions were imported in *in-vitro* form from 3 countries, including 137 from CIP, Lima, Peru, 13 varieties from the Netherlands, and five cultures from France. Besides, 171 accessions free from quarantined pests were introduced to the germplasm repository.

Presently more than 4700 accessions of cultivated and wild potato species, obtained from 30 countries, are conserved at the institute. These are being conserved in field gene banks, in vitro repositories, and also as true seeds. Many accessions were evaluated for various biotic and abiotic stresses, keeping quality, processing attributes, quality attributes, and adaptability to various thermos-photoperiods, and promising accessions were identified. Eight elite genetic stocks were registered with the ICAR-NBPGR, New Delhi.

The hybridization program produced 9,03,156 true potato seeds from 521 crosses involving superior parents for yield, quality, and resistance/tolerance to biotic and abiotic stresses. In all, 1,47,757 seedlings were recovered from 5,87,094 true potato seeds of 362 crosses, and at harvest, 20,415 promising clones were selected. In the initial clonal generation, 26,020 clones were evaluated, and 4,233 promising clones were selected at harvest. In advanced-stage hybrids trials, 456 advanced clones were assessed in 33 trials for yield, quality, and resistance/tolerance to biotic and abiotic stresses, and at harvest, 143 promising advanced clones were retained. GI values investigated in 40 genotypes were higher than 70, indicating a relatively high glycemic response. Based on consistently good performance over the years, 11 advanced-stage hybrids, namely MS/17-739, MS7/17-848 (nutritionally superior), J/14-242, J/14-245 (early bulking), PS/16-17 (red skin), MP/13-662, MP/16-173, MP/16-315 (processing), SM/92-338 (bacterial wilt resistant), WS/14-32 (water use efficient) and N/13-49 (nitrogen use efficient) has been introduced in AICRP for multi-location testing. Two biofortified potato genetic stocks, namely MSP/15-26 and MSP/15-51, were registered by NBPGR. Worked out optimum NPK requirement (kg/ha) of

varieties/advanced clones, namely, K. Lohit (240N, 60P, 80K), K. Uday (240N, 30P, 120K), K. Thar-2 (240N, 40P, 100K), MS/15-60 (180N, 40P, 100K) and K. Daksh (180N, 40P, 100K). Developed and used 50 KASP markers for high throughput homozygosity screening at different diploid germplasm loci. Three new potato varieties, namely K. Chipsona-5, K. Bhaskar, and K. Daksh were recommended for release in the 40th AICRP Potato group meeting held during October 7-9, 2022, at SKUAST-Kashmir.

In the year 2022, a panel of 56 potato varieties were established in the aeroponic facility and evaluated for nitrogen use efficiency (NUE) parameters under three different doses/applications of nitrogen viz. high (5.0 mM), optimum (2.0 mM) and low (0.2 mM). From root, leaf, and stolon tissues, 53, 57, and 159 differentially expressed lncRNAs had been identified, which showed upregulation and downregulation under N-stress conditions. Similarly, 6, 24, and 17 differentially expressed circRNAs were identified in root, leaf, and stolon tissues showing upregulation and downregulation. Based on tuber shape, depth of eyes, uniformity of the produce and yield composition, a total of three genotypes, namely NUE/15-8, NUE/15-23, and NUE/15-67, were selected from F₁C₆ at CPRIRS, Modipuram and these were under field evaluation at three N regimes (50, 180 and 240 Kg N/ha). Transcriptome analysis revealed differentially regulated genes in wild *Solanum* species, somatic hybrids, and potato varieties for late blight (*Phytophthora infestans*) resistance. Transcriptome analysis resulted in high-quality paired-end read data (QV > 25) ranging between 8.88 to 11.13 Gb using the Illumina platform. Overall in resistant genotypes, genes found to be up-regulated, such as CC-NBS-LRR resistance protein, ankyrin repeat family protein, cytochrome P450, leucine-rich repeat family protein/protein kinase family, MYB transcription factor, zinc finger protein, so on. Whereas genes found to be down-regulated were 1-aminocyclopropane-1-carboxylate synthase 2, AP2/ERF domain-containing transcription factor, C2H2-type zinc finger protein, NAC domain protein, transcription factor TSRF1, WRKY transcription factor so on. Selected 12 genes (2 genes from each sample of

both up-regulated and down-regulated) were validated by RT-qPCR analysis. A total of 155 genomic-SSR markers covering all the linkage groups of potatoes were evaluated for their polymorphic potential in a representative set of 12 potato genotypes, comprising of varieties, germplasm, somatic hybrids, and wild species to develop a core set of SSR markers for potato germplasm and varieties characterization. So far, 43 SSR markers are polymorphic.

Using the Arabidopsis *DMC1* (*AtDMC1*) gene sequence, we retrieved *Solanum tuberosum* *DMC1* (*StDMC1*) from the diploid potato genome, and subsequently, sense and antisense regions of the *StDMC1* gene were amplified in potato cv. Kufri Jyoti. In total, 310 putative transgenic lines were obtained using *Agrobacterium*-mediated transformation, which was grown in a glass house under controlled conditions and screened using *NPTII* marker. Out of 310 lines, 137 were found positive, with the *NPTII* marker showing a product size of 530bp. Overall, a transformation efficiency of 44% was obtained to get mutants. Genome editing of potato cultivars K. Chipsona-I and K. Sangam has been targeted for modifying starch composition for high amylose content with resistant starch properties. *In silico* analysis of starch branching enzyme target genes, *SBE 2.1* and *SBE 2.2* were carried out. Further, multi-cistronic gRNA CRISPR cassette for two isoforms of starch branching enzymes viz. *SBE 2* genes (*SBE 2.1* and *SBE 2.2*) were constructed through CRISPR RGEN Tools (<http://www.rgenome.net/cas-designer>). The successful ligation of multi-cistronic gRNA CRISPR cassette with Cas9 containing binary vector pDIRECT23_C is successful. The CRISPR vector pDIRECT 23_C carrying the gRNA construct of desired target gene *SBE 2.1* and *2.2* was transferred into *Agrobacterium tumefaciens* strain GV3101 by the freeze/ thaw method. *Agrobacterium*-mediated transformation of internodal tissue and shoot multiplication and elongation of transformed shoots is in progress.

A diversity panel of 353 tetraploid potato accessions comprising 256 from the germplasm *Solanum tuberosum* ssp. *tuberosum*, 49 from the germplasm *Solanum tuberosum* ssp. *andigena* and 48 cultivated Indian potato varieties were screened against the dry rot pathogen (*Fusarium sambucinum*), and phenotypic data of 160

germplasm accessions were generated. None of the cultivars/accessions tested were immune to the dry rot pathogen. A total of 14 accessions (CP 3809, CP 1468, Kufri Garima, J/A 947, etc.) showed a diameter <11 mm, which can be considered tolerant to dry rot pathogen based on this year's study.

Total production of 2801.83 tons of nucleus and breeder seed was achieved from 137.42 ha. Of these, 2120.43 tons' production from 102.44 ha was through conventional and 760.70 tons from 34.98 ha through hi-tech seed production systems, respectively. In total 2229.45 tons of breeder seed was supplied to various government and private agencies. Last year 38 pots of 19 varieties were planted and tested with ELISA/PCR against different potato viruses. After conducting a series of testing through PCR/ELISA, all healthy varieties were shifted *in-vitro* were included in the micro plants' multiplication and supply chain. A total of 224 virus-free *in vitro* culture tubes of basic seed material of 31 varieties were supplied to 31 different seed-producing organizations in India, generating a revenue of Rs.11,20,000/-. In addition, an amount of Rs.1,00,000 was received as a registration fee @Rs. 10,000/firm, valid for a period of five years. Disposal of breeder seed has generated 11 crores during the last year. Results revealed that one-year older aeroponic tubers could also be used successfully as a seed source without a doubt. Besides producing more tuber number /plant compared to check treatment) (Solution-I, solution-II and Solution-III) economized the N and K use by more than 90% and P by 45%. The study suggests that plant origin significantly affects yield-attributing traits under aeroponics. In-vitro plants are the best planting source for aeroponic minituber production. Interaction effect reveals that undersize tubers were minimum when 3-10g min-tubers of K. Karan were planted at 60x20cm and were maximum with 20-40g mini-tubers at 60x10cm planting geometry. Fresh breeder seed (648000 and 33.50t/ha) reported significantly higher total tuber number and weight, followed by CO SPT (621000 and 30.71t/ha) over COWSPT (51900 and 26.33 t/ha). For obtaining maximum yields, the crop duration in Kufri Jyoti and Kufri Himalini should be 120 days, and for Kufri Karan and Kufri Girdhari, the optimum crop duration should be 140 days. Under each

irrigation scheduling strategy, applying paddy straw mulch @ 5 t ha⁻¹ resulted in higher total tuber numbers than the control (without mulch).

DIVISION OF CROP PRODUCTION

A simulation study was carried out using INFOCROP – Potato model. The simulation was done for two climatic scenarios; RCP 4.5 and RCP 6.0 of IPCC AR5, for three time slices (2030s, 2050s and 2080s). It was observed that tuber yield is likely to reduce in all the three slices under both the RCPs and this can be countered by reducing the irrigation interval from 8 days to 5 days. Further in order to suggest management option to reduce the impact of elevated temperature a study was carried out in OTCs at CPRI RS Jalandhar. It was observed that tuber yield as well as soil organic carbon decreased with increased temperature but the extent of decrease, in both, was less in soils where paddy straw was incorporated. The estimation of carbon footprint was studied and it was observed that the integrated crop management (ICM) resulted in slightly higher carbon footprints compared to farmers' practice but overall, ICM is a better option over FP w.r.t. potato productivity, bio-energy and carbon output in diverse potato production systems of wet-temperate NW Himalayas.

An investigation was also conducted to reveal the impact of climate change on early blight severity and black scurf disease incidence on different level of resistance cultivars at different dates of planting. The population of aphids, whiteflies and leafhoppers were monitored at weekly interval in unsprayed potato fields in the early planted and main crop at Modipuram. Effect of sowing dates on incidence of aphids, whiteflies and leafhoppers in unsprayed potato crop showed that there was no statistically significant difference in the incidence of aphids, whiteflies and leafhoppers among different sowing dates however there is a huge variation in the mean population densities among different sowing dates. Experiments were also laid down to generate data for calibrating & validating Aquacrop simulation model for determining crop water productivity under changing climatic conditions. It was observed that tuber yield at harvest increased with water application rate from 50-150 % of ET_{ref} under both mulch and no mulch condition. Paddy

straw mulching lead to maximum increase in tuber yield under most water-limited environment.

The field experiments were laid out at Modipuram to study the effect of different nutrients management options using crops of green manure and pulses, organic & inorganic sources of nutrition under drip, sprinkler and conventional furrow irrigation methods for enhancing water and nutrient use efficiency. The results revealed that drip irrigation gave maximum tuber yield (32.1 t/ha) and tuber numbers (656 000/ha) against furrow irrigation attaining tuber yield (27.8 t/ha) and numbers (653 000/ha). Sprinkler irrigation was found intermediate in category having tuber yields of 29.0 t/ha. Nutrition (100% NPK) recorded highest tuber yields under drip (37.6 t/ha), sprinkler (35.7 t/ha) and furrow (34.0 t/ha) in comparison to other fertility levels. Recommended 100% NPK dose had higher mean tuber yield (35.9 t/ha) than other treatments across all irrigation methods. In another trial at Modipuram, application of 180 kg N/ha and recommended irrigations (TWA 334 mm) produced significantly higher tuber yield (36.9 t/ha) and numbers (998 000/ha) followed by tuber yield (34.4 t/ha) and numbers (889 000/ha), respectively when irrigations was applied at critical stages of crop (284 mm water) and nutrition of 15 t FYM+ 180 kg N/ha thus saving 26% of irrigation water. Similarly, irrigation at 20 mm CPE in Kufri Thar-3 produced significantly higher tuber yield (29.9 t/ha) and numbers (902 000/ha) which were at par with treatment of 25 mm CPE (29.4 t/ha).

At Gwalior, maximum tuber yield (32.2 t/ha) of Kufri Jyoti was obtained with application of 75% RDF NPK along with *Sesbania* spp. green manuring followed by 50% RDF NPK+15 t FYM/ha (32.0 t/ha) and 100% RDF NPK (31 t/ha). At Shillong, total and marketable tuber yield of potato was significantly higher in six-month-old naturally weathered (SMS6) SMS @ 20 t ha⁻¹+RDF (22.02 and 14.59 t ha⁻¹) than FYM 15 t ha⁻¹+RDF (14.98 and 9.50 t ha⁻¹) and absolute control (6.7 and 3.44 t ha⁻¹). At Shimla, application of P₂₀+PSB+AMF, P₂₀+2FSP [Two foliar-P sprays of 2% mono-ammonium phosphate (MAP) applied at vegetative stage (VS) & tuberization stage (TS) in potato]; and P₂₀+PSB+AMF+2 FSP led to 14.2, 12.9 & 19.2% higher tuber productivity over sole use of P₂₀. On an average, application of P₄₀+PSB+AMF, P₄₀+2FSP; and P₄₀+PSB+AMF+2 FSP

led to 9.5, 8.0 & 15% higher tuber productivity over sole use of P_{40} in pot experiment. Five hundred (500) bacterial isolates were also isolated from tubers, roots of potatoes, rhizosphere of potato and tested for P-solubilization. Out of these 500 rhizobacterial 137 isolates showed solubilization of insoluble P. Solubilization index for P ranged from 1.05–3.60. At Shimla, a single spray of Zn as zinc nitrate (200 ppm Zn) and zinc sulphate (400 ppm Zn) and nano Zn (50 ppm) increased the plant height, biomass and tuber zinc concentration significantly over control. A single spray of zinc @200 ppm as zinc nitrate resulted in highest increase of 18.5% (Kufri Chipsona-1) to 27% (Kufri Jyoti) in tuber zinc concentration.

In export activity, early season trials at Modipuram concluded that cvs. Kufri (K) Daksh (4.95 t/ha), K. Kiran (4.63 t/ha) and K. Neelkanth (4.32 t/ha) are promising with sustainable export-grade (size >55 mm) tuber yield. In main crop, experience from Uttar Pradesh and Gujarat was encouraging as K. Frysona, K. Ganga, K. Sangam, K. Neelkanth and K. Chipsona-3 recorded more than 25 t/ha export grade yield, having more than 18% tuber dry matter with better storability. A catalogue of suitable exportable potato varieties has been developed and uploaded on institute website along with QR code for creating awareness among all stakeholders. Efforts are on for development of future export purpose varieties and ten clones (MS/15-1001, MS/11-664, MS/9-723, MS/15-1422, MS/14-505, MCIP/11-185, MS/14-1381, MS/16-1156, HT/12-830 and MS/15-758) have shown potential at Modipuram. Under natural farming, efforts are going on for developing sustainable varieties, seed, production and protection technologies at Modipuram, Gwalior, Shimla and Shillong. Eleven promising advanced clones (HT/12-751, MS/15-1001, MS/16-1156, MS/14-505, MSP/17-07, MS/15-1422, MCIP/17-89, HT/MK-21, MS/15-758, HT/12-830 and MS/9-723) were identified. Seed production under natural farming is possible as highest seed size (14.7 t/ha) and total (25.4 t/ha) tuber yield was recorded with organic sources (200% FYM on N basis+ *Mahua* cake @2.5 t/ha + biofertilizers). Sustainable yields are now possible with newly developed varieties. Weed management through silver-black polythene mulch was highly successful as comparable total (14.39 t/ha) and marketable (9.37 t/ha) tuber yields to weed-free control (16.52 & 10.62 t/ha)

were observed. Late blight control in natural farming with botanicals and restricted use Cu based chemicals has shown a ray of hope as lowest disease severity (36.67%) was recorded in spray schedule of *Neem* oil @ 4.0%- Copper hydroxide @ 0.3%- *Neem* oil @ 4.0%- Copper hydroxide @ 0.3%. Black scurf of potato was efficiently controlled by *Trichoderma* spp (compost multiplied @100g/1.8m²) and as lowest disease incidence (42.67%) and severity (19.50%) was recorded over diseased control having highest disease intensity (87.33%) and severity (41.83%). Vector white fly can effectively be controlled with Pongamia soap as highest population reduction (94.85%) was observed one day after its spray. Spray of *Metarhizium anisopliae* @ 3g/l was found most effective against whitefly, thrips, and aphids with population reduction of 60.9%, 58.1% and 59.8%, respectively over untreated control. System based package development is going on at Shimla, Gwalior, Shillong and Ooty.

At Gwalior, rice- potato- green manure (*Sesbania* spp) crop sequence under natural farming gave sustainable rice equivalent yields (13.9 t/ha) in comparison to inorganic nutrition (19.1 t/ha). At Shimla, potato-garlic cropping system was stable with highest system productivity (PEY: 76.7 t/ha) when 75% NPK + FYM @ 10 t/ha was applied to potato and 75% NPK+ 25% NPK through FYM was applied to garlic. Potato+ cauliflower (PEY: 21.94 t/ha) intercropping was the best system for Meghalaya. Variety K. Himalini was most suited for north- eastern hills as it achieved maximum total (23.96 t/ha) and marketable (19.80 t/ha) tuber yield, and highest B:C ratio (1.79). At Jalandhar, refinement in rapid seed potato production technologies suggests that aeroponic minitubers of even 1.0-1.5g size can be used commercially in G-1 stage. CPRI formulation is exhibiting exciting results consistently as tuber number were enhanced in varieties K. Khyati, K. Chandramukhi, K. Himalini and K. Badshah by 17.5%, 19.8%, 18.9% and 28.87%, respectively. Two hand tools were designed for marking on prepared soil ridges during minituber planting process. A battery operated pull type spraying system has been developed for spraying of agrochemicals with consideration of human safety. Three patents were granted during this period for engineering team working at Jalandhar.

DIVISION OF PLANT PROTECTION

Losses due to late blight were insignificant as disease appeared late in the season. Incidence of common scab is increasing across agro-ecologies. Homothallic isolates of *Phytophthora infestans* were observed in potato fields. Isolates of *Phytophthora infestans* were still observed resistant and intermediate resistant to metalaxyl while sensitive to new molecules (cymoxanil, dimethomorph, fenamidone and amisulbrom). Results of SSR genotyping revealed that population of *P. infestans* in India EU_13_A2 clonal lineage only. Characterization of *Streptomyces* species isolates revealed that 18 isolates were positive for all the three pathogenicity genes (*txtAB*, *tomA* & *nec1*); six for two genes (*txtAB* & *tomA*); two for *txtAB* and *nec1*; five for *tomA* & *nec1* and one for *txtAB* only and were rated as mild to severe in aggressiveness. Indo-Blightcast model predicted appearance of late blight accurately across agro-ecologies and accordingly agro-advisories were issued for its management. *Fusarium sambucinum* and *F. verticilloides* could grow and sporulate well even at 4°C storage temperature thus imposing a serious threat of dry rot even in cold storages. Kinetic metabolite profiling of potato leaves infected with *P. infestans* revealed drastic elevation of putrescine metabolite. Spray schedule of chlorothalonil 75% @ 0.2% (before the appearance of disease) followed by flupicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3% (at onset of the disease) and one more spray of flupicolide 62.5 + propamocarb hydrochlorid 625 SC @ 0.3% (after 7 days of second spray) recorded lowest disease severity. Tuber seed treatment with thifluzamide @0.35% (spray method) and Penflufen @0.1% (dip method) at the time of planting recorded lowest incidence of black scurf. Two cultures namely SM/92-338 and Badami Alu did not show any wilt symptoms till harvesting. Four lines viz., CP 1012, CP 1271, CP 2110 and JEX/A-197 exhibited resistance to thaxtomin A toxin production by *Streptomyces scabies*.

Developed reverse transcriptase-recombinase polymerase amplification (RT-RPA) assay for rapid detection of *Potato leafroll virus*. Transgenic lines developed for ToLCNDV- potato (GTLC2-127 and KPLC2-53) resistance were screened this year also and found resistant.

Insect vectors (aphids, whiteflies, leafhoppers) and soil pests were monitored at Modipuram, Shimla and Gwalior on potato (unsprayed crop)

during 2022 crop season. *Myzus persicae* did not cross the critical level till last week of December at Modipuram. The population showed increasing trend after third week of December and fluctuated between 2 and 38 non alate morphs per 100 compound leaves. The population of whiteflies remained above economic threshold till the 1st week of November and after that less than one whitefly per plant was recorded. Initially aphid population dominated by *Aphis gossypii*, subsequently it was predominated by *M. persicae*. The population of aphids and whiteflies remained below ETL since the beginning of crop season till first week of January on unsprayed potato crop at Murana (MP). Among the eight potato varieties namely, Kufri Sangam, K. Kiran, K. Neelkanth, K. Surya, K. Mohan, K. Anand, K. Chipsona-1 and K. Bahar, K. Sangam (3.38 ± 1.13) and K. Kiran (3.50 ± 1.16) found to be less preferred by whiteflies, whereas K. Mohan (5.00 ± 1.41), K. Anand (4.75 ± 1.47) and K. Bahar (4.75 ± 1.41) found to be highly preferred by whiteflies. In electrophysiological studies, winged *A. gossypii*'s antennae responded consistently to estragole in basil oil, as sticky trap with basil oil caught more number of aphids in the potato fields. An experiment was conducted to study the efficacy of drone spraying and to compare it with tractor and battery operated knapsack spray along with untreated control. In general, after four spraying schedule only 10.5-62.45 % reduction over control was observed with drone spraying whereas 21.04-70.53 % and 53.30-69.38 % reduction over control observed in Tractor mounted spray and knapsack spray respectively against whiteflies. The least percent tuber losses and percent weight loss were observed in the treatment of Clothianidin 50DWG @ 250 g/ha against white grub in potato. The resistance ratio of *M. persicae* (Karnal population) suggests a very high level of resistance (RR 129.7). *Steinernema cholaschanense* is compatible with the recommended agrochemicals and can be readily combined and used under the field conditions against *Phthorimea operculella*. The application of Cyantraniliprole significantly reduced the new leaf mines population after each spray and resulted in higher yield of potato compared to other treatments. The IPM module worked effectively against insect vectors with low incidence of viral diseases in plots using barrier crop (maize) and trap crop (mustard) along with plant products and yellow sticky traps. Significantly less nematode reproduction factor

($R_f = F_p / I_p$) was recorded in the treatment with the application of *Bacillus cereus* @ 30 kg/ha with trap crop (35DAP) followed by non-host crop (mustard) followed by fallow. Alone planting of resistant hybrid (SM/11-120) followed by fallow, recorded significantly less PCN reproduction factor (R_f : 0.63). A significantly less nematode reproduction factor (R_f) was recorded in the treatment comprised with application of Bleaching Powder @ 40kg/ha followed by non-host crop (Oat) followed by fallow. After four years of following management strategies at Kufri Farm by growing Oat-Oat- Mustard-Trap resulted maximum reduction (61.4%) of PCN population followed by Potato-Rajmash-Trap-Rajmash (48.7%). In the absence of the primary host crop, the potato, rajmash roots leachates also sustain PCN hatching. RNA-Seq results were validated through quantitative real time PCR and it was observed that ATP, CD, CYTO, DR, FLAV, GP, LBR, LYS, and PR genes (resistant gene) were up-regulated at 7 DAI in SM/11-120 genotypes. Field survey showed that, the RKN was prevalent in Sabarkantha and Aravalli districts of Gujarat and found responsible for qualitative (bumps on the tubers making them unmarketable) as well as quantitative (reduced healthy tubers) reductions in potato yields. PCN is responsible for about 31-69% decrease in tuber yield. Similarly, the highest yield of 17.21 t/ha was observed in the plots treated with Dazomet however the lowest yield of 10.18 t/ha was noted in untreated control.

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

Under the post-harvest management of potatoes, a new combination of naturally occurring oil which is effective to control sprout grown in potatoes stored at 10-12°C was identified. This year we have evaluated the efficacy of this formulation on 19 different varieties. Results revealed that this formulation can suppress the potato sprouting upto 120 days. In continuation to the work on effects on sensory and quality attributes, of various cooking methods and ingredients during cooking of potato, experimentations on effect of potato- cooking oil combination and retrogradation on available carbohydrate (ACHO) revealed that the addition of cooking oil to the potato tubers significant lowering ($P < 0.05$) of

available carbohydrate (ACHO) in the potato-cooking oil combination. In case of Kufri Jyoti ACHO of was 13.78 g/100 g DW and on the addition of mustard, sunflower, soybean, ghee, olive, rice bran and coconut oil the ACHO was reduced to 10.87, 11.26, 10.81, 8.84, 7.90, 9.85 and 9.06 g/100 g DW, respectively. The maximum (42.7%) and minimum (18.3%) reduction in ACHO were noted in potato (KJ)-olive oil and potato (KJ)-soybean oil, respectively. Similarly, the addition of olive oil, ghee and coconut oil to tubers of Kufri Chipsona-3 variety resulted in a significant reduction ($P < 0.05$) in ACHO by 47.7, 39.4 and 39.3%, respectively. Cooking of potato in potato-ghee, potato-coconut oil and potato -olive oil combinations, resulted in increase in starch hydrolysis index (SHI) by 30.8, 30.1 and 28.1 %, respectively when compared with control. Cooking of potato tuber with different oils followed by cooling also resulted in a significant lowering of SHI. Also, addition of different cooking oils exhibited significant glycemic index (GI) and glycemic load (GL) lowering effects on potato. The addition of each of the cooking oil (seven different types) increased the resistant starch content (RSC) significantly for potato tubers.

Excess rains on the time of ready to harvest or fully mature potato is very challenging and deteriorate the quality of crop. The artificial simulation on excess water stress studies in two potato varieties Kufri Chipsona-3 and Kufri Frysona showed variety specific effects of water dipping on free amino acids and total phenol content of potato tubers.

Work on development of functional fermented probiotics beverages from potato juices resulted in identification of three potential microbes viz: *Lactobacillus acidophilus*, *Lactobacillus plantarum* and *Lactobacillus fermentum* having probiotics attributes for potato probiotics beverages. Work on exploring novel value-added products from potatoes led to the development of potato-Bengal Gram-based *boondi* for sweet and *raita*, and potato-based *boondi* snack. Boondi is a deep-fat fried spherical traditional product made out of droplets of chickpea/ Bengal gram / *besan* (*Cicer arietinum*) flour batter. We have developed the boondi by replacing more than 50% of Bengal gram flour with the potato flour. The crispiness and crunchiness of the developed boondi was found to be better than traditional *boondi*.

Developed boondi was suitable for both sweet and *raita* preparation. Another *boondi* variation was developed by combining potato flour, black gram flour, corn flour and chickpea flour to be eaten as a salty snack. The developed boondi snack. Unlike other fried processed potato dishes, the *boondi* can be made from any type of potato. In-continuation to work on understanding sucrose metabolism and its role in potato shelf-life and post-harvest sensory attributes, genome-wide landscape of sucrose transporter (SUT) genes in potato was analysed. The analysis revealed presence of only one SUT gene (id PGSC0003DMG400025610) in Potato Genome Sequence Database which was found to be located on chromosome number 5. The size of the Gene was found to be 1515 nucleotides containing Open Reading Frame (ORF) of 825 nucleotides, possessing 5 introns and encoding a protein composed of 274 amino acids, having theoretical isoelectric point of 5.25 and molecular weight of 28.99 kDa. The gene exhibited different expression behaviour in different cultivars on potato during post-harvest storage.

DIVISION OF SOCIAL SCIENCES

A survey conducted in Patna and Nalanda districts of Bihar revealed that based on weighted mean score (WMS), the major constraints perceived by farmers were lack of good quality seed (WMS=2.43), high cost of cultivation (2.43), low market price of the produce (2.42) and lack of suitable potato varieties (2.40). The major suggestions were training on potato production and processing, which were suggested by 42.5 percent of the respondents, controlling potato price fluctuation (41.57%), ensure availability of quality seeds of HYVs (41.67%), number of cold

stores should be increased (25.83%), availability of processing units nearby (25.83) and availability of credit and subsidy facilities (20.00%). The analysis of the sources of potato seeds in Bihar revealed that the most important seed source was seed traders/dealers, which was used by about 38.90 percent of farmers. The second important seed sources were friends and relatives (22.00%). The high cost of quality seeds with an overall weighted mean score (WMS) of 2.63 was ranked as the first major constraint in the study areas, subsequently followed by lack of seed of required varieties (WMS=2.56), lack of information about improved varieties (WMS=2.26), poor quality of available seeds (WMS=2.26) and lack and high cost of storage facilities (WMS=1.83). The seed replacement rate of improved varieties in Bihar was high about 73.84 percent. For popularization of technologies developed by the institute, a total of 845 FLDs were conducted at farmer's fields of states UP, MP, Bihar, Tamil Nadu and Meghalaya. The institute also conducted 64 training programmes at the headquarters and the regional stations for the officials, farmers and other potato stakeholders in the country. The institute organized 26 exhibitions, fairs, celebration of important days, chat shows and *kisan goshties*. Expert scientists from different disciplines of ICAR-CPRI, Shimla and its regional stations participated in 11 live phone-in programmes on *Doordarshan* and *Aakashvani*. More than 300 queries of potato growers were attended at Kisan Call Centre, Moodipuram station. Under HRD Cell, 15 Scientists, 14 Technical officers and 4 Administrative officers were sent to participate in various training programmes and many scientists and officers attended 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, SK Luthra, Raj Kumar, Ajay Kumar Thakur, Salej Sood, Dalamu, Vikas Mangal, Shambu Kumar, Sarla Yadav, Ratna Preeti Kaur, Babita Chaudhary, Pooja Mankar, Sanjeev Sharma, Ravinder Kumar, Anuj Bhatnagar, Arvind Kumar Jaiswal, Bandana, Ashwani Kr. Sharma, Priyank Hanuman Mhatre, Aarti Bairwa, Kailash Chandra Naga, Rahul Tiwari, Name Singh, Jagdev Sharma, Som Dutt, Vinay Sagar, Brajesh Singh, Clarissa Challam and P Janani
2.	Genetic enhancement of potato through molecular and genomic tools. HORTCPRISIL202000500144	PI: Dr. Ajay Thakur. Associates: Drs. Som Dutt, Vinay Bhardwaj, Salej Sood, Brajesh Singh, Milan K. Lal, Sushil S. Changan, Dharmendra Kumar, Sanjeev Sharma, Aarti Bairwa, Jagdev Sharma, Vijay K. Dua, Tanuja Buckseth, Vinod Kumar, Satish K. Luthra, Devendra Kumar, Manoj Kumar, Ratna P. Kaur, Ashwini K. Sharma, Dalamu, Priyank Mahatre, Clarissa Challam, Vikas Mangal and Chandan Maharana
3.	Breeding trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses HORTCPRISIL202000400143	PI: Dr. SK Luthra. Associates: Drs. Babita Chaudhary, Dalamu, Brajesh Singh, Jagdev Sharma, VK Dua, Bandana, Arvind Kumar Jaiswal, Mehi Lal, Sanjay Rawal, Anuj Bhatnagar, Milan Kumar Lal, Raj Kumar, Ratna Preeti Kaur, Shambhu Kumar, Sarla Yadav, VK Gupta, Vinay Bhardwaj, Bandana, Salej Sood, Sanjeev Sharma, Priyank Mhatre, Clarissa Challam, Aarti Bairwa, Sundaresha S., Ravinder Kumar, Kailash Naga, Vinod Kumar, Ashwani K. Sharma, Devendra Kumar, Name Singh, Som Dutt, Sugani Devi, Sushil Sudhakar Changan, Manoj Kumar, Prince Kumar, Hemant Kardile, Ajay Thakur, Dalamu, Pooja Mankar, Vikas Mangal, Tanuja Buckseth
4.	Development and production of nucleus and breeder seed of notified potato varieties through conventional and hi-tech systems. HORTCPRISIL202001000149	PI: Dr. Vinod Kumar. Associates: Drs. Manoj Kumar, Vinay Singh, Dhruv Kumar, Ashwani Kumar Sharma, Subhash S, Anil Sharma, RP Kaur, Sugani Devi, SP Singh, Murlidhar Sadawarti, Subhash Katare, Raj Kumar Singh, N. Sailo, C. Clarissa, Anil Choudhary, Sushil Changan, Jagdev Sharma, Sunayan Saha, Tanuja Buckseth
5.	Vulnerability and resilience to climate change for sustainable potato production HORTCPRISIL202100100150	PI: Dr. VK Dua/Anil Sharma. Associates: Drs. Sanjay Rawal, SP Singh, Paresh Chaukhande, Sunayan Saha, Name Singh, Anil K. Chaudhary, Devendra Kumar, Vijay Paul, Prince Kumar, Jagdev Sharma, VK Gupta, Som Dutt, Hemant Kardile, Brajesh Nare, Sanjeev Sharma, Mehi Lal, Anuj Bhatnagar, Subhash Katare, Subhash Chander, Rabindra Padariya, Pynbianglang Kharumnuid, Subhash S
6.	Nutrient and water management for improved productivity and sustainability of potato HORTCPRISIL202000200141	PI: Dr. Name Singh/Sanjay Rawal. Associates: Drs. Manoj Kumar, SP Singh, Prince Kumar, Sunayan Saha, RK Singh, Sunayan Saha, VK Dua, Jagdev Sharma, Anil Sharma, Manoj Kumar Nanda, Brajesh Nare, Anil K Choudhary, Janani P., Divya K Lekshmanan, Dharmendra Kumar, Priyank Mhatre, Ajay Thakur, Yogesh Gautam

Sr. No.	Research Programmes & Institute Code No.	Programme Leader and Associates
7.	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., Bapi Das, SP Singh, Subhash Katare, Murlidhar Sadawarti, Anil Sharma, Anil K Choudhary, RK Singh, Janani P., VK Dua, Clarissa Challam, N. Sailo, Anuj Bhatnagar, Vinay Sagar, Paresh Chaukhande, Brajesh Nare, Sukhwinder Singh, Sugani Devi, Som Dutt, Ratna Preeti Kaur, Prince Kumar, Dharmendra Kumar, Kailash C Naga, Yogesh Gautam
8.	Re-defining epidemiological parameters and management approaches for potato pathogens HORTCPRISIL202000600145	PI: Dr. Sanjeev Sharma. Associates: Drs. Vinay Sagar, Sundaresha S., Ravinder Kumar, Mehi Lal, Rahul Kumar Tiwari, Jagdev Sharma, Vinay Bhardwaj, Kailash Naga, Subhash S, Murlidhar Sadawarti, Subhash Katare, Chandan Maharana, Priyank H Mhatre
9.	Biology, ecology and management of insects and nematodes pests of potato. HORTCPRISIL202000700146	PI: Dr. Anuj Bhatnagar. Associates: Drs. Subhash Katare, Kailash Naga, Subhash S., Aarti Bairwa, Priyank Mhatre, Ravinder Kumar, Sanjeev Sharma, Kamala Jayanthi, Jagdev Sharma, N Sailo, Rahul Kumar Tiwari, Chandan Maharana, Ashwani K Sharma, Sundaresha S, Tanuja Buckseth, Dalamu
10.	Post-harvest management and nutritional enhancement of potatoes HORTCPRISIL202000800147	PI: Dr. Brajesh Singh. Associates: Drs. Som Dutt, 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, Rahul Tiwari, Jagdev Sharma, Sanjay Rawal, Pynbianglang Kharumunid, Sukhwinder Singh, Brajesh Nare
11.	Transfer of potato technologies to stakeholders and assessment of their impacts HORTCPRISIL202000900148	PI: Dr. Ravinder Kumar. Associates: Drs. Pynbianglang Kharumnuid, RK Singh, Yogesh Gautam, Rahul Kumar Tiwari, Milan Kumar Lal, Ashok Chauhan, Arjun K. Sharma, DK Gupta



DIVISION OF CROP IMPROVEMENT & SEED TECHNOLOGY

PROGRAMME: MANAGEMENT OF POTATO GENETIC RESOURCES

Genetic resources are a strategic resource for sustainable crop production. Conserving the potato genetic resources (PGRs) is critical for the long-term future of potato improvement programs. This program aims to conserve and provide diverse genetic material to potato researchers. The collection is evaluated, characterized, and documented in an easily retrievable form for use by the researchers.

Collection

Last year, 155 accessions were imported in *in-vitro* form from 3 different countries, including 137 from CIP, Lima, Peru, 13 varieties from the Netherlands, and five cultures from France. During the year, 171 accessions free from quarantined pests were introduced to the germplasm repository. Presently more than 4700 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	62	65		65	
Advanced hybrids	86	50	-	96	
Indigenous varieties	51	107	-	107	
Indigenous samples	97	42		97	
Exotic	1945	2850	-	3050	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				4717	

Conservation

Field conservation: One thousand five hundred and ninety Tuberosum accessions, 701 Andigena accessions, and 63 indigenous samples were maintained in fields at Jalandhar. In field conditions at Kufri, 1480 cultivated potato germplasm were conserved. This includes CPRI-bred varieties (65 nos.), indigenous varieties (117 nos), and CP No. (*Solanum tuberosum ssp. tuberosum*) (1306 nos.). Besides this, 301 Tuberosum accessions were maintained at Modipuram. In wild species, 350 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 2950 Tuberosum accessions and 130 accessions of 29 wild species were maintained in *in-vitro* form. Minutubers of 81 accessions from *in vitro* repository were produced and added to the germplasm collection maintained under field conditions at Modipuram. During this year, three varieties, namely Kufri Kiran, Kufri Thar-3, and Kufri Chipsona-5, and three advanced hybrids, MP/14-71, MP/13-662 & MP/15-698, were made free from all viruses using meristem tip culture.

Evaluation

Adaptability

Temperate long days

Kufri: In a single-row trial set, 94 indigenous genotypes were evaluated along with Kufri Jyoti, Kufri Himalini, and Kufri Girdhari as control. PSK/76, Rangpuria, VK/JG-1, and Jalandhar performed well at the Kufri condition with higher avg. yield per plant over best control Kufri Girdhari (Avg. tuber yield per plant 225 g).

Sub-tropic short days

Jalandhar: One hundred (100) Tuberosum accessions were evaluated under spring planting conditions. The yield of germplasm accessions ranged from 20 to 310 g/plant, while the best control variety was Kufri Jyoti (250 g/plant). The other control Kufri Pukhraj yielded 260 g/plant. Only one accession (CP 3469) out yielded the better control (310 g/plant).

Modipuram: Under early planting, 68 Tuberosum genotypes were evaluated under heat stress conditions in a replicated trial at 75 DAP. The highest tuber yield/plant was recorded in Sunred (340g) followed by K Bahar (301g), K Ganga (269g), K Mohan (266g), K Garima (266g), 302 (264g), K Lima (259g), K Sindauri (246g), K Arun (240g) and K Neelkanth (235g).

Under normal planting, 37 Tuberosum genotypes were evaluated under heat stress conditions in a replicated trial at 75 DAP. The highest tuber yield/plant was recorded in CP 3421 (953g), followed by CP 3364 (587g), CP 2094 (529g), CP 3326 (521g), CP 3414 (514g), CP 3437 (487g) and CP 1651 (480g).

Reaction to late blight

Ninety-four cultivated germplasm with controls Kufri Jyoti, Kufri Girdhari, and Kufri Himalini were screened for foliar blight resistance under Kufri's natural open epiphytotic condition. Based on late blight incidence recorded four times at an interval of seven days between two subsequent readings, only four accessions viz., Rangpuria, Kanpuria Safed, JG-1 & Desi alu were highly resistant (AUDPC < 250). The moderately resistant genotypes were Jalandhar, NJ-47, NJ-75, NJ-62 & Australian White (AUDPC 351-650), and the remaining genotypes were either susceptible (AUDPC 651-1200) or highly susceptible (AUDPC > 1200).

Forty germplasm were evaluated for late blight resistance under lab conditions i.e., tuber resistance by tuber slice method and foliar resistance by detached leaf method. Desi alu, Kanpuria Safed, and Rangpuria were highly resistant in the tuber slice method based on reaction. The resistant accessions were AGR/56, Aruconia, Australian white, Beeta, Garlentic, K-

22, KP/PC-292, Lal Mitti-1, and VB-8, while Edony, G-4, Kacha Bhutia, PSK-76 and Taurus were moderately resistant. The leftover accessions were susceptible. In the detached leaf assay, resistant accessions were: Beeta, Dehati Alu, Desi Alu, DRR blue, Deshla Lal, Edony, Garlentic, G-4, Hamraj Hatti, HZD/01-58, Kanpuria Safed, Kacha Bhutia, KP/PC-292, Lal Mitti-1, Lal Mitti-2, NJ-62 and Rajendra-1. The moderately resistant were: AGR/56, Aruconia, Australian white, Bengal Jyoti, Bhura Alu, JG-2 and Lal Gulab. The remaining were susceptible.

Viruses

Forty germplasm accessions were screened for resistance through DAS-ELISA against PVX and PVY. Eleven accessions, namely Australian White, Desi Alu, DRR Blue, Edony, Lal Mitti-2, Lal Gulab, NJ-47, NJ-130, Panamera, Taurus, and VB-8, had combined resistance to PVX and PVY. In comparison, 14 and 30 accessions showed resistance to PVX and PVY, respectively.

Field screening of 43 potato germplasm was conducted under field conditions at Modipuram against APCLV & hopper burn. Eighteen accessions (A-97-14, A-98-40, A-98-47, J-13-97, A-98-175, A-98-166, N-13-49, A-98-54, J-14-15, A-98-44, J-14-174, N-13-149, J-14-245, A-98-181, A-98-103, A-97-22, J-14-201 and A-98-94) did not show any symptoms of APCLV.

Common scab

Pathogenic *Streptomyces* species synthesize the phytotoxin thaxtomin, which elicits scab symptoms and is the primary pathogenicity determinant in common scab-causing species. Due to its central importance in disease expression, selection for tolerance to thaxtomin may be an effective preliminary screening of potato lines for resistance to *Streptomyces* sp. A total of 88 local collections were screened for their tolerance to Thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay. Only three lines, i.e., VK/JG-2, Garlentic, and Kranti, showed resistance (tested twice), and the rest were found highly sensitive to the toxin resulting in brown to black necrosis of tissues along with medium to deep pit formation on tuber slices.

Dry Rot

For Dry rot screening, the uniform size healthy tubers were surface sterilized and wounded with a cork borer up to 3 mm depth. The mycelial plug was removed from the pure culture of *Fusarium sambucinum* and inoculated on the tuber wounds. Potato tubers without physical injuries or visible infection were chosen for the screening. Healthy non-inoculated tubers were kept in control. After

21 days of incubation at 18°C and 85-90% relative humidity, the lesion index and volume of tuber rot were calculated using the formula and scale previously used by Trabelsi et al. (2015). It varied significantly depending on the different accessions. Out of 88 local collections screened for dry rot pathogen, two accessions NJ 2303 and HZD/01-58 were highly susceptible, while Kranti and Lah Syntiew were moderately tolerant.



Fig. 1: Potato tubers after 21 days of pathogen (*F. sambucinum*) inoculation

Leaf-hopper and mites

Of 184 accessions, 42 accessions had hopper burn below 20%, whereas no mite damage was observed in any of the accessions.

Cyst nematodes

Forty-one indigenous accessions were screened for potato cyst nematode (*Globodera rostochiensis* and *G. pallida*) resistance through root ball technique under glasshouse conditions at Kufri. Based on cyst count at 55 days after planting, three accessions i.e., JG-1, Jeevan Jyoti, and Garlentic, were highly resistant to both species. The remaining accessions were either moderately resistant, susceptible, or highly susceptible.

At Ooty, out of 246 accessions, nine accessions (CP 1137, CP 1674, CP 1932, CP 1988, CP 2285, CP 2418, CP 3183, CP 3201, and CP3881) were resistant to both the species of PCN (*G. rostochiensis* & *G. pallida*), whereas twenty-one accessions were resistant to *G. rostochiensis*.

Keeping quality

Forty-six accessions were evaluated for keeping quality at room temperature (14-38°C, 44-75% RH) compared to three control cultivars: Kufri Dewa, Kufri Ashoka, and Kufri Pukhraj. Periodical observations on weight loss, sprouting, and rotting in tubers were recorded at 30 days

intervals up to 90 days of storage (DOS). Firmness was recorded on a scale of 1-5, with a score of 5 assigned to the firmest as freshly harvested/cold-stored potatoes. Accessions were rated in different categories based on storage performance, viz., weight loss, rotting, total loss, and physical appearance of tubers after 90 DOS. Out of the 46 accessions, only one accession (CP 3905) was found to be a good keeper having less than 15% total storage losses, whereas eight accessions (CP Nos. 3426, 3471, 3647, 3724, 3880, 3898, 3985, and 4007) as average keeper with storage losses in the range of 15.00 to 20.00%.

Chipping and Physico-chemical constituents

At Jalandhar, 45 Tuberosum accessions were evaluated for processing quality parameters, viz. chip color, dry matter, and reducing sugar and sucrose contents. Based on chip color (acceptable score up to 3 on a 1-10 scale of increasing dark color), dry matter (>21%), and reducing sugar (<100 mg/100g fresh tuber wt.), none of the accession was found suitable for chipping.

Seventy-five accessions were also evaluated for vitamin C content which varied widely between 17.83 to 40.40 (mg/100 g fr. wt.) with minimum and maximum values registered by CP 3211 and CP 3347, respectively. The ten top most

accessions for vitamin C content (mg/100g fr. wt.) were: CP 3347 (40.40), CP 3259 (40.25), CP 3246 (39.46), CP 3266 (39.30), CP 3256 (39.14), CP 3342 (38.98), CP 3277 (37.88), CP 3208 (38.83), CP 3242 (38.51) and CP 3336 (37.09).

Micro-nutrient Content

Twenty-five accessions were evaluated for iron and zinc content. Iron content varied from 26.44 (Lal Gulab) to 38.61 mg/kg (Lal mitti-1), whereas the range for Zn content was from 15.48 (Aber chibi) to 28.68 mg/kg (Lal mitti-1) on a dry weight basis. The top most five accessions for Zn content (mg/kg) were: Lal mitti-1 (28.69), Desi alu (23.95), Dolly (23.43), K-22 (22.30) and Lah saw khasi (21.71) and for Fe content (mg/kg) were: Lal mitti-1 (38.61), Tauras (35.45), Desi Lal (34.64), K-22 (34.25) and Jeevan Jyoti (33).

Water use efficiency

Germplasm accessions are being evaluated at three 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. Out of 20 accessions, eight accessions, namely CP 3770, CP 3780, CP 3797, CP 3850, CP 3853, CP 4030, CP 4140, and CP 4388, were found promising in the 3rd year evaluation; in another lot, 20 accessions were evaluated and four accessions namely CP Nos. 4393, 4473, 4535, and 4536 gave significantly higher yield as produced by var. Kufri Pukhraj in the 2nd year of testing and seems to be promising for higher water use efficiency.

Foliage maturity

Out of 99 Tuberosum accessions screened for foliage maturity at Patna, 22 accessions, namely CP Nos. 3656, 3660, 3661, 3665, 3673, 3690, 3702, 3724, 3730, 3734, 3735, 3763, 3773, 3774, 3776, 3780, 3786, 3791, 3838, 3847, 3850 and 3878 were found early maturing having > 90% foliage maturity at 80 DAP.

Wild Species

Wild species screening against late blight resistance

Fifty-four clones of 20 accessions belonging to 7 species were screened for late blight resistance under natural epiphytotic conditions at Kufri. Eight clones viz. SS2834-03 (*Solanum acaule*), SS2837-08 (*S. acaule*), SS2846-05 (*S. berthaulti*), SS2876-01 (*S. berthaulti*), SS2894-03 (*S. brevicaulis*), SS2936-02 (*S. chacoense*), SS2936-04 (*S. chacoense*), SS3103-0 (*S. verrucosum*) were highly resistant, and four clones namely, SS2837-03 (*S. acaule*), SS3005-04 (*S. kurtizianum*), SS3038-0 (*S. verrucosum*) and SS3058-0 (*S. verrucosum*) were resistant to late blight. The average AUDPC values ranged from 0-2120, with 12 clones having below 50 AUDPC. In addition, 330 clones of different species were also evaluated for late blight resistance using leaf disc assay in lab. Four clones namely SS1769-14 (*S. Carnegie*), SS1840-17 (*S. demissum*), SS2686-03 (*S. tuberosum* subsp. *andigena*) and SS2936-02 (*S. chacoense*) showed a highly resistant reaction, 168 clones were resistant, 102 were moderately resistant, and 62 were susceptible.

Diversity analyses of germplasm using SSR markers

In 2022-23, genetic diversity evaluation in a germplasm panel (SVAM collection) comprising 37 potato germplasm accessions procured from North-Eastern India has been initiated using genomic-SSR markers. Leaf material of these accessions was procured from the Kufri farm, and pooled leaf samples for each genotype were used for genomic-DNA extraction using the modified CTAB method (Doyle and Doyle, 1990). A set of 90 selected SSR markers covering all the potato chromosomes were used for genotyping work. In Total, 52 SSRs were found polymorphic, while 38 SSRs resulted in monomorphic amplicons. Further, allele scoring and data analysis work are in progress.

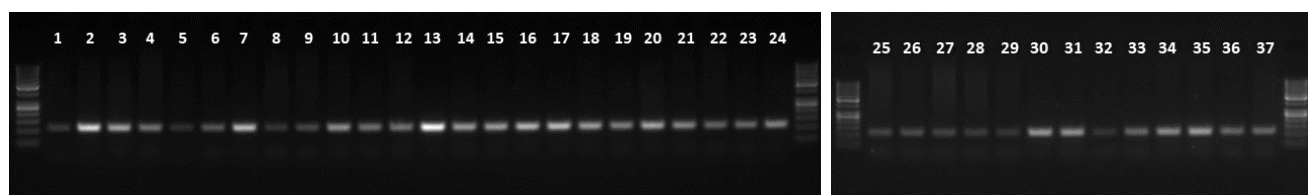


Fig. 2: Amplification profile of S182 SSR marker in potato germplasm accessions

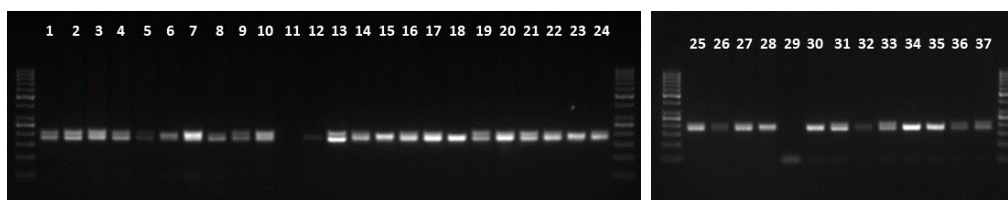


Fig. 3: Amplification profile of STM1057 SSR marker in potato germplasm accessions

Germplasm registered

Eight elite potato clones were registered with the ICAR-NBPGR, New Delhi. These are important genetic materials for somatic hybridization and parental line for different breeding programs.

S. No.	Elite Germplasm	INGR No.	Details of Special Achievements
1.	MSH/14-7	21169	MSH/14-7: Interspecific somatic hybrid-derived clone MSH/14-7 [cv. Kufri Garima × Bulk pollen of somatic hybrids (<i>S. tuberosum</i> + <i>S. pinnatisect</i>)] with the wider genetic base having high yield combined with moderate resistance to late blight under field conditions.
2.	CPH62	21170	CPH62: <i>Solanum cardiophyllum</i> (Acc. no. PI283062). Highly resistant to late blight disease. Diploid species with diverse genetic bases. Suitable for protoplast fusion and somatic hybrid development.
3.	PNT 43	21171	PNT43: <i>Solanum pinnatisectum</i> (Acc. no. CGN17443). Highly resistant to late blight disease. Diploid species with diverse genetic bases. Suitable for protoplast fusion and somatic hybrid development.
4.	STO 61	21172	STO61: <i>Solanum stoloniferum</i> (Acc. no. PI225661). Highly resistant to late blight disease. Diploid species with diverse genetic bases.
5.	MSH/17-16	21173	Interspecific somatic hybrid - derived potato hybrid [cv. Kufri Garima × somatic hybrid 'Crd10' (<i>S. tuberosum</i> + <i>S. cardiophyllum</i>)] with a broader genetic base. Yellow tuber flesh color hybrid with high carotenoid content.
6.	NUE/15-8	21174	NUE/15-8: Kufri Jyoti × Kufri Gaurav. High nitrogen use efficiency traits such as NUE, Agronomic NUE (AgNUE), Nitrogen Uptake Efficiency (NUpE), and Nitrogen Utilization Efficiency (NUtE). High yield under low nitrogen (50 kg N/ha) supply under field conditions and suitable for low input agriculture.
7.	MSP/15-26	22062	MSP/15-26: Barely Red x CP 3770. It is an elite cultivated clone with high carotenoids in the flesh (823 µg / 100g FW) and yellow flesh with red vascular rings.
8.	MSP/15-51	22063	MSP/15-51: Barely Red x CP 3770. It is an elite cultivated clone with high ascorbic acid in the flesh (68 mg / 100g FW) and distinct red-purple flesh.

Documentation

Computer databases of cultivated and 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: GENETIC ENHANCEMENT OF POTATO THROUGH MOLECULAR AND GENOMIC TOOLS

Transcriptome analysis for NUE in potato

In the year 2022-23, a panel of 56 potato varieties has been established in aeroponic facility and evaluated for nitrogen use efficiency (NUE) parameters under three different doses/applications of nitrogen viz. high (5.0 mM), optimum (2.0 mM) and low (0.2 mM) (Fig. 1). Various parameters evaluated were plant height,

leaf area, total biomass, root system architecture, total nitrogen content, chlorophyll content, tuber number and tuber yield. Further, data analysis is in progress. On the basis of these observations, contrasting varieties under different regimes of nitrogen would be identified and used for Real-time validation of NUE candidate genes.

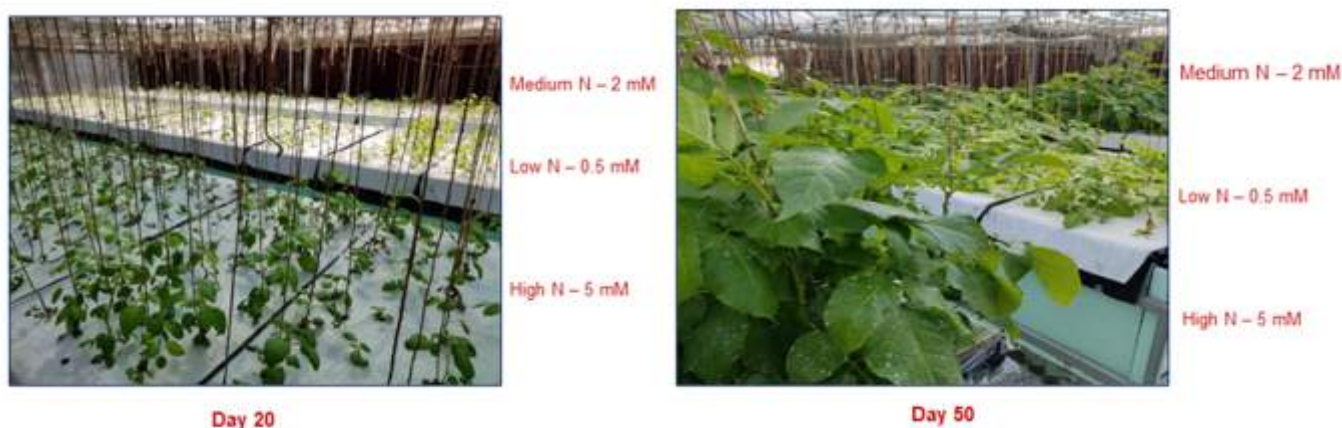


Fig. 1: Potato varieties performing under different doses of nitrogen in aeroponic facility

Transcriptome sequence data for NUE of potato varieties had been further analysed for identification of long non-coding RNAs (lncRNAs), which are expressed in a specific tissue and under specific conditions. lncRNAs also alter the affinity of vicinity genes under nitrogen stress conditions. From root, leaf and stolon tissues, a total of 53, 57 and 159 differentially expressed lncRNAs had been identified (Table 1), which showed upregulation

and downregulation under N-stress conditions. Similarly, a total of 6, 24 and 17 differentially expressed circRNAs were identified in root, leaf and stolon tissues showing upregulation and downregulation (Table 2). mRNA binds to circular-RNAs and thus inhibits the metabolic pathway. Fig. 2 depicts the location of the differentially expressed circRNAs on different chromosomes of potato.

Table 1. Differential expressed lncRNA in Potato under nitrogen stress

Tissue	Exon >1 & length >200	Rfam (Discarded)	CPC (non coding)	UTR (Discarded)	Diff_lncRNA	UP	DOWN
Root	45568	45053	4717	2956	53	24	29
Leaf	46475	45963	4884	3087	57	34	23
Stolon	45369	44876	4712	2931	159	100	59

Table 2. Differential expressed circRNA in Potato under nitrogen stress

Tissue	No. of Circ RNAs	DE circRNA	Sponge mi RNA	UP	DW
Root	299	6	6	3	3
Leaf	261	24	22	10	14
Stolon	335	17	15	11	6

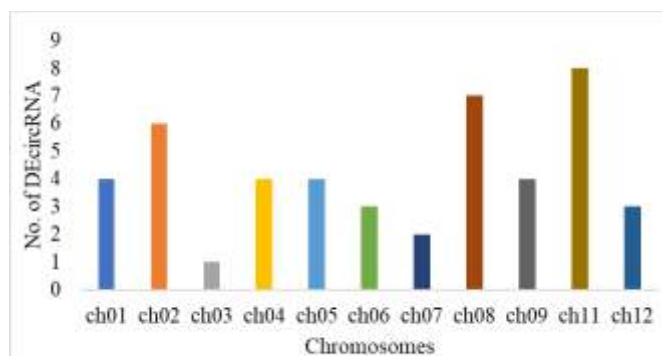


Fig. 2: Chromosomal location of DE circRNAs in potato

Development of potato genotypes for higher NUE

Based on tuber shape, depth of eyes, uniformity of the produce and yield composition, a total of three genotypes namely NUE/15-8, NUE/15-23, and NUE/15-67 were selected from F_1C_6 at CPRIRS, Modipuram and these were under field evaluation at three N regimes (50, 180 and 240 Kg N/ha). Both the parents namely Kufri Gaurav and Kufri Jyoti were kept as control (Table 3). Advance potato hybrid NUE/15-8 was registered as Potato germplasm (INGR 21174) for high NUE in ICAR-NBPGR during last year and another potato hybrid NUE/15-23 has been registered as Potato germplasm (INGR 22188) for high NUE in ICAR-NBPGR this year.

Table 3. Performance of NUE hybrids during 2021-22 at Modipuram

Hybrid	Total tuber yield (t/ha)			Tuber dry matter (%)
	N ₅₀	N ₁₈₀	N ₂₄₀	
NUE/15-8	36.8	42.5	41.7	17.63
NUE/15-23	39.7	45.9	44.4	18.57
NUE/15-67	36.6	42.1	38.9	17.41
K. Gaurav	32.8	37.9	39.2	16.32
K. Jyoti	32.5	35.0	34.7	17.56
CD (5%)	1.8	2.1	2.2	--

Transcriptome analysis reveals differentially regulated genes in wild *Solanum* species, somatic hybrids and potato varieties for late blight (*Phytophthora infestans*) resistance

Late blight is a serious disease of potato. This study aimed to unveil genes involved in late blight resistance in potatoes by artificial inoculation of *P. infestans* under controlled conditions. Diverse potato genotypes used in this study were wild species (*S. pinnatisectum* 'PIN45' and *S. cardiophyllum* 'CPH62'), somatic hybrids (P7: *S. tuberosum* dihaploid C-13 + *S. pinnatisectum*; and Crd6: *S. tuberosum* dihaploid clone C-13 + *S. cardiophyllum*) and potato varieties (Kufri Girdhari, Kufri Jyoti, and Kufri

Bahar). All seven potato genotypes were tested in two years (2021 and 2022) for late blight resistance by artificial inoculation of *P. infestans*. Late blight resistance test confirmed our earlier findings of highly resistant genotypes like somatic hybrids viz., P7 (AUPDC: 20.58) and Crd6 (AUPDC: 19.58), wild species viz., PIN45 (AUPDC: 0.75) and CPH62 (1.00), and potato cv. Kufri Girdhari (KG) (AUPDC: 1.33). The most popular cv. Kufri Jyoti (KJ) (AUPDC: 180.25) was susceptible compared to the highly susceptible control Kufri Bahar (KB) (AUPDC: 256.66). Late blight resistance test confirmed highly resistant P7, Crd6, PIN45, CPH62, and Kufri Girdhari, and susceptible Kufri Jyoti compared to highly susceptible Kufri Bahar (control) (Fig. 3).

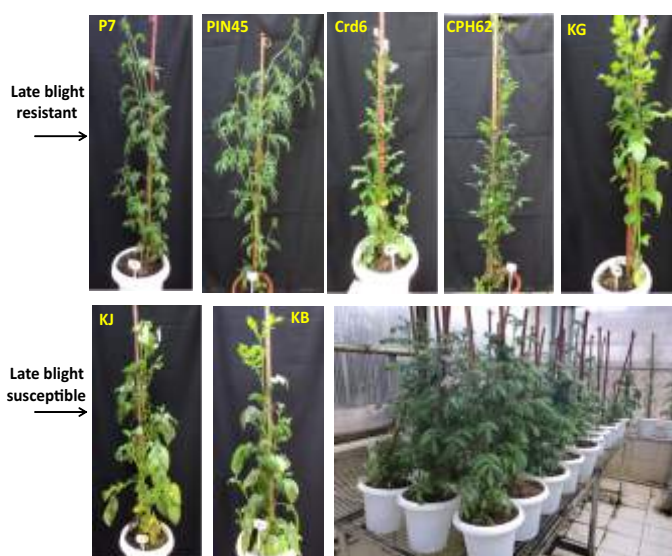


Fig. 3. Late blight resistance test of potato genotypes viz., highly resistant (P7, PIN45, Crd6, CPH62, and KG) and susceptible (KJ and KB) under controlled conditions after artificial inoculation with *P. infestans*. Genotype P7: somatic hybrid (*S. tuberosum* dihaploid C-13 + *S. pinnatisectum*), genotype PIN45: wild species *S. pinnatisectum*, genotype Crd6: somatic hybrid (*S. tuberosum* dihaploid C-13 + *S. cardiophyllum*), genotype CPH62: wild species *S. cardiophyllum*, potato cv. Kufri Girdhari (KG), cv. Kufri Jyoti (KJ), and cv. Kufri Bahar (KB).

Transcriptome analysis

Transcriptome analysis resulted in high-quality paired-end read data (QV > 25) ranging between 8.88 to 11.13 Gb using Illumina platform. Statistically significant ($p < 0.05$) differentially expressed genes (DEGs) were deduced in each genotype using Kufri Bahar (control) and grouped as either up-regulated ($> 2 \log_2$ fold change, FC) or down-regulated ($< -2 \log_2$ FC)

(Table 4). Heat maps of all six combinations are shown individually in Fig. 4 (P7 and Crd6), Fig. 5 (PIN45 and CPH62), and Fig. 6 (KJ and KG) versus KB as control for all test genotypes. In the heat maps, red and green colour shows up-regulated and down-regulated DEGs, respectively. Scatter plots and volcano plots show significant ($p \leq 0.05$) up-regulated and down-regulated DEGs. DEGs were functionally characterized with Gene Ontology (GO) terms and Kyoto Encyclopedia of Genes and Genomes (KEGG) pathways. Overall in resistant

genotypes, genes found to be up-regulated such as CC-NBS-LRR resistance protein, ankyrin repeat family protein, cytochrome P450, leucine-rich repeat family protein/protein kinase family, MYB transcription factor, zinc finger protein so on. Whereas genes found to be down-regulated were 1-aminocyclopropane-1- carboxylate synthase 2, AP2/ERF domain-containing transcription factor, C2H2-type zinc finger protein, NAC domain protein, transcription factor TSRF1, WRKY transcription factor so on.

Table 4. Summary of differentially expressed genes (DEGs) by RNA-sequencing in potato somatic hybrids, wild species and common varieties after artificial inoculation with *P. infestans* for late blight resistance

Genotype	Total expressed genes	Statistically significant DEGs ($p < 0.05$)		
		Up-regulated	Down-regulated	Exclusive (in one genotype only)
Somatic hybrid 'P7'	18529	273	300	402 (P7), 374 (KB)
Somatic hybrid 'Crd6'	19957	207	269	345 (Crd6), 430 (KB)
Wild species <i>S. pinnatisectum</i> 'PIN45'	16066	174	248	202 (PIN45), 1532 (KB)
Wild species <i>S. cardiophyllum</i> 'CPH62'	11082	46	106	99 (CPH62), 1458 (KB)
cv. Kufri Jyoti	18503	407	208	293 (KJ), 164 (KB)
cv. Kufri Girdhari	19071	221	378	428 (KG), 280 (KB)

P7: somatic hybrid (*Solanum tuberosum* + *S. pinnatisectum*; highly resistant), Crd6 (*S. tuberosum* + *S. cardiophyllum*; highly resistant), PIN45 (wild species *S. pinnatisectum*; highly resistant), CPH62 (wild species *S. cardiophyllum*; highly resistant), KJ (potato cv. Kufri Jyoti, susceptible), KG (potato cv. Kufri Girdhari, highly resistant), KB (potato cv. Kufri Bahar, highly susceptible). DEGs were identified in all genotypes using Kufri Bahar as a control variety.

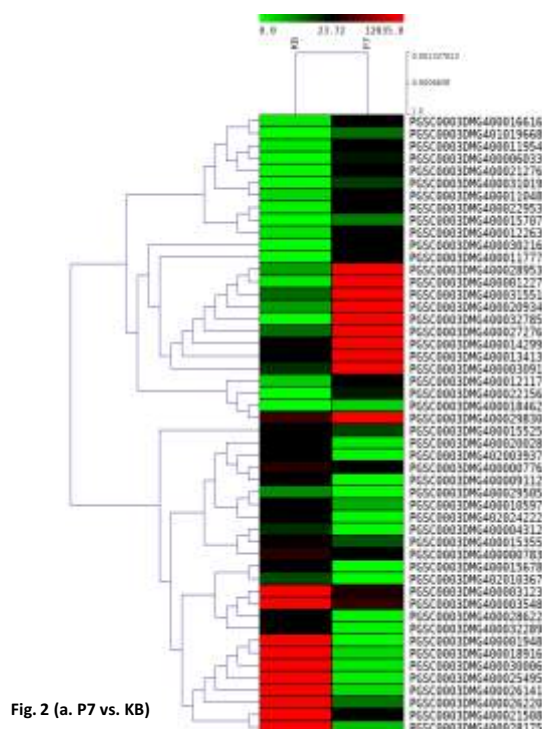


Fig. 2 (a. P7 vs. KB)

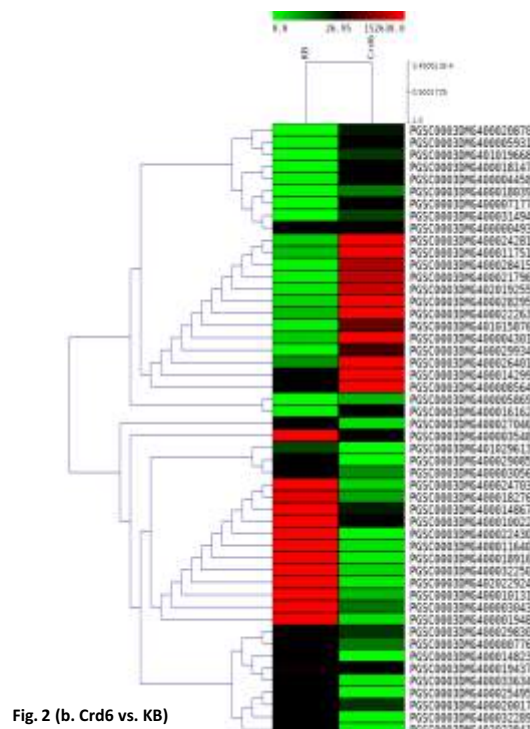


Fig. 2 (b. Crd6 vs. KB)

Fig. 4: Heat maps of top 50 differentially expressed genes in potato somatic hybrids a) P7 versus Kufri Bahar (KB, control), b) Crd6 versus KB (control) analysed by RNA-seq after artificial inoculation of *P. infestans* under controlled conditions. In the heat maps, each horizontal line refers to a gene. Relatively up-regulated genes are shown in red colour, whereas down-regulated genes are shown in green colour in a) P7 vs. KB, b) Crd6 vs. KB. Genotype P7: somatic hybrid (*S. tuberosum* dihaploid C-13 + *S. pinnatisectum*), and genotype Crd6: somatic hybrid (*S. tuberosum* dihaploid C-13 + *S. cardiophyllum*)

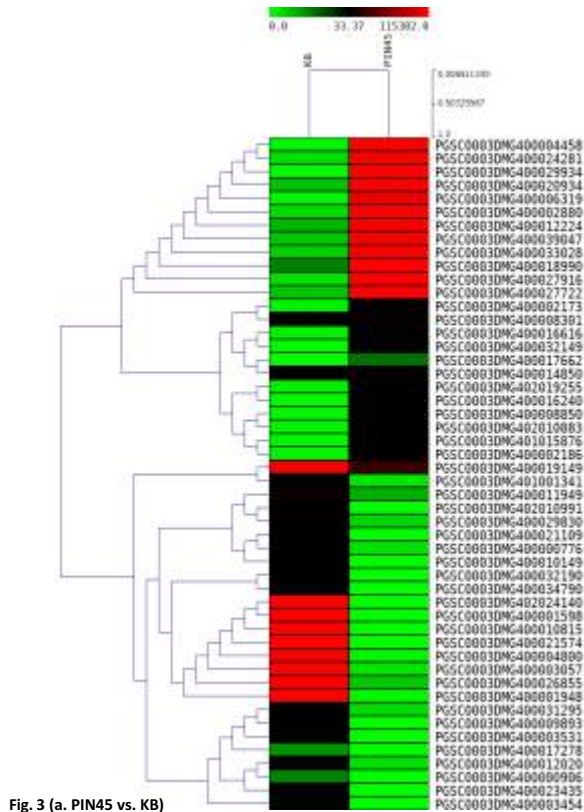


Fig. 3 (a. PIN45 vs. KB)

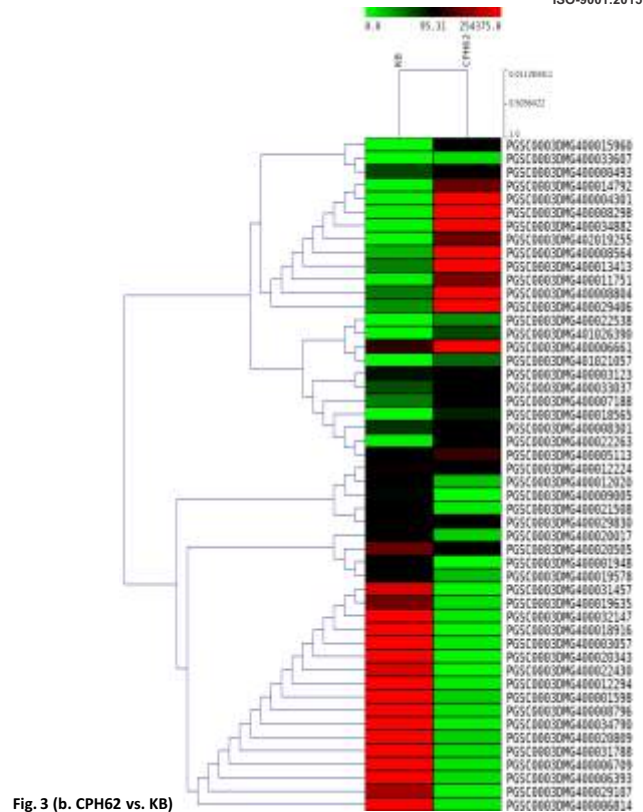


Fig. 3 (b. CPH62 vs. KB)

Fig. 5: Heat maps of top 50 differentially expressed genes in potato wild species a) PIN45 (*S. pinnstisectum*) versus Kufri Bahar (KB, control), b) CPH62 (*S. cardiophyllum*) versus KB (control) analysed by RNA-seq after artificial inoculation of *P. infestans* under controlled conditions. In the heat maps, each horizontal line refers to a gene. Relatively up-regulated genes are shown in red colour, whereas down-regulated genes are shown in green colour in a) PIN45 vs. KB, b) CPH62 vs. KB. Genotype PIN45: wild species *S. pinnstisectum*, and genotype CPH62: wild species *S. cardiophyllum*

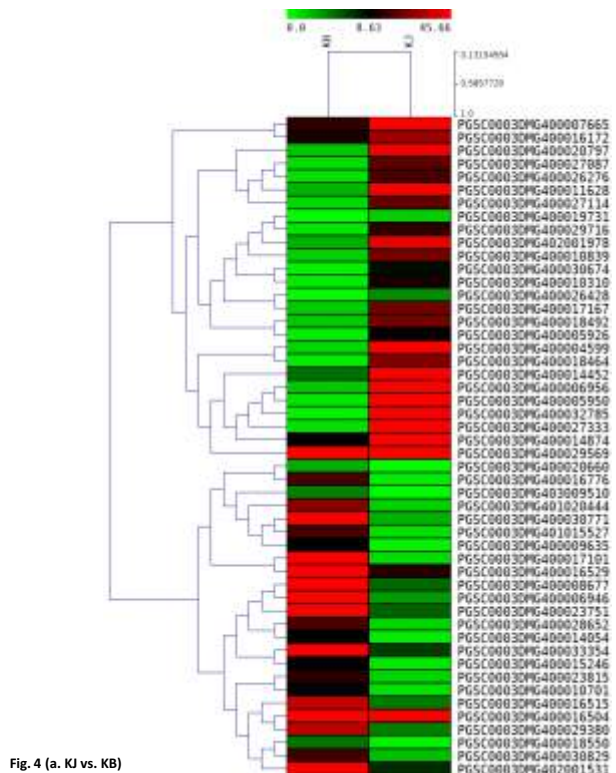


Fig. 4 (a. KJ vs. KB)

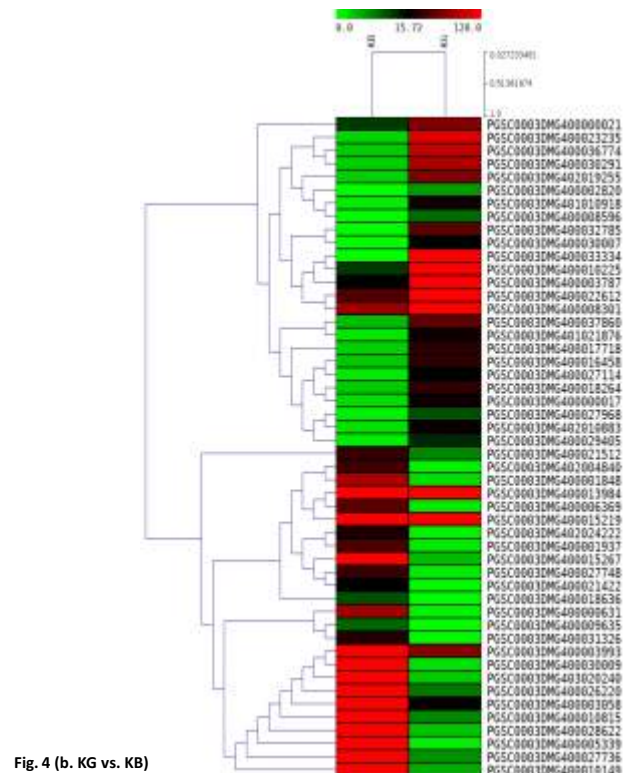


Fig. 4 (b. KG vs. KB)

Fig. 6: Heat maps of top 50 differentially expressed genes in potato varieties a) Kufri Jyoti (KJ) versus Kufri Bahar (KB, control), b) Kufri Girdhari (KG) versus KB (control) analysed by RNA-seq after artificial inoculation of *P. infestans* under controlled conditions. In the heat maps, each horizontal line refers to a gene. Relatively up-regulated genes are shown in red colour, whereas down-regulated genes are shown in green colour in a) KJ vs. KB, b) KG vs. KB

Venn diagram combination showed common genes such as i) 59 (up-regulated) and 76 (down-regulated) between somatic hybrid (P7) and wild *S. pinnatisectum* (PIN45), ii) 20 (up-regulated) and

41 (down-regulated) between another somatic hybrid (Crd6) and wild *S. cardiophyllum* (CPH62); and iii) 37 (up-regulated) and 26 (down-regulated) between Kufri Jyoti and Kufri Girdhari (Fig. 7).

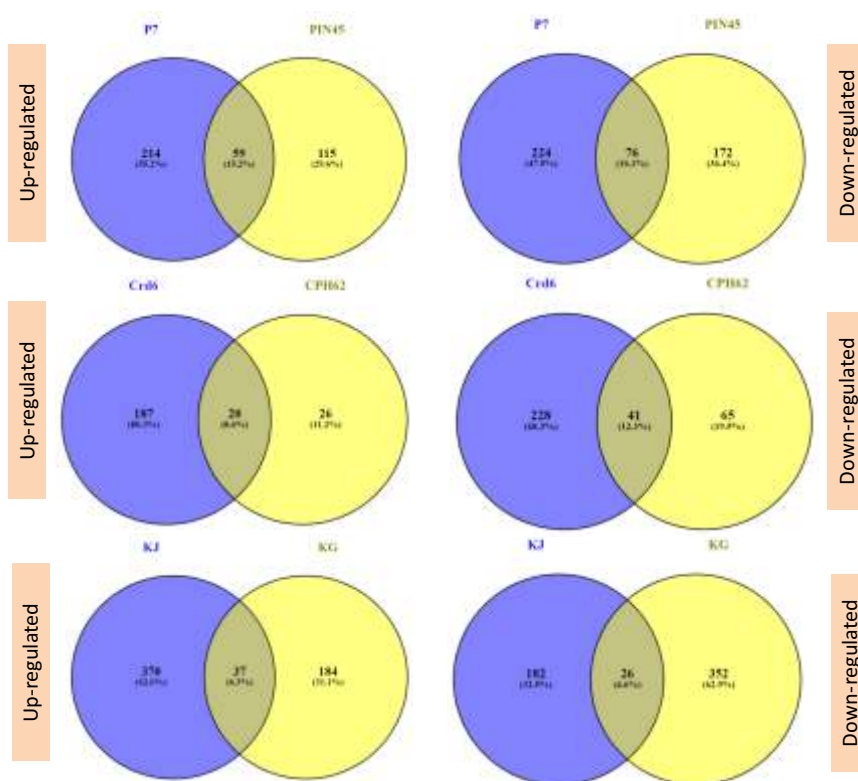


Fig. 7: Venn diagrams of up-regulated and down-regulated DEGs both common and exclusive genes distribution in different potato genotypes combinations viz., P7 and PIN45 (top), Crd6 and CPH62 (middle), and KJ and KG (bottom). Genotype P7: somatic hybrid (*Solanum tuberosum* + *S. pinnatisectum*), genotype Crd6 (*S. tuberosum* + *S. cardiophyllum*), genotype PIN45 (*S. pinnatisectum*), genotype CPH62 (*S. cardiophyllum*); genotype KJ = cv. Kufri Jyoti, genotype KG = cv. Kufri Girdhari, and genotype KB = cv. Kufri Bahar.

Selected 12 genes (2 genes from each sample of both up-regulated and down-regulated) were validated by RT-qPCR analysis. Like DEGs analysis, potato cv. KB was used as a control in RT-qPCR analysis also. RT-qPCR analysis was performed for one each gene from up-regulated/down-regulated DEGs such as disease resistance protein and C2H2-type zinc finger protein for P7, gamma aminobutyrate transaminase isoform 2, and pathogen-and wound-inducible antifungal protein CBP20 in Crd6, DNA-binding protein S1FA and Snakin-2 in PNT45, pectinesterase and lichenase in CPH62, disease resistance protein and protein kinase domain-containing protein in KJ, and bacterial spot disease resistance protein 4 and leucine-rich repeat protein in KG. RT-qPCR results are consistent with the RNA-seq results with minor variation in gene expression values. Our study elucidates genes and regulatory

elements imparting late blight resistance in potatoes originated from different genetic backgrounds.

Development of potato genotypes for higher yield and late blight resistance

At CPRIRS, Modipuram, 5452 true potato seeds of 5 crosses developed by crossing somatic hybrid (C13 + *S. pinnectisectum*/*S. Cardiophyllum*) with indigenous varieties were grown for seedling raising and 2340 seedling (5 crosses) were recovered/transplanted in the field. At harvest, 121 clones of 5 crosses were selected. At F_1C_1 stage, 123 clones of 8 crosses (developed using somatic hybrids (C13 + *S. pinnectisectum*/*S. Cardiophyllum*) as parent in combination with indigenous varieties were evaluated in short row trial (5 tubers) at 90 DAP. At harvest 16 clones of 4 crosses were retained. At F_1C_2 stage, 15 clones of 5 crosses were evaluated in duplicate row trial at

90 DAP and at harvest and 10 clones namely MSH/20-05, MSH/20-10, MSH/20-30, MSV/20-12, MSV/20-15, MSV/20-17, MSV/20-24 and MSV/20-27 were retained. Further at F_1C_3 stage, 17 clones were evaluated in multiple row trial at 90 DAP and at harvest three promising clones namely MSH/19-180, MSH/19-241 and MSP/19-190 were retained.

Development of a core set of SSR markers for characterization of potato germplasm and

varieties

A total of 155 genomic-SSR markers covering all the linkage groups of potato had been evaluated for their polymorphic potential in a representative set of 12 potato genotypes, comprising of varieties, germplasm, somatic hybrids and wild species to develop a core set of SSR markers for potato germplasm and varieties characterization. So far, 43 SSR markers were found to be polymorphic (Fig. 8).

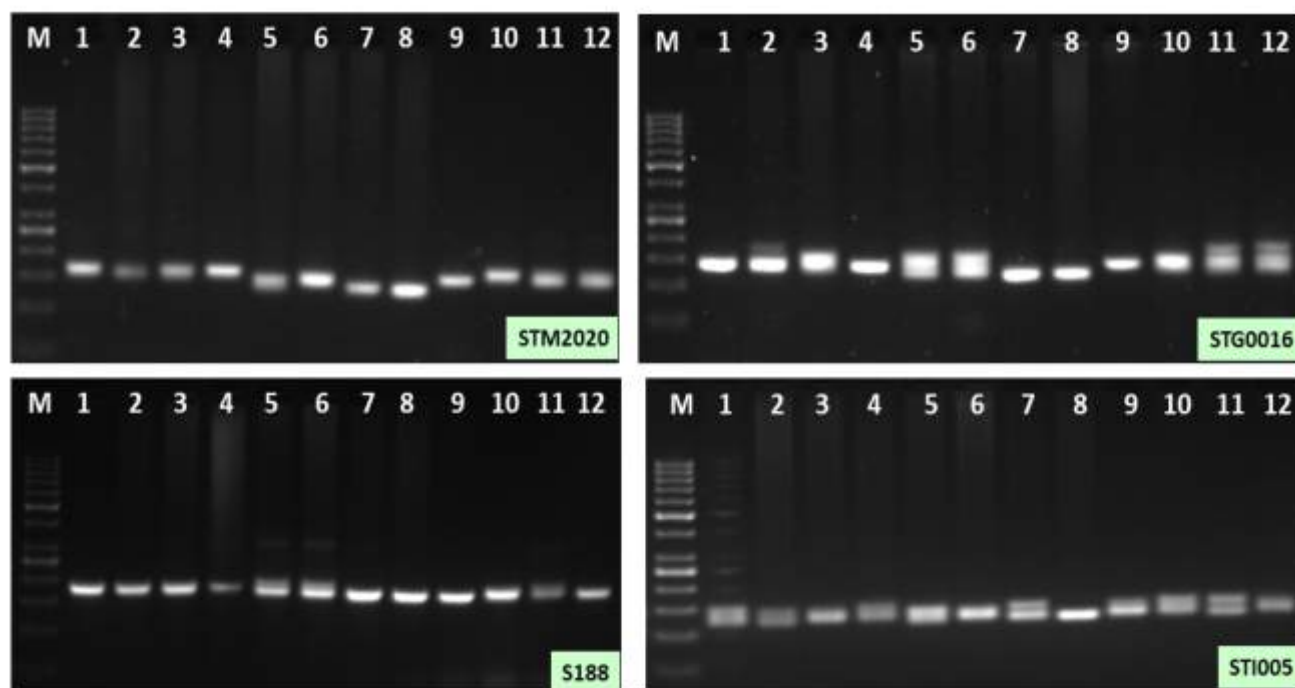


Fig. 8: Amplification profile of SSR markers in twelve genotypes of potato

M: 50 bp DNA ladder; 1: Kufri Jyoti, 2: K. Himalini, 3: K. Girdhari, 4: K. Pukhraj, 5: P1 (Interspecific potato somatic hybrid, C13 + *S. pinnatisectum*), 6: Crd 6 (C13 + *S. cardiophyllum*), 7: PNT 44 (*S. pinnatisectum*), 8: CPH 62 (*S. cardiophyllum*), 9: BER 57 (*S. barthaultii*), 10: CP 3258, 11: HZD/01/58, 12: CP 3845

Generation of non-recombined mutants by disrupting *St DMC1* gene using RNA interference

Fixing the genomic composition and multiplication through true potato seed (TPS) is an important challenge in autotetraploid potato. Disrupted meiotic cDNA (*DMC1*) is a meiotic gene that plays a central role in DNA recombination through crossing over in meiosis. Using the Arabidopsis *DMC1* (*AtDMC1*) gene sequence, we retrieved *Solanum tuberosum DMC1* (*StDMC1*) from the diploid potato genome, and subsequently, sense and antisense regions of the *StDMC1* gene were amplified in potato cv.

Kufri Jyoti. The CDS sequence of the *AtDMC1* gene showed 81% similarity with the diploid potato *DMC1* CDS sequence. Primers designed from the gene sequence (Sol-tu. DM. 09G025170.1) were used to amplify the *DMC1* gene sequence in the tetraploid Kufri Jyoti cultivar (Fig. 9). The sequence of Kufri Jyoti for the *DMC1* gene was analyzed for sequence similarity using the NCBI nucleotide BLAST tool. The phylogenetic analysis carried out using MEGA 11.0.13 revealed that Kufri Jyoti's *DMC1* has high sequence similarity with *Solanum lycopersicum* and *Capsicum Spp.* followed

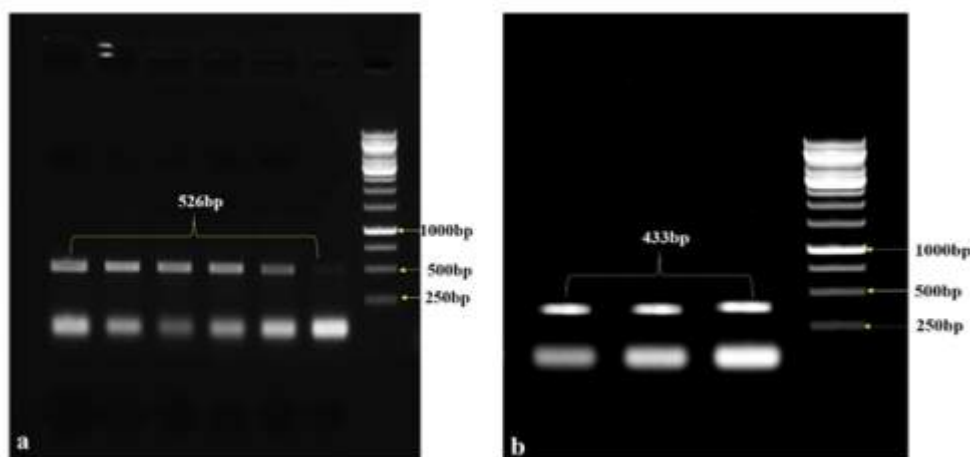


Fig. 9: PCR Amplification of *StDMC1* gene of sense fragment with *StDMC* sense primers flanked with restriction sites *Sal* I and *Kpn* I resulting in product size 526 bp 9a) Amplification of antisense gene fragment with *StDMC1* antisense primers flanked with restriction sites *Bam* HI and *Kpn* I resulting in product size 433 bp (b).

by *Nicotiana tomentosiformis* and *N. tabacum* (Fig. 10). The sense and antisense fragments were confirmed by Sanger-sequencing and cloned in the pRI101 vector (Fig. 11). In total, 310 putative transgenic lines were obtained using *Agrobacterium*- mediated transformation (Fig. 12), which were grown in a glass house under controlled conditions and screened using *NPTII* marker. Out of 310 lines, 137 lines were found positive with the *NPTII* marker showing a product size of 530bp (Fig. 13). Overall, a transformation efficiency of 44% was obtained to

get mutants (Table 5). These mutant lines were further validated through pollen viability testing (Fig. 14). The acetocarmine-based pollen staining showed reduced pollen viability ranging from 14 to 21% in four *DMC1* mutant lines (DMC4-37, DMC4-41, DMC6-20, and DMC6-21), as compared to the Kufri Jyoti control plants, which on average exhibited 78% pollen viability. The mutant lines will be further verified using qPCR and cytology. This is the first report of *StDMC1* mutant line generation in tetraploid potatoes and will be a step forward in generating non-recombinant mutants through sexual reproduction in potatoes.

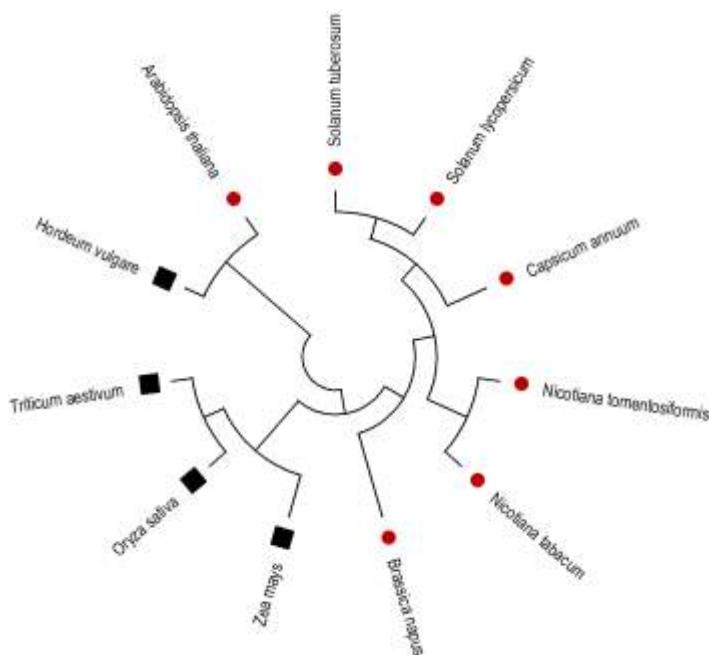


Fig. 10: Phylogenetic analysis and comparison of potato *StDMC1* gene sequence with major crops by Maximum likelihood method. In this phylogenetic tree, red color circles represent dicot species and black squares represent monocot species.

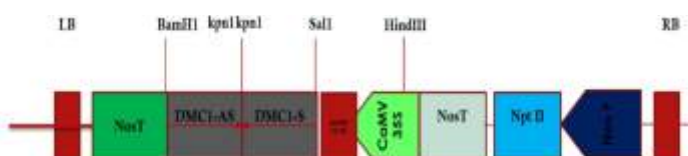
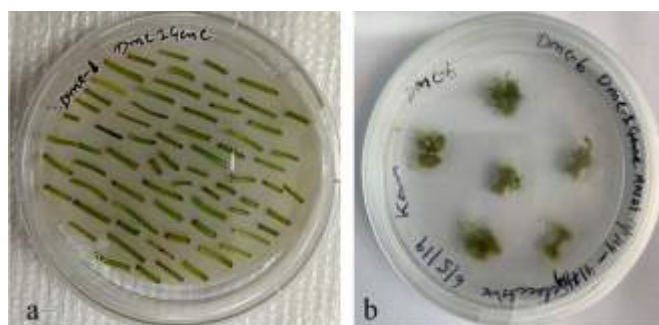


Fig. 11: A schematic diagram of the RNAi vector construct. The hairpin structure consisting of a sense *StDMC1* sequence (oriented in *Sal* I - *Kpn* I site) and the antisense *StDMC1* sequence (oriented in *Bam* HI - *Kpn* I site) was inserted between the (CaMV) 35S promoter and the nopaline synthase gene (NOS) terminator.



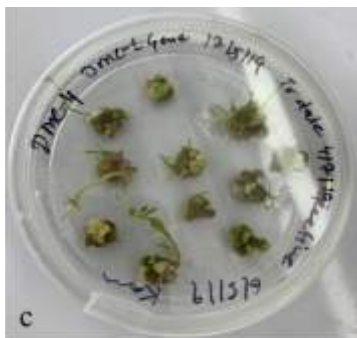


Fig. 12: *Agrobacterium* harboring *StDMC1* RNAi construct used for genetic transformation. a) *In vitro* 15 days old tissue culture internodal stem cuttings were placed on pre-selective basal MS medium for 48 hrs. b) The treated cuttings were transferred to regeneration medium containing Indoleacetic acid (IAA) (1 mg/ml), Naphthalene acetic acid (NAA) (0.01 mg/L), Gibberellic acid (GA3) (3 mg/ml), Cefotaxime (100 mg/ml), Kanamycin (50 µg/ml) and Carbenicillin (100 mg/ml) and plates were kept at 20±2°C under fluorescent light at 100 mol m⁻²s⁻¹ with 16 hrs light and 8 hrs dark for callus formation. c) Shoot development in putative transformants.

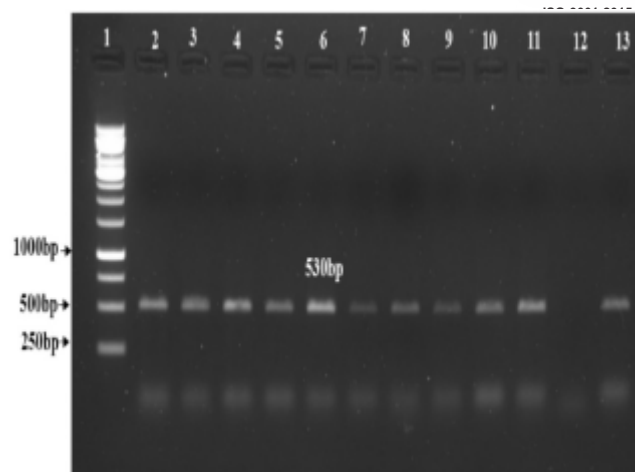


Fig. 13: Validation of transformed lines by PCR amplification using NPTII primers resulting in product size of 530 bp. Lane 1: 1 Kb Ladder, Lane 2-11: Transformed Lines, Lane 12: Non Transformed line i.e. Kufri Jyoti (Control), and Lane 13: Positive Plasmid Containing *StDMC1* sense::*StDMC1* antisense:pRI101AN

Table 5. Transformation efficiency of potato cultivar 'Kufri Jyoti' genetically transformed with *Agrobacterium* strain GV3101 harbouring binary vector pRI101

Explant (internode)	No. of cuttings	Callus	No of regeneration of shoots	NPTII positive	Percentage of transformation efficiency
Kufri Jyoti	140	100	310	137	44

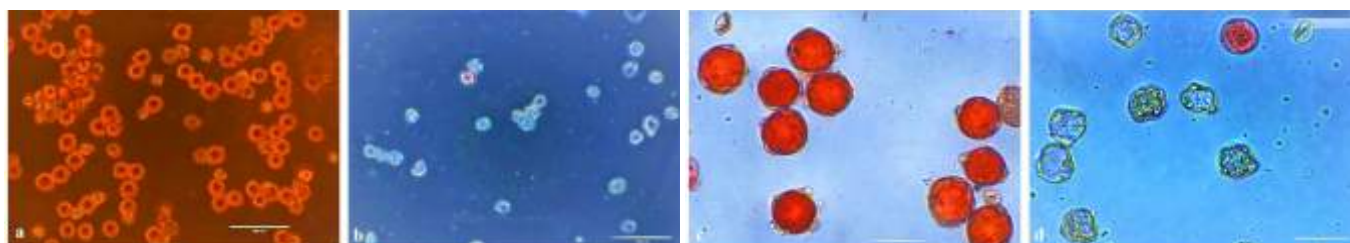


Fig. 14: Pollen viability using acetocarmine (2%) under EVOS XL Core Imaging System Microscope (Invitrogen™). Five frames of each slide were examined to count the viable and non-viable pollen grains. Viable pollen grains retained the stain whereas the non-viable pollen grains were unable to retain the stain. a) Control 'Kufri Jyoti' pollen grains (Scale bar=200 µm), b) RNAi lines showing non-viable pollen (Scale bar=200 µm), c) Control 'Kufri Jyoti' pollen grains (Scale bar=50 µm), and d) RNAi lines showing non-viable pollen (Scale bar=50 µm)

Genome editing of potato for modifying starch composition

Genome editing of potato cultivars K. Chipsona-I and K. Sangam has been targeted for modifying starch composition for high amylose content with resistant starch properties. In silico analysis of starch branching enzyme target genes SBE 2.1 and SBE 2.2 had been carried out. The SBE 2.1 and SBE 2.2 genes were mined from the published genome sequence of (Double haploid) potato from Potato Genome Sequence Consortium (PGSC), a potato-centric database that hosts PGSC genome sequence and

associated annotation data and provides access to recently generated large-scale potato datasets (http://solanaceae.plantbiology.msu.edu/pgsc_download.shtml). Further, multi-cistronic gRNA CRISPR cassette for two isoforms of starch branching enzymes viz. SBE 2 genes (SBE 2.1 and SBE 2.2) was constructed through CRISPR RGEN Tools (<http://www.rgenome.net/cas-designer>). The successful ligation of multi-cistronic gRNA CRISPR cassette with Cas9 containing binary vector pDIRECT23_C is successfully done (Fig. 15a and b).

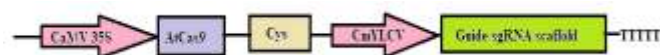


Fig. 15a

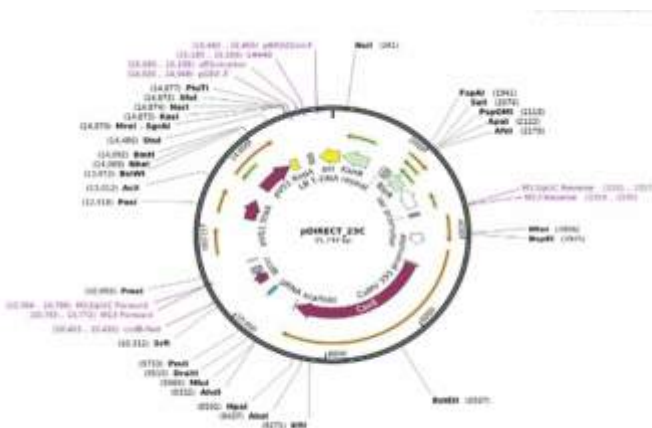


Fig. 15b

Fig. 15 a & b: Multi-cistronic gRNA CRISPR cassette with Cas9 containing binary vector pDIRECT23_C

The CRISPR vector pDIRECT 23_C carrying the gRNA construct of desired target gene SBE 2.1 and 2.2 was transferred into *Agrobacterium tumefaciens* strain GV3101 by freeze/ thaw method (Wise et al., 2006). Transformed *Agrobacterium* cells were selected on media containing 50 mg/l kanamycin and 10 mg/ml rifampicin. These were introduced into *Agrobacterium* strain GV3101 and were confirmed by PCR-based method (Fig. 16). *Agrobacterium*-mediated transformation of internodal tissue was performed by following a protocol for internode transformation (Fig. 17). Further shoot multiplication and elongation of transformed shoots is in progress.

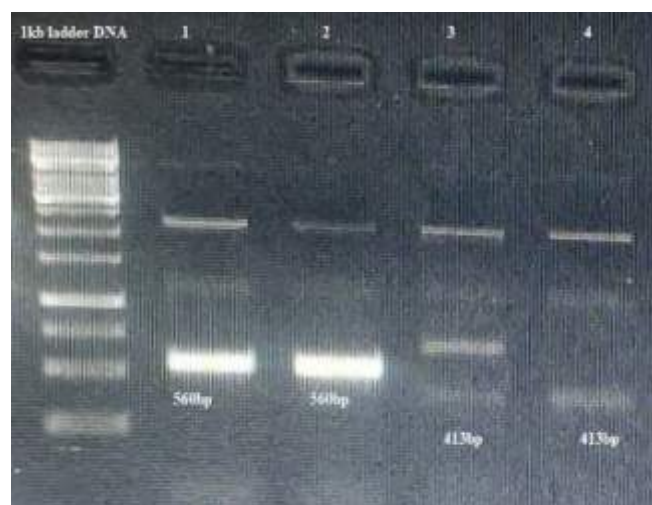


Fig. 16: PCR confirmation of cloned Cas9 (560bp) and Bar (413bp) gene in transformed *Agrobacterium tumefaciens* GV3101

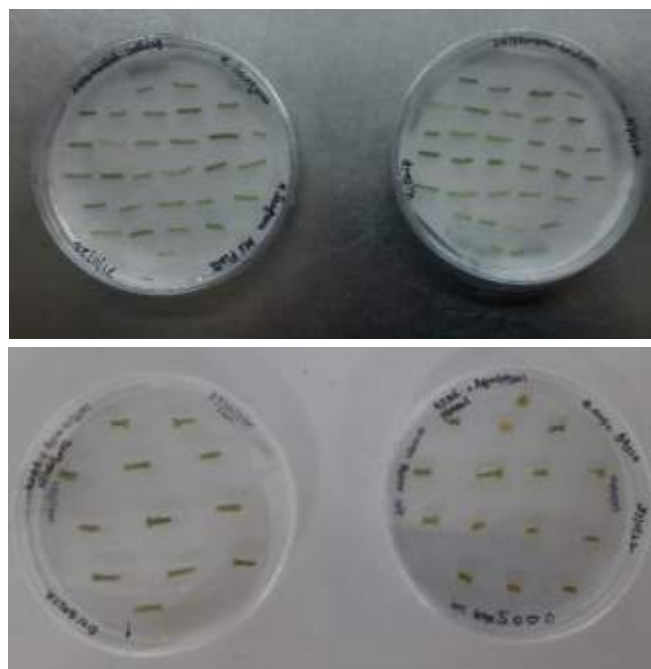


Fig. 17: Internode explants maintained on MS plates containing 0.005% and 0.01% selection marker BASTA

Genome-wide association study in potato for dry rot

A diversity panel of 353 tetraploid potato accessions comprising 256 from the germplasm *Solanum tuberosum* ssp. *tuberosum*, 49 from the germplasm *Solanum tuberosum* ssp. *andigena*, and 48 cultivated Indian potato varieties will be screened against dry rot pathogen (*Fusarium sambucinum*) and phenotypic data will be generated. The genotypic data of diversity panel were generated by the double enzyme based genotypic by sequencing (GBS) method. This year phenotypic data of 160 germplasm accessions were generated for dry rot pathogen by tuber inoculation method. Out of different dry rot causing pathogens, *Fusarium sambucinum* was selected which is the most dominant pathogenic *Fusarium* species in pathogenicity evaluation. 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 *Fusarium sambucinum* and inoculated on the tuber wounds. Potato tubers

without physical injuries or visible infection were chosen for the screening purpose. Healthy non-inoculated tubers were kept in control. After 21 days of incubation at 18°C and 85- 90% relative humidity the lesion index and volume of tuber rot was calculated using the formula and scale previously used by Trabelsi et al. (2015).

Tolerant: Lesion diameter ≤ 11 mm; **Moderately susceptible:** $11 \text{ mm} < \text{Lesion diameter} < 15$ mm; **Highly susceptible:** Lesion diameter ≥ 15 mm

It varied significantly depending on the different accessions. The lesion diameter, height and volume were reported in the range of 8.67 (CP 3809) – 35.67 mm (CP 2224), 5.33 (CP 1868) – 29 mm (CP 1557) and 97.49 (CP 1468) – 9182.98 mm³ (CP 2224), respectively. None of the cultivars/accessions tested was completely immune to the tested dry rot pathogen. A total of 14 accessions (CP 3809, CP 1468, Kufri Garima,

J/A 947 etc.) showed a diameter < 11 mm which can be considered as tolerant to dry rot pathogen on the basis of this year's study. Fig. 18 showed the lesion diameter of potato tubers after 21 days of pathogen inoculation. Fig. 19 exhibited the lesion depth of some of the tolerant and susceptible potato accessions. Fig. 20 and Fig. 21 showed how much the data values of lesion diameter, lesion height and lesion volume vary or spread out with the help of box plots.



Fig. 18: Potato tubers after 21 days of pathogen inoculation (A) Control (B) Inoculated tuber

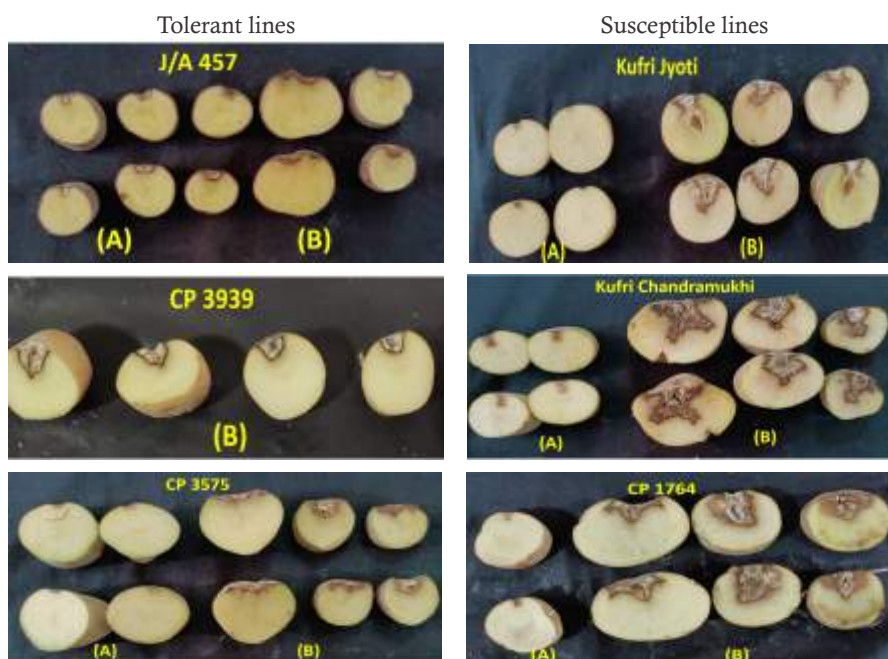


Fig. 19: Tolerant and susceptible lines for dry rot pathogen (A) Control (B) Inoculated tuber

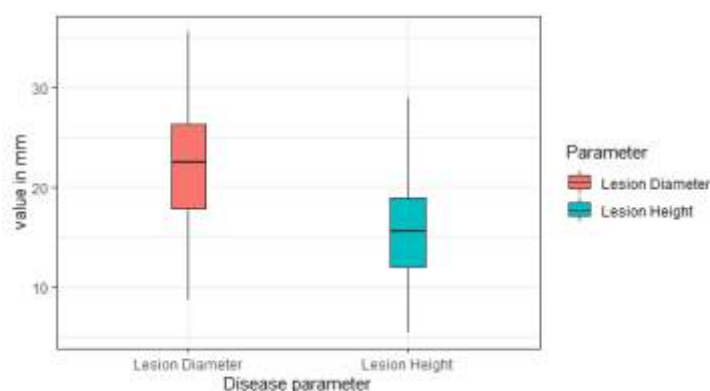


Fig. 20: Box plots showing lesion diameter (mm) and lesion height (mm)

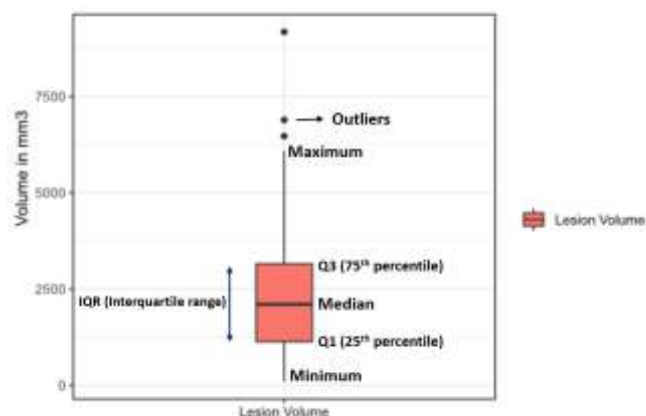


Fig. 21: Box plots showing lesion diameter and lesion volume (mm³)

RNA seq analysis of potato cyst nematode interactions with resistant and susceptible genotypes:

A study was conducted twice to know the gene expression in highly resistant advance hybrid SM/11-120 and highly susceptible cultivar Kufri Jyoti. 30 days after planting (DAP) both the genotypes were inoculated with 2000 juveniles (J2s) of PCN per pot. After 24, 48, 72 h, 7, 14 and 21 days roots were collected and observed for PCN infestation by root staining. Results showed that there was no infestation in the advance hybrid SM/11-120 whereas nematode penetration was started in Kufri Jyoti after 72 h of inoculation. Accordingly, gene expression profiling of Kufri Jyoti and SM/11-120 genotypes roots were studied before (0 DAI) and after 24, 48, 72 h, 7 days infection (DAI) of PCN J2s through RNA sequencing (Total 11 combinations made, Fig. 22). Total reads generated ranged between ~13-27 million per sample with read mapping of 51.6-68.3% to the potato reference genome. High quality data, ranging between 4.1 and 8.0 Gb were generated on Illumina platform using 2 x 150 bp chemistry.

The high quality reads of each of the samples were mapped to the reference genome of Potato *Solanum tuberosum* (SolTub_3.0) using Tophat at default parameters. The read mapping % age was found to lowest in KJ3 sample (72 h after inoculation) (51.6) and highest in SM1 (un-inoculated) (68.3). Individual transcriptomes were then assembled and differentially expressed genes were identified using Cufflinks and Cuffdiff respectively. The genes which were assigned to the GO domain “Molecular Function” were found to be the highest in number among all the combinations across most of the conditions. The identified genes for all the 10 combinations were classified into 24 functional pathway categories using KAAS. Total SNPs identified for all the 10 combinations ranging between 36,143 and 45,955. Furthermore, RNA-Seq results were validated through quantitative real time PCR and it was observed that ATP, CD, CYTO, DR, FLAV, GP, LBR, LYS, and PR genes (resistant gene) were up-regulated at 7 DAI in SM/11-120 genotype While in Kufri Jyoti, which were subsequently down regulated.

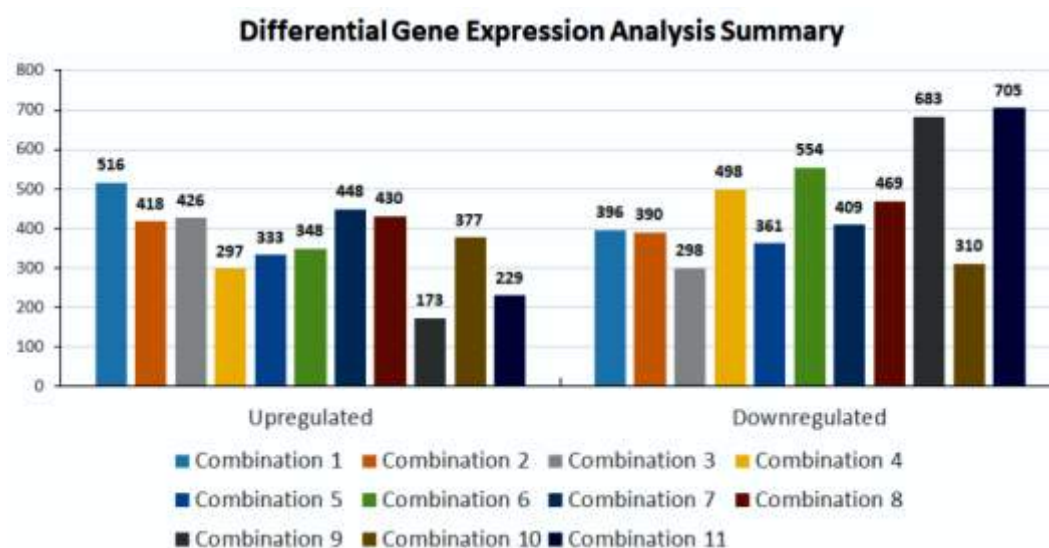


Fig. 22: Differential gene expression summary



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

Research activity 1: Breeding nutritionally superior potatoes varieties

Research activity leader: *Dr SK Luthra,*
Component workers: *Drs Babita Chaudhary, Dalamu, Vinod Kumar, Brajesh Singh, Jagdev Sharma, VK Dua, Bandana, Arvind Kumar Jaiswal, Sanjay Rawal, Mehi Lal, Milan Kumar Lal and Pooja Mankar.*

Hybridization: A total of 2,80,430 TPS were generated at Kufri/Modipuram from 93 diverse crosses involving diverse parental lines.

Seedling stage: In seedling stage 1093 promising clones of 34 families were selected from 30,975 seedlings raised by sowing 1,01,182 true potato seeds of 35 crosses.

Initial clonal stages: In initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 175 promising clones of 59 families were selected from the 1256 clones of 96 families evaluated at 90 days

Advanced stage trials: In all, 37 advanced clones were evaluated in four yield trials at 75/90 days at Modipuram and 16 promising advanced clones were selected. In Preliminary yield trial 1 (nutritionally superior clones-red/purple group), four promising clones namely MS/17-198, MS/17-848, MS/18-101 and MS/18-1272 were selected from the 12 advanced clones evaluated. In preliminary yield trial 2 (nutritionally superior clones-white/yellow group) six promising advanced clones namely MSP/16-272, MSP/17-07, MSA/16-126, MSA/16-140, MSA/16-333 and MSA/16-353B were retained from the eight advanced clones evaluated. In preliminary yield trial 3 (white group) three promising advanced clones namely MS/18-393, MS/18-463 and MS/18-465 were retained from the 12 advanced clones evaluated. In the confirmatory yield trial, five advanced clones were evaluated along with controls at 75 and 90 DAP) and based on tuber yield and tuber characters, three advanced clones namely MS/16-1157, MS/17-621 and MS/17-739 were retained.

Processing attributes at Modipuram: Processing attributes investigated in 29 advanced

clones/varieties revealed chip colour range from 2.5 (Lady Rosetta) to 9.0 (K. Lohit) and mean values 6.2 on the visual score. Among advanced clones, MSA/16-333, MSA/16-353B and MS/17-198 (purple coloured) recorded acceptable chip colour scores as compared to processing varieties K. Chipsona-3 and Lady Rosetta. In addition, MS/17-848 (3.5) produced red coloured chips.

Nutritional profiling at Shimla: In all 47 genotypes were assessed for nutritional components.

Amylose content (%): It ranged from 23 (MS/19-155) to 40% (MS/19-175) with mean values of 31%. The genotypes with high amylose content were MS/19-175 (40), MS/19-135, MS/19-253 (37), MS/17-621, MS/19-149 (36), MS/18-101, MSA/16-126, MSP/17-07 (35), Lady Rosetta and MS/16-1157 (34%).

Ascorbic acid content (mg/100 g FW): It ranged from 22 (MS/19-664) to 79 (MS/19-602) with mean values of 37 mg/100 g FW. The genotypes with high ascorbic acid content were MS/19-602 (79), MS/19-571 (65), MS/17-848 (55), MS/17-197, MSP/19-190 (54), MS/19-155 (53), MS/19-271, MS/19-370, MSH/19-180 and MS/17-739 (43 mg/100 g FW).

Anthocyanins (mg/100 g FW): Anthocyanins in flesh ranged from 0.36 (MSH/19-180) to 45 (MS/17-848) with mean values of 7 mg/100 g FW. The genotypes with high anthocyanins in flesh were: MS/17-848 (45), MS/19-571 (32), MS/19-602 (32), MSP/19-190 (30), Badami Aloo (22), MS/17-197 (19), MS/19-155 (12), MS/18-101 (10), MS/18-1272 (8) and MS/19-150 (7). Anthocyanins on a whole tuber basis ranged from 1.46 (MSH/19-180) to 169 (MS/19-571) with mean values of 34 mg/100 g FW. The genotypes with high total anthocyanins were MS/19-571 (169), MS/17-848 (153), MS/17-197 (136), MS/19-602 (120), MSP/19-190 (119), Badami Aloo (84), MS/19-271, MS/19-492 (69), K Neelkanth (68) and MSP/17-212 (45 mg/100 g FW).

Carotenoids (ug/100g FW): Carotenoids in flesh ranged from 10 (MS/16-1157) to 270 (MS/19-135) with mean values of 67 ug/100g FW. The genotypes with high carotenoids were: MS/19-135 (270), MS/19-640 (262), MSP/19-190 (205), MSP/16-272 (194), MS/19-664 (164), MSP/17-07 (143), MS/18-383 (126), MSP/17-212 (116), MS/19-41 (113) and MSH/19-180 (94 ug/100g FW).

Glycoalkaloids content (mg/100g FW): Glycoalkaloids are naturally synthesized in potato tubers and sometimes their concentration exceeds the threshold levels of 20mg/100g fresh tuber weight. Among the 47 clones/varieties assessed, the glycoalkaloids content ranged from 0.16 (MS-16-1157) to 5.07 (MSA/16-353B) with mean values of 1.35 mg/100g FW. The results indicate that the tested advanced clones and varieties have safer limits of glycoalkaloids contents.

Zinc content (ppm): Zinc content (flesh) on a dry weight basis ranged from 13.61 (MS/19-230) to 26.54 ppm (MS/17-848) followed by MS/18-101 (26.17), MS/18-1272 (25.44), MS/13-527 (25.37), Lady Rosetta (25.19), MSP/17-212 (24.78), MS/17-739 (24.75), K. Manik (24.73), K. Bahar (24.36) and K. Neelkanth (24.00 ppm), whereas, zinc content on whole tuber basis ranged from 16.88 (MS/19-230) to 30.72 ppm (MS/17-848) followed by MS/18-101 (29.42), K. Manik (28.28), Lady Rosetta (28.03), MS/13-527 (27.86), MS/18-1272 (27.33), MSH/19-180 (26.97), MS/17-739 (26.85), MSP/17-212 (26.69) and K. Bahar (26.66 ppm).

Iron content (ppm): Iron content (flesh) on a dry weight basis ranged from 23.86 (MS/19-149) to 40.17 ppm (MS/18-101) followed by MS/17-848 (37.81), MS/17-739 (37.07), K. Manik (36.49), MS/18-1272 (35.89), K. Neelkanth (35.56), MS/19-571 (35.35), MS/19-625 (34.60), K. Lohit (33.81) and MS/19-155 (32.78 ppm); whereas iron content on whole tuber basis ranged from 31.19 (MS/19-149) to 49.59 ppm (MS/18-101) followed by MS/17-848 (47.22), MS/17-739 (46.39), MS/18-1272 (46.02), MS/19-571 (44.61), K. Manik (44.19), MS/19-640 (44.12), K. Lohit (43.86), MS/13-527 (43.86) and MS/19-625 (43.27 ppm).

Screening of genotypes based on *in vitro* glycemic response

Starch hydrolysis index (SHI): In potatoes, the starch hydrolysis index (SHI) is an essential parameter that influences the glycemic response. The minimum and maximum SHI among 40 genotypes were 43.6 and 56.96, respectively with of average 48. ANOVA analysis showed that SHI differed considerably ($P < 0.001$) across varieties (**Table 1**). K. Sadabahar and K. Chandramukhi showed minimum and maximum SHI of 43.6 and 56.96, respectively, among table purpose varieties, however in processing varieties, the minimum and maximum SHI was found in K. Himsona (46.33) and K. Chipsona-3 (54.6), respectively (**Fig. 1A and B**).

Glycemic index (GI): The GI when averaged over 40 genotypes were reported to be 77.75. GI varied

Table 1: Screening of different parameters based on starch hydrolysis index (SHI), glycemic index (GI) and resistant starch (RS) in forty genotypes.

Parameters	Table purpose varieties		Processing purpose varieties		Mean	CD	Pvalue summary	Significant (alpha=0.05)
	Minimum	Maximum	Minimum	Maximum				
Starch hydrolysis index	43.60, K. Sadabahar	56.96, K. Chandramukhi	46.33, K. Himsona	54.6, K. Chipsona 3	48	1.73	****	Yes
Glycemic index	74.30, K. Sadabahar	84.95, K. Chandramukhi	76.41, K. Himsona	83.07, K. Chipsona 3	77.75	1.1	****	Yes
Resistant starch	1.40%, K. Lalit	2.18 %, K. Jyoti	1.08%, K. Chipsona 2	1.62%, K. Frysona	1.49	0.06	****	Yes

significantly ($P < 0.0001$) among genotypes from 74.3 to 84.95 (**Table 1**). The minimum and maximum GI of 74.3 and 84.95 was reported in K. Sadabahar and K. Chandramukhi, respectively in table purpose varieties and similarly, processing purpose varieties showed GI

values of 76.41 and 83.07 respectively in K. Himsona and K. Chipsona 3 (**Fig. 2A and B**). Higher GI contributed due to the higher carbohydrate content that ultimately might result in a postprandial increase in blood sugar level.

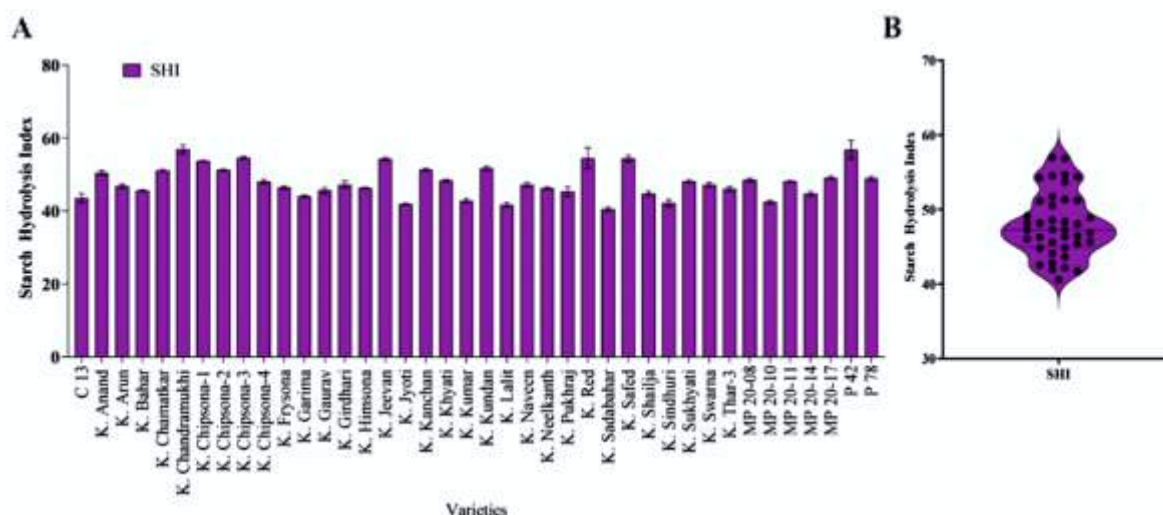


Fig. 1: (A) Variation in Starch hydrolysis index represented by histograms
(B) Violin plot of variation in starch hydrolysis index of about forty genotypes.

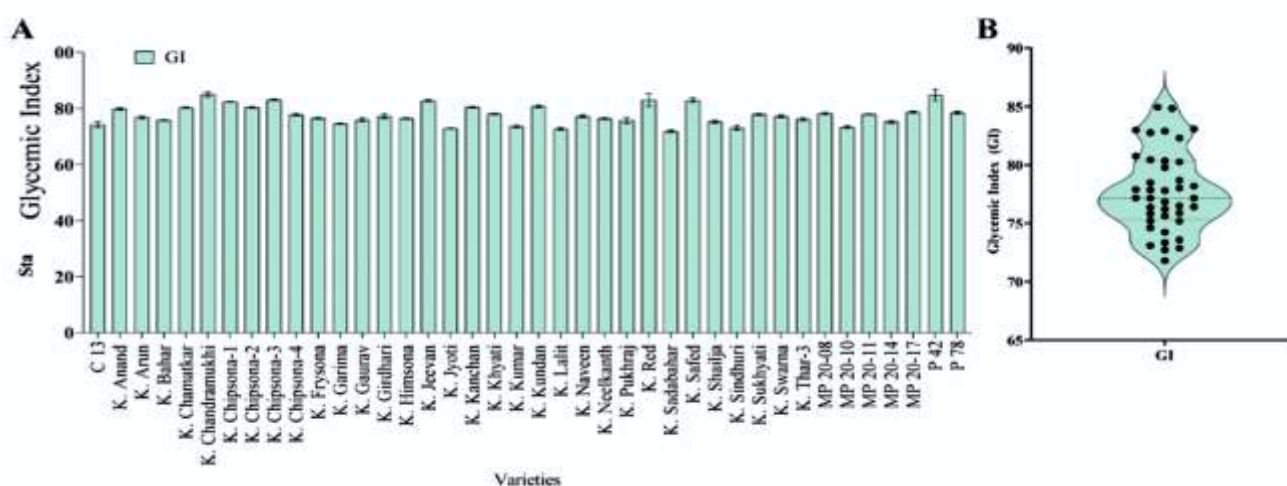


Fig. 2: (A) Variation in glycemic index (GI) represented by histograms
(B) Violin plot of variation in GI of forty genotypes.

Resistant starch (RS): In terms of enzymatic digestion and starch digestibility, resistant starch (RS) is a significant component of starch that requires special attention. The RS content ranged between 1.08 to 2.18 % and K. Lalit (1.4%) and K. Jyoti (2.18%) have the lowest and greatest amylose levels among table varieties, respectively, however, K. Chipsona 2 (1.08%) and K. Frysona (1.62%) had the lowest and highest RS content among processing varieties, respectively (Fig. 3A and B). The mean value of RS content was found to be 1.49 % averaging over forty genotypes (Fig. 3B).

Glycemic load (GL): Glycemic load (GL) is an important parameter that is controlled by the ACHO and GI of potatoes and other starchy crops. Among 40 genotypes, the maximum and

minimum GL was found as 17.36 and 22.91 with the mean value of 19.34 (Fig. 4A and B). The GL also varied significantly ($P < 0.005$) among genotypes. In the table varieties, the higher GL was reported in K. Pukhraj (17.36) and the lowest reported in K. Chandramukhi (22.91) (Fig. 4A and B). In processing varieties, the minimum and maximum GL was found in K. Frysona (17.86) and K. Chipsona 3 (20.94), respectively (Fig. 4A and B).

Based on the results, it appears that the GI values of potato genotypes were found to be higher than 70, indicating a relatively high glycemic response. To validate these results in-vivo analysis may help to confirm the extreme values of glycemic index and glycemic load of potato genotypes.

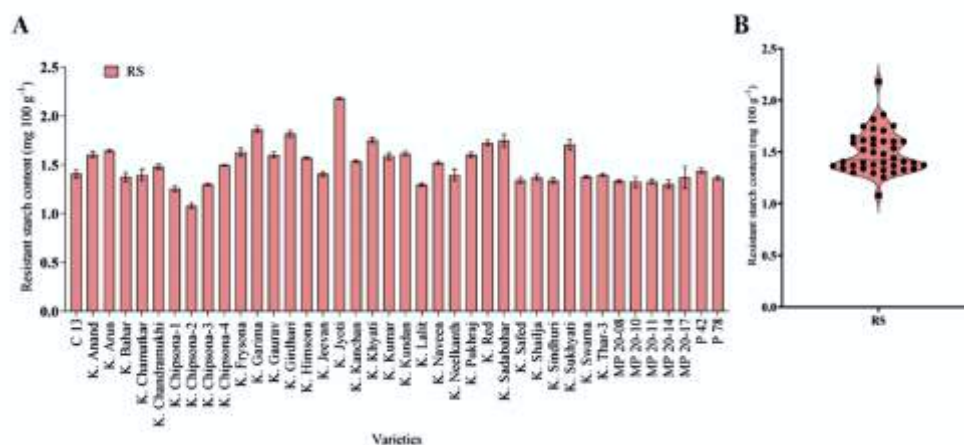


Fig. 3: (A) Variation in resistant starch (RS) content represented by histograms (B) Violin plot of variation in RS of about forty genotypes.

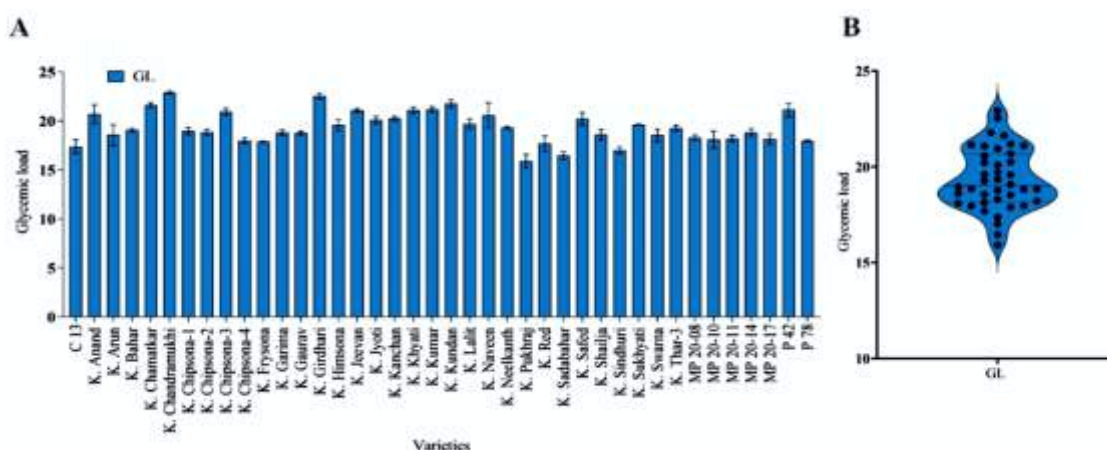


Fig. 4: (A) Variation in glycemic load (GL) represented by histograms (B) Violin plot of variation in GL of about forty genotypes.

Gluten-free anthocyanin rich potato porridge and semolina: Anthocyanins are natural phytochemical colourants that have grown in popularity due to their extensive range of colours and beneficial health effects, such as their role in the prevention of neuronal and cardiovascular illnesses, cancer and diabetes, among others. Furthermore, the health effects of these chemicals may improve the overall quality of our food products, allowing the design of new functional and natural products that will be well received by the market. Although anthocyanins have a high potential for use in food and other industries, their use has been limited due to their relative instability, low extraction percentages, and the effects of heat processing. ICAR-CPRI has developed some nutritionally dense red and purple-fleshed potato advanced clones, rich in phenolic compounds, particularly anthocyanins, with approximately three times the total phenolic compound content of the widely consumed white- and yellow-fleshed tubers and two to three times the antioxidant activity. However,



Fig. 5: Anthocyanin rich potato porridge (A and B) and semolina (C and D)



Fig. 6: Anthocyanin rich potato ice- cream (A and B)

consumer acceptance and availability are major challenges that deprive consumers of their wonderful benefits. In this regard, we have standardised the process for dehydrating these nutritionally dense fresh potatoes with minimal processing and expanded its use in the form of porridge/*daliya* (**Fig. 5 A and B**) and semolina (**Fig. 5 C and D**). Which can be cooked and eaten in the same way as traditional wheat-based *Daliya/sooji*. This technology applies to both fresh and cold-stored potatoes of any variety, age, or size. If stored in a cool, dark, and dry place, these products have a shelf life of nine months.

Anthocyanin rich potato ice cream: Anthocyanins are well-known natural food colouring pigments that are water-soluble and responsible for the colours red, purple, and blue. Potatoes also contain red to purplish-blue anthocyanin pigments. The colour and stability of these pigments are influenced by pH, light, temperature, structure, and heat. Considering the stability of these pigments, we developed a process for using these nutritionally rich coloured potatoes in popular frozen desserts—ice creams (**Fig. 6 A & B**) without any artificial colouring. Where only minimal heat processing was used to preserve the health-promoting effects of anthocyanin pigments. We discovered that dehydrated anthocyanin-rich potato flour can be

used for up to 12% of the dry ingredients without adversely affecting the ice cream texture.

Sharing of breeding material: About 46200 TPS of 10 crosses were sent to AICRP center, Raipur for seedling raising and further selection as per institute breeding protocol for promotion of region-specific breeding. For hybridization purposes 36 promising parental lines were sent to Kufri.

Introduction of advanced clones in AICRP: Introduced advanced clones MS/17-739 (**Fig. 7**) and MSP/17-848 (**Fig. 8**) in AICRP for multi-location testing.

MS/17-739 (MP/6-39 x CP3687): The advanced clone produced 9% high total tuber yield of 49 t/ha as compared to 45 t/ha of K. Bahar at 90 days. It produces attractive 10-11 tubers/plant having white-cream ovoid tubers with shallow eyes and white flesh. MS/17-739 possesses high tuber dry matter (19%) as compared to 18% in K. Bahar at 90 days. It possesses excellent keeping quality by virtue of low total weight losses and long tuber dormancy period, waxy texture, high zinc (27 ppm) and iron (46 ppm). It is slightly resistant to late blight (AUDPC:758) as compared to K. Bahar (AUDPC:1151).



Fig. 7: Morphological characters of MS/17-739: Leaf, Inflorescence, tubes and sprout.

MS/17-848 (MS/82-797 x CP4242): The advanced clones produced attractive 10-12 tubers/plant having red ovoid tubers with shallow eyes and red flesh having cream colour outside the vascular bundle. MS/17-848 (40 t/ha) produced 10-15% high total tuber yield as compared to red controls (K. Lalima, K. Lalit and K. Manik) at 75 days. The advanced clone (45

t/ha) produced 2 and 8% high total tuber yield than K. Lalima and K. Lalit respectively and remained at par with K. Manik at 90 days. MS/17-848 possesses 17% tuber dry matter (90 days), very good keeping quality, mealy texture, high total anthocyanins (151 mg/100g FW), amylose (27%), zinc (31 ppm) and iron (47 ppm). It is susceptible to late blight.



Fig. 8: Morphological characters of MS/17-739: Leaf, Inflorescence, tubes and sprout.

Registration of elite germplasm: Two biofortified potato genetic stocks namely MSP/15-26 and MSP/15-51(**Fig.9**) were registered with ICAR - NBPGR, New Delhi.

MSP/15-26 (INGR22062, Parents

Bareilly Red × CP 3770): It is late maturing elite clone produces attractive, medium sized red round tubers (18-20 tubers/plant) with medium eyes, yellow flesh and red vascular ring. It has 18% tuber dry matter and a floury texture. It possesses high carotenoids (823 ug/100g FW) as compared to parents Bareilly Red (460) and CP3770 (422 ug/100g FW). It is moderately resistant to late blight and possesses excellent keeping quality with extremely long dormancy (>10 weeks) and excellent tuber appearance after 75 days of storage.



Fig. 9: Biofortified potato genetic stocks: MSP/15-26 and MSP/15-51 registered with ICAR-NBPGR

MSP/15-51 (INGR22063) Parents

Bareilly Red × CP 3770 : It is late maturing elite clone produces purple, oblong tubers (small (30-32 tubers/plant), with medium eyes and red purple flesh. It has 21% tuber dry matter and a mealy texture. It possesses high ascorbic acid (68 mg/100g FW) in comparison to parents Bareilly Red (56) and CP3770 (26). It is moderately resistant to late blight and possesses excellent keeping quality with extremely long tuber dormancy (>10 weeks) and have an excellent tuber appearance after 75 days of storage.

Optimizing agro-technology: A dose of 240 N+ 30 P₂O₅ + 120 K₂O kg/ha was found optimum for the new red skin potato variety K. Uday. However, for another red skinned newly released variety K Lohit, doses of 240 kg N, 60 kg P₂O₅, and 80 K₂O kg per ha were found sufficient based upon two year pooled results. In the case of drought tolerant variety K. Thar-2 nutrient levels of 240 kg N, 40 kg P₂O₅, and 100 kg K₂O/ha were sufficient for achieving the highest mean marketable tuber yields (38.9- 43.0 t/ha). Advanced clones for baby potatoes MS/15-60, responded up to 180 kg N, 40 kg P₂O₅, and 100 K₂O kg per ha. The mean baby potato grade yield (25- 40 mm) was 11.9- 12.6 t/ha, while the mean tuber dry matter content ranged between 17-19%.

Late blight screening at Kufri: Forty one potato genotypes were screened for late blight resistance under natural epiphytotic field condition and advanced clones MSH/19-241 was highly resistant (AUDPC<250), while CP4682 was resistant (AUDPC 250-350). MS/13-527, MCIP/14-241, MSA/16-126, CP4678 and CP4681 were moderately resistant (AUDPC 351-650). The remaining were either susceptible or highly susceptible.

Evaluation for late blight resistance at

Modipuram: Seventy four potato genotypes were evaluated for late blight resistance under field and lab conditions. All the advanced clones showed less Area Under Disease Progress Curve (AUDPC) than the highly susceptible variety K. Bahar (1307.50). Among fifty eight advanced clones, less AUDPC was recorded in advanced clones namely MSH/19-241 (160), MS/13-527 (251), MSA/16-333 (257), MSA/16-126 (286), MCIP/14-211 (293), MSA/16-159C (413), MCIP/18-59 (521) and MS/17-605 (619), MSP/17-07 (723) as compared to standard cv. K. Bahar (1308). These advanced stage clones also

showed less rAUDPC. However, rAUDPC ranged from 0.106 to 0.872. Among the clones, the lowest rAUDPC was recorded in MSH/19-241 (0.106) and the highest was in MSP/18-68 (0.836) as against K. Bahar (0.872). Under laboratory conditions, by detach leaf method, 36 clones (MCIP/14-211, MCIP/16-209, MCIP/18-59, MS/13-391, MS/13-527, MS/14-243, MS/16-1157, MS/17-605, MS/17-621, MS/18-393, MS/18-463, MS/18-772, MS/18-880, MS/18-1090, MS/18-1175, MS/18-1272, MSA/16-126, MSA/16-140, MSA/16-353B, MSH/19-97, MSH/19-132, MSH/19-146, MSH/19-159, MSH/19-180, MSH/19-216, MSH/19-141, MSP/17-07, MSP/17-147, MSP/17-212, MSP/18-68, MSP/19-101, MSP/19-178, MSP/19-179 and MSV/19-04) were moderately resistant and remaining were susceptible. Under laboratory conditions, through tuber slice method, three advanced clones MS/18-463, MS/18-465 and MS/18-722 showed high resistance, 40 advanced clones were moderately resistant and the remaining were susceptible.

Screening of advanced clones for black scurf and hollow heart: Changes in climatic condition and erratic rainfall during the growing season leads to tuber deformities. In this context, seventy four potato genotypes were evaluated for hollow heart and none of the clones showed hollow heart symptoms. Besides, in some advanced clones, different level of disease incidence of black scurf was recorded. The black scurf disease incidence ranged from 0-10%. In nine advanced clones along with three varieties; MCIP/18-50 (8.8%), MS/18-393 (7.8%), MS/18-722, MSA/16-1596 (7.7%), Atlantic (5.0%), K. Pukhraj (5.2%), MS/13-391, K. Ganga (4.2%), MS/17-621 (4.0%), MSP/14-1003 (3.2%) and MSP/19-190 (2.8%) different level of black scurf incidence was noted.

Research activity 2: Breeding early bulking agile potato varieties suitable for intensive cropping systems

Research activity leader: Dr Raj Kumar,

Component's workers: Dr Ratna Preeti Kaur.

Hybridization: A total of 39625 seeds of 55 crosses were obtained.

Seedling stage: 6736 promising clones were selected from 24226 seedlings raised by sowing 84538 true potato seeds of 45 crosses.

Initial clonal stages: In the initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 782 promising clones were selected from the 7147 clones evaluated.

Advanced stage trials: In all, 74 advanced clone were evaluated in 5 yield trials at 65/75/ days at Jalandhar and 24 promising advanced clones were selected. In preliminary yield trials (three) at 60 and 75 days, 14 clones namely J/16-20, J/16-192, J/16-1, J/16-4, J/16-14, J/16-18, J/16-24, J/16-27, J/16-78, J/16-84, J/16-196, J/16-67, J/16-134 and J/16-198 were selected of the 46 advanced clones evaluated. In confirmatory yield trial, 10 advanced clones J/15-36, J/15-74, J/15-75, J/15-214, J/15-236, J/14-185, J/14-242, J/14-245, J/15-91 and J/15-332 were selected from the 28 advanced clones evaluated.

Introduction of hybrids in AICRP: Based on consistently good performance over years, two advanced clones namely J/14-242 and J/14-245 (Fig. 10) were introduced in the All India Coordinated Research Project on Potato (AICRP Potato).

J/14-242 (J/96-238 x J/97-247): It gave 16.1 % and 16.8% higher yield over control K. Khyati at 60 and 75 days harvests, respectively. It produces white round-ovoid tubers with shallow-medium eyes and light yellow flesh colour. It possesses 17 % tuber dry matter and good keeping quality.

J/14-245 (J/97-227 x MS/82-638): It gave 10.7 % and 11.7 % higher yields over control K. Khyati at 60 and 75 days harvests, respectively. It produces white ovoid tubers with shallow eyes and white cream flesh colour. It possesses 16%tuber dry matter and good keeping quality.



Fig. 10: Tubers of advanced clone's J/14-242 and J/14-245

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

Research activity leader: *Dr Shambhu Kumar,*
Component's workers: *Dr Sarala Yadav.*

Hybridization: A total of 24530 seeds of 77 crosses were obtained.

Seedling stage: In the seedling stage 745 promising clones were selected from 19173 seedlings raised by sowing 30653 true potato seeds of 84 crosses.

Initial clonal stages: In the initial clonal stages (F_1C_1 , F_1C_2 and F_1C_3), 182 promising clones were selected from the 956 clones evaluated at 75 days.

Advanced stage trials: In all, 36 advanced clones were evaluated in 3 yield trials at 75/90 days at Patna and 10 promising advanced clones were selected. In the preliminary yield trial, 7 clones namely PS/17-09, PS/17-11, PS/17-12, PS/17-15, PS/17-19, PS/17-20 and PS/17-22 were selected of the 28 advanced clones evaluated at 60 and 75 days. In the confirmatory yield trial, 3 advanced clones namely PS/16-02, PS/16-17 and PS/16-22 were selected from the 8 advanced clones evaluated.



Fig. 11: Tubers of PS/16-17

Introduction in AICRP: Advanced clones namely **PS/16-17** (**Fig. 11**) has been introduced in AICRP for multi-location testing.

PS/16-17 (ATL X CP4242): The advanced clone with 26 and 31 t/ha total tuber yield showed a yield increase over K. Neelkanth by 10 and 11% at 75 and 90 days respectively. It produces red round tubers with shallow eyes and light red flesh colour. It possesses 21% tuber dry matter, good keeping quality and a moderate level of late blight resistance. It possessed high carotenoids (103 $\mu\text{g}/100\text{gFW}$) as compared to K. Manik (54) and K. Neelkanth (30).

Research activity 4: Breeding for processing varieties

Research activity leader: *Dr VK Gupta,*
Component workers: *Drs Vinay Bhardwaj, Bandana, Arvind Jaiswal, Sanjay Rawal, Salej Sood, Mehi Lal.*

Hybridization A total of 99995 TPS of 57 crosses were produced at Kufri and at Modipuram.

Seedling stage: A total of 1332 clones of 49 crosses were selected from 31655 seedlings obtained from sowing 99995 TPS of 57 crosses at Modipuram.

Initial clonal generations: A total of 2577 clones (F_1C_1 , F_1C_2 and F_1C_3) were selected based on superior tuber characters and chip colour, and dry matter from the 2577 clones evaluated.

Preliminary yield trial (F_1C_4): Among the 16 advanced clones evaluated at 75, 90 and 110 days, eight promising advanced clones namely MP/16-226, MP/17-109, MP17-216, MP/17-257, MP17-330, MP/17-340, MP17-815 and MP/17-824 were selected based on processing grade yield and desirable traits for processing.

Final yield trial: Among the 16 advanced clones evaluated at 75, 90 and 110 days, six promising advanced clones namely **MP/13-662, MP/15-207, MP/16-173, MP/16-178, MP/16-315 and MP/16-334** were selected having superior yield (total and processing), dry matter, Chip colour and synchrony as compared with control varieties.

Evaluation trial in early planting season at Modipuram: Among the 23 advanced clones evaluated in early season planting at Modipuram at 90 days, eight clones outperformed, however, MP/19-367, MP/19-387, MP/19-360, were found to be superior with regard to yield as well as acceptable quality traits.

CPRI-ITC Trials in South, East and Northern India (Rabi): Field trials of 19 processing clones at Karnataka (Hiriyalachenahalli-Chikaballapur) and Telangana (Zaheerabad) at 90 days, resulted in the identification of promising clones at Karnataka (MP/12-126, MP/14-171, MP/15-651, MP/17-745, MP/16-173 and MP/16-315) and at Telangana (MP/17-745 and MP/15-651) for chips.

CPRI-ITC Trial in South India (Kharif): Multi-location field trials of 21 processing clones at three locations, viz., Lingadahalli-Chikamagalur (Karnataka), Kamalappur-Dharwad (Karnataka), and Igglur- Thalavadi, (Tamilnadu) at 90 days resulted in the identification of promising clones at, Thalavadi (MP/12-126, MP/15-651, MP/17-60, MP/18-746), Dharwad (MP/18-746) and Chikamagalur (MP/ 13-1045, MP/17-60 and MP/18-746) for chips.

Evaluation trial for French fry advanced clones in Gujarat

Amirgarh: The trial of nine advanced processing clones conducted following MTA protocol with Simplot (JRS India Foods) resulted in the identification of MP15-651 (54 t/ha), K Frysona (52 t/ha) followed by K Sangam (51 t/ha). MP/15-750, MP/11-30 and K FryoM resulted in average yield but have lower defects and good tuber size and shape for processing purposes at 100 days.

Idar: The trial of seven advanced processing clones conducted following MTA protocol with McCain's Food resulted in the identification of promising clones namely MP/15-651 (40 t/ha) and K FryoM (39 t/ha) at 100 days.

Himmatnagar: The trial of seven advanced processing clones conducted following MTA protocol with Hyfun foods resulted in the identification of MP/15-651 (43 t/ha), MP/11-30, K Fry oM and K. Sangam (40 t/ha) 100 days.

Storage behaviour of advanced hybrids under ambient conditions: Among the 21 advanced

clones evaluated for storage behaviour under ambient temperatures at Modipuram, lesser total weight loss (%) was noted in MP/17-824 (10%), MP/17-340 MP/17-257 (11%), MP/17-265 (12%), K. FryoM (13%) after 75 days of storage.

Introduction into AICRP: Based on superior performance during 2019-20-2021-22 at Modipuram three advanced clone MP/13-662, MP/16-173 and MP/16-315 (**Fig. 12**) for processing into chips have been introduced into AICRP for multi-location trials.

MP/13-662 (MP/99-322 X CP2350): MP/13-662 produced 7 % high mean processing (31 t/ha) and 5% higher total tuber yields (38 t/ha) than the best control K. Chipsona-1. It possesses white cream ovoid tubers with shallow eyes and cream flesh. It has resistance to late blight (115 AUDPC).

MP/16-173 (MP/4-816 x MP/8-57): MP/16-173 produced 9 % high mean processing (31 t/ha) and total tuber yields (36 t/ha) than the best control K. Chipsona-1. It possesses white cream round tubers with shallow eyes and cream flesh. It has field resistance to late blight.

MP/16-315 (MP/9-90 x MP/6-595): MP/163-315 produced 28 % high mean processing (37 t/ha) and total tuber yields (42 t/ha) than the best control K. Chipsona-1. It produces white cream round tubers with shallow eyes and white flesh. It is moderately resistant to late blight than Lady Rosetta, Atalantic and K. Chipsona-1.



MP/13-662



MP/16-173



MP/16-315

Fig. 12: Advanced clones introduced in AICRP: MP/13-662, MP/16-173 and MP/16-315

Release of new chipping variety-K. Chipsona-5 (MP/09-45): K. Chipsona-5 (Fig. 13) a medium maturing (90-100 days), high-yielding (35 t/ha), with yield advantage over the check has been recommended for release for Northern, Central and Eastern plains of India (Haryana, UP, Uttarakhand, MP, Gujarat, Rajasthan and Chhattisgarh) for processing into chips. It has acceptable quality traits viz., tuber dry matter 20-21%, reducing sugars (60-75mg/100g fresh weight) and chip colour score (3). It produces white cream ovoid tubers with shallow eyes and cream flesh and has very good storability under ambient storage conditions. It is moderately resistant to late blight (AUDPC 487)



Fig. 13: Leaf, inflorescence, sprout and tubers of K. Chipsona-5

Evaluation of processing clones for late blight resistance at Shimla: In a trial at Kufri, MP/13-662 produced 12.6 t/ha total tuber yield, which was at par with K. Chipsona-5 (14.5) and better than Lady Rosetta (10.4 t/ha) and K. Chipsona-1 (10.6 t/ha). It showed the lowest mean AUDPC (412.2) than control varieties. Based on two years, results, MP/13-662 showed moderate late blight resistance and could be a suitable choice for processing in late blight prone areas.

Late blight screening at Modipuram: Among the 11 advanced clones evaluated for late blight resistance under field and lab conditions at Modipuram, all clones showed less Area under disease Progress Curve (AUDPC) than control highly susceptible variety K. Bahar (1307.50). Less AUDPC was in MP/15-207 (594), MP/14-1029 (615) and MP/14-171 (616) as compared K. Bahar (1308). These advanced stage clones also showed less rAUDPC and the lowest rAUDPC was recorded in MP/15-207 (0.396) and the

highest was in MP/15-750 (0.699) as against K. Bahar (0.872). Under lab condition, by detached leaf test, 7 clones (MP/9-45, MP/12-126, MP/12-223, MP/13-1045, MP/14-1003, MP/14-1029 and MP/15-207) were moderately resistant and remaining were susceptible. Under laboratory conditions, by tuber slice method, three clones i.e. MP/9-45, MP/13-1045, MP/14-171 were resistant and four clones (MP/11-30, MP/12-126, MP/14-1003, MP/15-207) were moderately resistant and remaining were susceptible.

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

Research activity leader: Dr Vinay Bhardwaj,
Component workers: Drs Salej Sood, Dalamu, Vikas Mangal, Sanjeev Sharma, Priyank Hanuman Mhatre, Clarissa Challam, Mehi Lal, Babita Chaudhary, Aarti Bairwa, S. Sundaresha, Ravinder Kumar, Kailash Chandra Naga, Vinod Kumar, Ashwani Sharma, VK Dua, Tanuja Buckseth.

Hybridization: Ninety two successful crosses at Kufri/ Shimla, Ooty and Shillong between PCN, late blight and virus tolerant parents having early to medium maturity, better quality traits and good adaptability resulted in 1,59,019 hybrid TPS.

Seedling raising and screening for late blight resistance:

A total of 22100 TPS of 8 crosses were screened under controlled conditions against complex races of *Phytophthora infestans* at Shimla and a total of 1414 resistant seedlings were transplanted in the earthen pots and at harvest 780 clones were retained. The highest number of resistant seedlings (%) were obtained in the cross K.Karan × Columba (10.1%), SM/11-120×Farida (9.3%) and CP1971× CP4311 (7.5%). At Ooty, among the 11490 true seeds of 12 crosses sown, 1458 seedlings were transplanted and at harvest, 129 late blight resistant selections were made. At Shillong, 15,000 TPS of 5 crosses were raised and screened of which 1472 clones were selected.

Initial clonal evaluations: In the initial stages (F_1C_2 to F_1C_4), 934 genotypes were evaluated under natural field conditions at Kufri/Ooty/ Shillong for their disease resistance and adaptability and 210 clones were selected.

Evaluation of advanced clones at Modipuram to identify day-neutral hybrids: Twenty advanced clones along with nine control varieties were evaluated in two trials. In trial 1, two clones viz., SM/14-213 and SM/15-251 were found superior to K. Bahar and K. Himalini and in trial 4 clones viz., SM/15-245, SM/10-05, SM/14-342 and SM/14-335 (trial 2) were found promising and were statistically superior to K. Bahar and K. Himalini.

Yield trials at Kufri: Among the 31 advanced clones evaluated in 3 trials at Kufri, seven advanced clones were selected. In the F_1C_5 trial, SM/09-152, SM/03-25, SM/10-10, SM/10-243 and SM/16-221 showed 123.4%, 108.9%, 108.9%, 61.4% and 29.5% yield superiority over the best control K. Himalini. In the F_1C_6 trial, SM/09-82 showed a 45.4% yield gain over the best control K. Girdhari and SM/09-47 showed statistically at par yield performance to the best control. Both advanced clones were moderately resistant to late blight.

Yield trials at Ooty: Among 27 advanced clones evaluated, seven were selected on the basis of agronomic traits and resistance to potato cyst nematodes and late blight. In another trial, three advanced clones were assessed and OS/14-318, OS/14-436 and OS/14-208 recorded the maximum yields (29.13, 27.13 and 26.91 t/ha respectively) as compared to the best control Kufri Girdhari (18.86 t/ha). OS/14-318 possessed high resistance to late blight as well as to both the species of potato cyst nematodes. However, OS/14-208 and OS/14-436 were highly resistant to late blight disease.

Yield trials at Shillong: Among 35 advanced clones evaluated, six promising clones namely SS/12-732, SS/18-17, SS/18-213, SS/18-180, SS/16-57 and SS/18-112 were selected based on tuber characteristics.

Evaluation of potato germplasm for tolerance to PCN: Among the 278 accessions/core collections and 20 check varieties screened against both the species potato cyst nematodes, *Globodera pallida* and *G. rostochiensis* at Kufri, 15 accessions (JEX/A-164, JEX/A-15, JEX/A-317, CP3549, CP2418, CP3881, CP3641, CP3718, CP3891, CP3816, CP3577, CP1736,

CP1988, CP1218 and CP1435) were found highly resistant (HR) to both the species of *Globodera*. Five accessions (JEX/A-26, JEX/A-390, CP2285, CP3809 and CP3893) were found HR to *G. rostochiensis*. Two accessions (CP4052 and CP3634) recorded HR reaction to *G. pallida*. Further, five accessions (CP3491, CP3894, CP4052, CP3634 and CP1447) observed resistant (R) reaction to *G. rostochiensis* and six accessions (JEX/A-390, CP2149, CP3885, CP3809, CP1664 and CP2285) recorded resistant reaction to *G. pallida*. Only one accession, CP3939 was found resistant to both species of *Globodera*.

Evaluation of advanced clones for late blight resistance at Modipuram: 162 advanced clones along with 5 control varieties were evaluated for late blight resistance under field conditions and terminal disease severity ranged from 0-100%. Among 162 clones, 15 clones (SM/15-222, SM/15-252, SM/15-264, SM/15-231, SM/15-316, SM/15-329, SM/17-03, SM/17-112, SM/17-442, SM/17-46, SM/17-98, SM/17-202, SM/17-578, SM/17-606, SM/17-646) were free from late blight infection and in 43 clones (SM/09-153, SM/10-05, SM/14-111, SM/14-126, SM/14-213, SM/14-229, SM/15-132, SM/15-138, SM/15-153, SM/15-158, SM/15-169, SM/15-173, SM/15-201, SM/15-205, SM/15-228, SM/15-260, SM/15-302, SM/15-315, SM/15-317, SM/15-320, SM/15-321, SM/15-326, SM/15-269, SM/15-163, SM/15-270, SM/15-332, SM/15-342, SM/17-101, SM/17-117, SM/17-148, SM/17-251, SM/17-622, SM/17-115, SM/17-12, SM/17-122, SM/17-140, SM/17-17, SM/17-540, SM/17-570, SM/17-607, SM/17-730, SM/17-65, SM/17-66) showed 1-10% disease severity. Thirty one and 20 clones showed 10.1-25% and 25.10-60% disease severity respectively, and the remaining clones showed > 60% disease severity.

Evaluation of advanced clones against leaf spot complex & Sclerotinia rots at Modipuram: Among the 30 advanced clones evaluated, 3 clones (SM/15-153, SM/15-228, SM/15-252) showed below 5% severity of early blight disease and seven clones SM/15-315 (7.5%), SM/15-320 (8.5%), SM/14-126 (10%), SM/15-321 (12.5%), SM/15-260 (15.0%) SM/15-169 (15.0%), SM/14-229 (17.5%) showed less infection of early blight. The highest disease severity of early

blight was recorded in SM/09-153 (65.00%) followed by SM/15-317 & SM/15-326 (25%). Besides, two clones SM/15-158 (22.0%) and SM/15-269 (85.0%) recorded a higher level of phoma infection. Two other clones namely SM/15-251 (8.88%) and SM/15-173 (6.67%) observed an incidence of sclerotinia rot.

Introduction in AICRP: An advanced clone SM/92-338 (HB/82-372 x K. Pukhraj) showed high average yield of 25t/ha in comparison to the best control K. Girdhari (23.5t/ha) at Kufri, Shimla and was found to be highly resistant to bacterial wilt under invitro conditions in the lab and sick plot field conditions. It is moderate resistance to late blight and produces attractive white-cream ovoid tubers with shallow eyes and cream flesh (Fig.14). It has 19% tuber dry matter and excellent keeping quality.



Fig. 14: Bacterial wilt resistance of SM/92-338 in sick plot and tubers

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

Research activity leader: Dr Devendra Kumar,
Component workers: Drs VK Gupta, Sanjay Rawal, Name Singh, Babita Chaudhary, Dalamu, Vikas Mangal, Anuj Bhatnagar, Brajesh Singh, Som Dutt, Sugani Devi, Sushil Sudhakar Changan, Milan Kumar.

Breeding for heat tolerance

Hybridization: A total of 2,66,979 TPS were recovered from the 101 crosses attempted at Kufri/Modipuram

Seedling stage: In all 7728 seedlings were recovered from 95473 TPS (83 crosses) and 515 clones were selected.

Initial clonal stages: In all 190 promising clones were selected from the 1389 clones evaluated in F_1C_1 , F_1C_2 and F_1C_3 stages.

Advanced stage trials at Modipuram: Forty advanced clones (F_1C_4 & F_1C_5 stage) were evaluated in two replicated trials, in the early season at 75 days and at harvest 15 promising advance clones namely HT/17-162, HT/17-164,

HT/17-202, HT/17-257, HT/18-487, HTMK-002, HTMK-004, HTMK-012 and MP/13-1045 (trial 1); HT/19-126, HT/19-284, HT/19-331, HT/19-386, HT/19-393 and HT/19-405 (trial 2) were retained.

Advanced stage trial at Pune and Bhubaneswar:

At Pune (Maharashtra) 18 advanced stage clones were evaluated in the replicated trial under Kharif season at 90 days and high total tuber yield was obtained in HTMK/17-1, HTMK/17-9, HT/17-202, HT/12-830, HTMK/17-6, HTMK/17-4 and HTMK/17-2 (20 t/ha), HT/17-257 (19 t/ha), K. Surya, (17t/ha). At Bhubaneswar 21 advanced hybrids were evaluated in the rabi season at 75 and 90 days. At 75 days high tuber yield was obtained in HT/15-240 (22 t/ha), HTMK/2 (19 t/ha) followed by K Kiran (18 t/ha). At 90 days high tuber yield was obtained in HT/15-240 (23 t/ha), K Kiran (22 t/ha)

Storage behaviour of advanced hybrids under ambient conditions:

Seventeen genotypes were evaluated for storage behaviour under ambient temperatures at Modipuram and genotypes viz., HTMK/17-6 (10%), K Lauvkar (11%), HTMK/17-10 (13%), HTMK/17-9 (13.5%), HT/15-240 (14%) and K. Surya (15%) were noted for superior storability owing to lesser storage losses (10-15%) after 75 days of storage.

Recommendation of new heat tolerant variety

K. Bhaskar: Based on superior performance, the heat tolerant advanced clone HT/11-3 has been recommended for release in the 40th Group of AICRP (Potato) held at Srinagar in 2022. The new variety with 34 t/ha total tuber yield at 75 days crop showed 18 and 12% superiority over the heat tolerant variety K. Suyra and K. Kiran respectively. It produces white cream round-ovoid tubers with shallow eyes and cream flesh (Fig. 15). The variety is early medium to medium (85-90 days) maturing and has very good storability under ambient conditions. It has very good taste, aroma, mealy texture, excellent tubers and no tuber cracking. It possesses 19% tuber dry matter and has a tolerance to mite and hopper burn. The new variety performed well in UP, Haryana, Punjab, Uttarakhand (early crop planting) and Chhatisgarh, Gujarat, Rajasthan and Odisha (main crop planting), therefore, it has been recommended for potato production as the early crop in northern plains and as the main crop in central and plateau regions of the country.



Fig. 15: Kufri Bhaskar: Leaf, inflorescence, tubers and sprout

Breeding for drought tolerance

Parent selection and multiplication: Twenty accessions were screened for drought tolerance by analyzing various physio-chemical parameters (RWC, MSI, ABA, proline etc. for identification of the best parents for use in breeding. The CP1665 was found drought tolerant with respect to RWC (70.56%), while CP2302 showed significant drought tolerance in terms of MSI (65.58%) and MDA (2.7 nmole/g), and CP3085 in terms of proline and peroxidase (3.43 μ mole/min/g).

Seedling stage: In all 2626 seedlings were recovered from 19350 TPS (9 crosses) and 291 clones were selected.

Initial clonal stages: In all 190 promising clones were selected from the 768 clones evaluated in F_1C_1 , F_1C_2 and F_1C_3 stages.

Advanced stage trial: A total of 16 advanced clones were evaluated in two trials under water stress and well-watered along with K. Thar-1 and K. Thar-3. Irrigations were regulated to be in an equal quantity of water, using a digital water

meter. Based on field phenotypic traits viz. leaf vigor (SPAD value), stay-green traits during crop growth and total tuber yield, tuber dry matter under stress at harvest advanced clones WS/17-209, WS/17-402, WS/17-806 and WS/17-814 were retained for further evaluation and advanced clone WS/14-32 was identified for introduction in AICRP.

Introduction in AICRP: Based on consistent performance under water deficit conditions, advanced clone WS/14-32 (Fig. 16) has been introduced in AICRP for multilocation testing

WS/14-32 (CP3173 x YY6): Based on three year consistent performance under water deficit conditions at Modipuram, advanced clone WS/14-32 produced 11% higher total tuber yield under well watered control and >20% high total tuber yield under water stress than K. Thar-3. It produces white-cream, round-ovoid tubers with shallow eyes and cream flesh, >19% dry matter, moderate resistance to late blight, long tuber dormancy and very good keeping quality. Besides, a reduced tuber deformity is an additional trait under stress. Higher SPAD value, indicative of better stress management, towards the terminal end of the crop (80 DAP) appears to play a crucial role in better yield realization in WS/14-32 under deficit water stress.



Fig. 16: Tubers of advanced clone WS/14-32

Release of K. Daksh: New water use efficient variety (WS/07-113) has been recommended for release in the 40th AICRP Potato group meeting held during October 7-9, 2022 at SKUAST-Kashmir for cultivation in central plains (Gujarat, Madhya Pradesh and Chhatisgarh) and eastern plains (Orissa and Uttar Pradesh). : It is medium maturing (90 days), high-yielding clone (32 t/ha) under water and heat stress, moderately resistant

to late blight, and has a substantial yield advantage over the check varieties. It produces white cream, ovoid tubers with shallow eyes and creamy flesh (Fig. 17) and has good storability under ambient storage conditions

Optimizing agro-technology water efficient variety K. Daksh: K. Daksh at 90 days crop duration, responded to doses of 180 kg N, 40 kg P₂O₅, and 100 kg K₂O per ha for achieving optimum mean marketable tuber yields (35.2-37.5 t/ha). The mean dry matter content was 18%.



Fig.17: K. Daksh: Leaf, inflorescence, tuber and sprout

Breeding for salt tolerance

Hybridization: A total of 10 crosses were attempted using potential salt tolerant parents and 10,000 TPS were obtained.

Initial clonal Stage: In all 230 promising clones were selected from the 400 clones evaluated in F₁C₁ and F₁C₂ stages.

In-vitro screening for salinity tolerance: Twelve varieties were screened for salinity under in-vitro conditions at three levels of salinity stress viz., 25, 50 and 75 mM salt (5 NaCl: 1 Na₂SO₄: 1 CaCl₂). Single node cutting from established cultures was planted on MS culture media containing different concentrations of salt (25, 50 and 75 mM) and compared to MS medium without salt (0 mM). These cultures were maintained at 25±2°C with a 16/8 h light/dark cycle for 5 weeks. After 5 weeks, growth parameters and morphological characters were recorded (Fig. 18 and 19). In the present experiment, shoot length (cm), root length (cm), shoot fresh weight (mg), root fresh weight (mg), root volume (cm³), total root length (cm) and analyzed region area (cm²) varies from 4 cm-14.67 cm, 0-14 cm, 58.83-513.33 mg, 0-350.50 mg, 0.015-0.84 cm³, 28.13-429.46 cm and 101.83-1095.67 cm², respectively. At higher concentrations (75 mM) maximum shoot length (cm), root length (cm), shoot fresh weight (mg), root fresh weight (mg), root volume (cm³), total root length (cm) and analyzed region area (cm²) shown by variety, K. Neelkanth (13.67 cm), K. Thar-2 (12.17 cm), K. Manik (513.33 mg), K. Thar-2 (350.50 mg), K. Manik (0.493 cm³), K. Sahyadri (288.01 cm) and K. FryoM (1095.67 cm²).

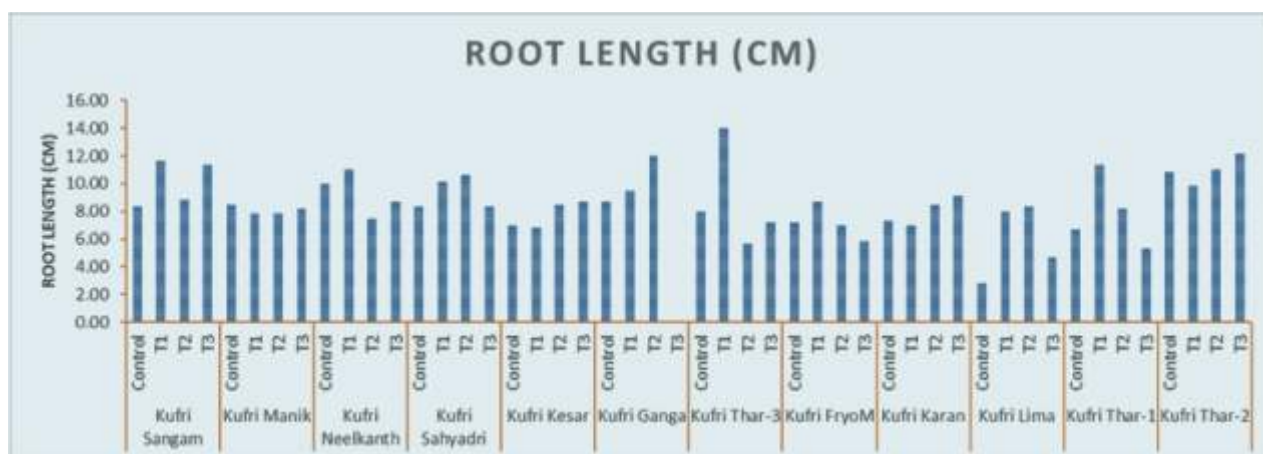


Fig. 18: Root length of different potato varieties under four salt treatments

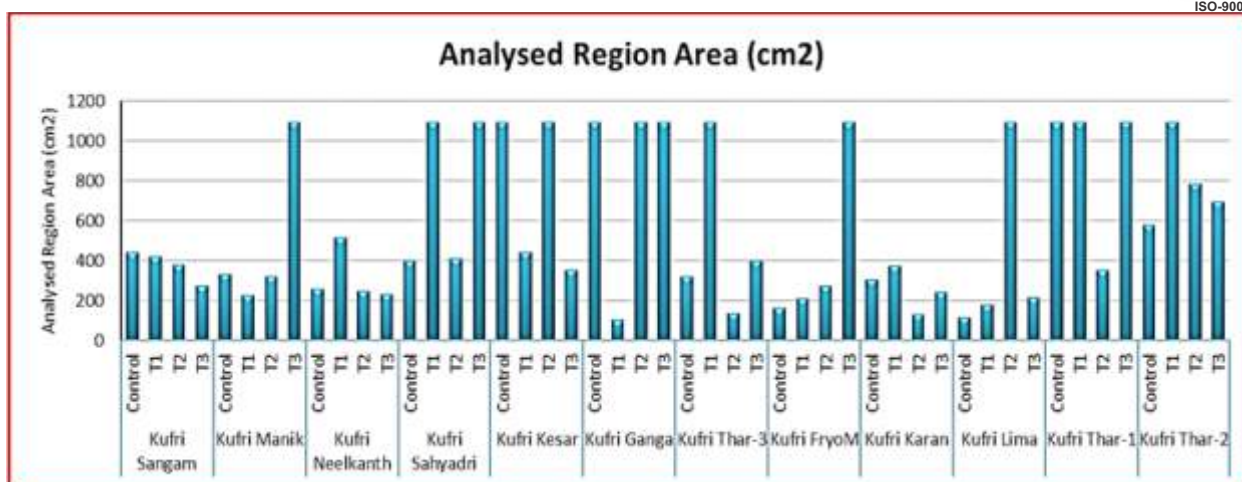


Fig. 19: Analysed region area (cm²) of different potato varieties under four salt treatments

Research activity 7 : Development of nitrogen use efficient varieties

Research activity leader: Dr Raj Kumar,
Component workers: Drs Manoj Kumar, Prince Kumar

Hybridization: A total of 22578 true potato seeds were obtained from 36 crosses.

Seedling stage: A total of 6922 selections were made from 27030 F₁ seedlings transplanted from the sowing of 107313 TPS of 24 crosses.

Evaluation in initial clonal stages: In all 10,593 clones were evaluated and at harvest 1789 promising clones were selected in comparison to K. Gaurav.

Advanced clone evaluation: Among the 66 advance clone evaluated in 5 preliminary yield trials at 90 days under normal planting conditions, 22 promising advanced clones namely N/17-56, N/17-63, N/17-152, N/17-313, N/17-34, N/17-46, N/17-60, N/17-193, N/17-136, N/17-139, N/17-207, N/17-258, N/17-320, N/17-100, N/17-240, N/17-325, N/17-125, N/17-161, N/17-169, N/17-183, N/17-285 and N/17-312 were selected. In three confirmatory yield trials, 27 advanced clones were evaluated at 90 days yield trial under normal planting conditions and 18 promising clones namely N/16-128, N/16-138, N/16-216, N/16-32, N/16-38, N/16-56, N/16-69, N/16-103, N/16-120, N/15-4, N/15-96, N/15-101, N/15-104, N/16-116, N/16-183, N/16-217, N/16-234 and N/16-249 were selected.

Supply of germplasm accessions for evaluation: Sixty tubers each of 20 accessions were supplied for evaluation for nutrient use efficiency at

Jallandhar and sixty tubers each of the same 20 accessions were supplied for evaluation for water use efficiency at Modipuram.

Evaluation for nitrogen use efficiency: Nine advanced clones were evaluated at 90 days in replicated yield trials with different doses of N for evaluation of nitrogen use efficiency and advanced clone N/13-49 performed better than



Fig. 20: Tubers of N/13-49

the control.

Introduction in AICRP: Based on consistently good performance over years, advanced clone N/13-49 (Fig. 20) has been introduced in AICRP Potato. N/13-49 gave 20.8 % and 7.7% higher agronomic use efficiency over K. Gaurav and K. Pukhraj, respectively. Tuber dry matter of N/13-49 (17.3%) was significantly better than controls K. Pukhraj (15.7%) and K. Gaurav (15.2%). It produces white ovoid tubers with shallow eyes and pale yellow flesh colour and possesses excellent keeping quality.

Research Activity 8.: Diploid F₁ hybrid breeding in potato

Research activity leader: *Dr Salej Sood,*

Component workers: *Drs Vikas Mangal, Vinay Bhardwaj, Dalamu, Tanuja Buckseth, AK Sharma, Brajesh Singh, Sanjeev Sharma, Babita Chaudhary, Hemant Kardile*

Elite lines selection: A set of 16 founder diploid clones (di-haploids, in-vitro multiplied diploid clones and TPS derived diploid clones) were tuber multiplied in the glasshouse at Shimla in the summer season. In addition, the TPS of 40 self-compatible diploid lines/crosses was raised and seedlings were transplanted in the field at Kufri

for tuber traits evaluation. Most of the plants were susceptible to late blight and only 43 plants showed moderate resistance to late blight and of these, only 12 plants formed small tubers. At Modipuram, 150 diploid lines were evaluated for tuber yield and tuber traits and tuber yield varied from 0.12 - 7.4 kg/plot (plot size 1.8m²) i.e., 0.6 - 41t/ha. The predominant tuber shape was round/ ovoid, skin colour and flesh colour were yellow, and eye depth was shallow. Based on yield and tuber shape data, 21 elite lines were selected for recurrent selection (Fig. 21).



Fig. 21: Elite heterozygous diploid lines

Late blight evaluation of diploid lines: A set of 94 diploid lines were planted for late blight resistance evaluation at Shimla. The AUDPC value ranged from 442 (BS 287) to 1692 (BS 258-12). All the lines showed high susceptibility to late blight.

In-vitro, diploid accession maintenance and multiplication under aeroponics: CP4590 diploid accession was maintained and multiplied *in vitro*. Further, hardened plants were planted in aeroponic. Sequential harvesting was done and a total of 100-120 mini-tubers were harvested (Fig. 22).



Fig. 22: Multiplication of haploid inducer line CP4590 under aeroponic conditions (Inflorescence and tubers)



Inbred development: Twenty-six *Sli* introgressed crosses of S₀ generation were raised from TPS at Shimla and seedlings were grown in pots for selfing. Selfing was attempted in all the plants of 26 crosses which resulted in 10-2150 TPS in S₁ generation. Similarly, selfing resulted in 834 and 4520 seeds in S₂ and S₃ generations, respectively (Fig. 23). The plants in S₄ generation were very weak with poor flowering. The selfing resulted in 55 S₅ generation seeds from two selfed berries.



Fig. 23: Flowering and berry setting through selfing in self-compatible diploid lines

***Sli* KASP™ markers for homozygosity:** We developed and used 50 KASP markers for high throughput screening of homozygosity at different loci in diploid germplasm. Out of 50 markers, one marker had missing allele call data for most of the lines therefore 49 markers were used for the degree of homozygosity evaluation of 357 diploid clones in different selfing generations. The average homozygosity assessed through 49 KASP markers distributed across all the chromosomes of the potato genome was 60%

in founder diploid clones, while different selfing generations i.e., S_0 , S_1 , S_2 and S_3 observed 65, 70, 75 and 81% average homozygosity, respectively (Table 2; Fig. 24). The diploid plants with ~90% homozygosity was also observed in the first selfing generation, which inferred that homozygosity assessment in the early generations itself could identify the best plants with high homozygosity to speed up the generation of diploid inbred lines.

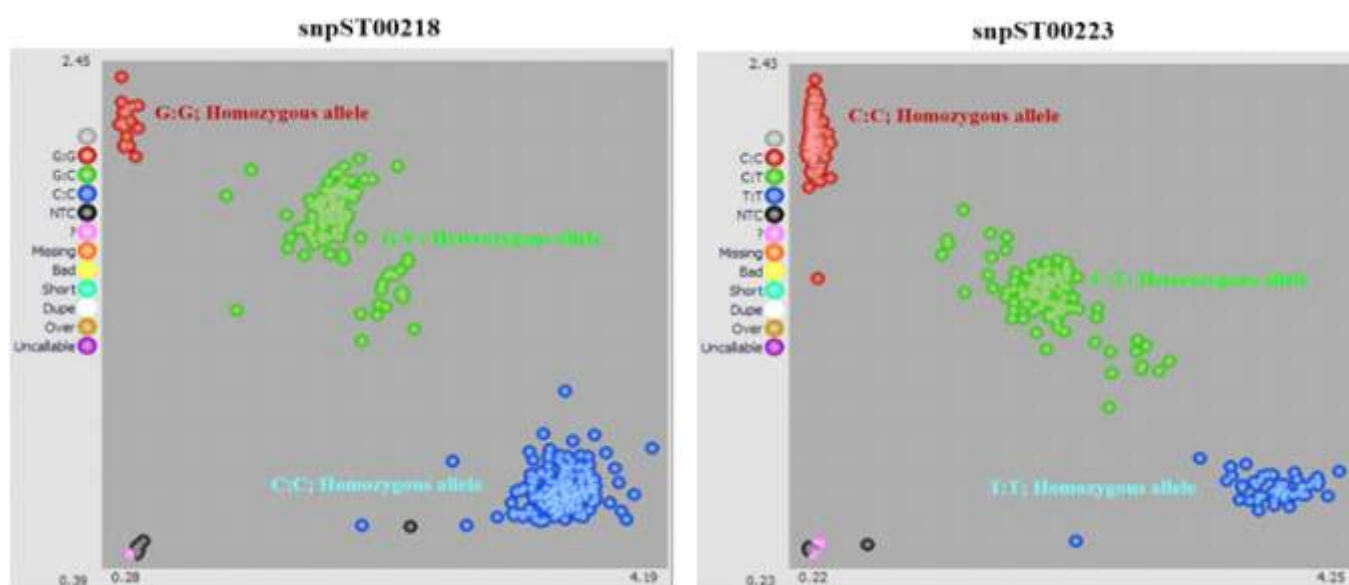


Fig. 24: Scatter plots for two kompetitive allele-specific PCR (KASP) marker assays for homozygosity evaluation of diploid lines in different selfing generations. Red and blue dots represent two homozygotes while green dots represent the heterozygous genotypes.

Table 2: Homozygosity percentage in different diploid potato generations assessed through 49 KASP SNP markers

Inbreeding Generation	N	Homozygosity (%)		
		Min	Max	Average
Initial diploid clones	132	22.9	87.8	60.7
<i>Sli</i> introgressed lines	18	54.2	82.6	73.2
First generation selfing	62	39.6	89.8	70.5
Second generation selfing	95	56.3	89.6	74.9
Third generation selfing	50	72.3	89.6	81.3

N- number of plants/diploid lines assayed

Hybridization for di-haploid induction

A set of 40 Indian potato varieties were grown under controlled conditions for hybridization with haploid inducer line, CP4590 (HI). Crosses were attempted in all 40 varieties but berry and seed set were observed in 20 varieties only. The berries were small in size and poorly developed in comparison to normal crosses. The TPS of individual berries was extracted separately in each cross to avoid self-pollinated TPS. The TPS

number varied from 1-80 in different berries of 20 crosses. The extracted seed was observed for preliminary screening based on embryo spot morphological marker to separate di-haploids from crossed seeds. The number of putative di-haploid TPS ranged from 1-55 in 20 different varieties, and the total di-haploid TPS number was 325 out of a total of 1465 seeds. Further confirmation of di-haploids will be done through flow cytometry.

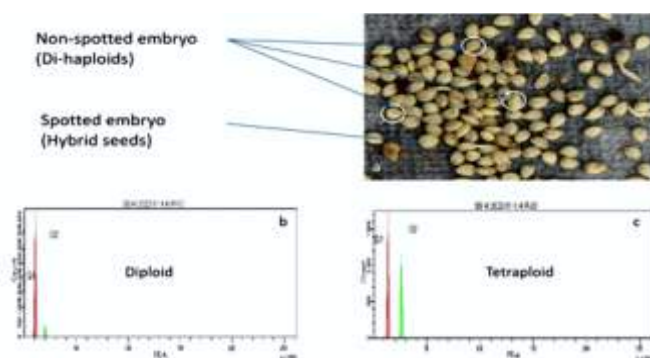


Fig. 25: Di-haploid identification a) Morphological marker embryo spot to separate hybrid seeds from non-spotted seeds (di-haploids) b) Di-haploid and c) Control tetraploid confirmation through flow cytometry.

Hybridization for di-haploid induction

A set of 40 Indian potato varieties were grown under controlled conditions for hybridization with haploid inducer line, CP4590 (HI). Crosses were attempted in all 40 varieties but berry and seed set were observed in 20 varieties only. The berries were small in size and poorly developed in

Ploidy analysis for di-haploids identification

The TPS generated from crosses between varieties and haploid inducer line was sorted to separate putative di-haploid TPS (non-spotted embryo) (Fig. 25a). Out of 3100 TPS of 12 varieties, 711 non-spotted TPS were separated based on visual identification under a compound microscope. The putative di-haploid TPS was raised and 30 days old individual seedlings were transplanted in disposable cups for ploidy detection through flow cytometry (Fig. 25b and c). In total 535 seedlings of 9 varieties were raised and examined for ploidy, which resulted in 10 di-haploids of seven varieties namely K. Pukhraj (2), K. Bahar (1), K. Swarna (1), K. Chipsona-1 (3), Atlantic (2) and Sarpo Mira (1). These 10 plants were grown further for flowering and maturity to check their self-compatibility and tubers. The visual characteristics of plants did not show any reduction in vigour but most of the plants did not flower.

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

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

A. Plains

A total production of 28018.33 qtls nucleus and breeder seed was achieved from an area of 137.42 ha. Of these, 21204.26 qtls production from 102.44 ha was through conventional and 7607.07

qtls from 34.98 ha through hi-tech seed production systems. The percentage of nucleus and breeder seed from the conventional system was 72.85 and 27.15 through hi-tech system.

1. Conventional Seed Production System: A total no. of 14420 indexed tubers of different commercial potato varieties were tested at regional stations in the plains (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	4358	4104 (94.17)	4014	3886 (96.18)
Jalandhar	6836	6756(98.8)	6756	6132(90.76)
Gwalior	1950	1900 (97.43)	1873	1763 (94.13)
Patna	1276	1260 (98.70)	1019	977 (95.8)

2. Station/stage-wise area and production of different potato varieties

Stage I: A total production of 198.95 qtls. was achieved from an area of 3.117 ha (Table-2) with an average production of 96.01, 34.20, 62.10, and 102.02qtls/ha at Modipuram, Jalandhar, Gwalior, and Patna, respectively.

Stage II: A total production of 958.59 qtls. was from an area of 6.36 ha (Table-2) with an average production of 118.62, 161.36, 201.59 and 175.17 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage III: A total production of 3616.46 qtls. was from an area of 18.44 ha (Table-2) with an average production of 215.47, 220.93, 151.24 and 229.52qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Stage IV: A total production of 15637.26 qtls. was from an area of 75.15 ha (Table-2) with an average production of 237.73, 178.72, 200.88 and 115.23 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively.

Table 2: Station & variety-wise area and production (qtls) in Conventional system 2022 (Plains)

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
I. Modipuram										
K. Anand	0.060	6.75	0.220	22.50	0.30	71.70	1.50	521.50	2.08	622.45
K. Bahar	0.430	37.10	1.500	188.00	3.85	770.00	15.00	3084.25	19.78	4079.35
K. Khyati	0.070	7.90	0.200	27.50	0.70	195.70	3.25	836.75	4.22	1067.85
K. Mohan	0.084	8.80	0.250	30.85	0.70	154.30	3.50	842.00	4.534	1035.95
K. Pukhraj	0.072	8.20	0.189	19.50	0.70	169.70	3.70	1078.00	4.661	1275.40
K. Surya	0.071	5.80	0.237	22.50	0.35	71.20	0.90	180.00	1.558	279.50
K. Chipsona-1	0.023	2.00	0.313	35.00	0.70	139.70	1.70	399.00	2.736	575.70
K. Chipsona-3	0.074	7.60	0.153	18.00	0.30	55.00	0.80	208.50	1.687	289.10
K. Frysona	0.058	5.80	0.187	23.00	0.40	96.50	1.40	398.00	2.045	523.30

Variety	Stage-I		Stage-II		Stage-III		Stage-IV		TOTAL	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
K. Thar-2	0.001	0.75	0.013	1.50	-	-	-	-	0.014	2.25
K. Lima	0.005	0.40	0.030	3.00	-	-	-	-	0.035	3.40
K. Neelkanth	0.001	0.60	0.005	0.50	-	-	-	-	0.006	1.10
K. Sangam	0.030	2.30	0.040	4.00	-	-	-	-	0.07	6.30
Total	0.979	94.00	3.337	395.85	8.00	1723.80	31.75	7548.00	43.43	9761.65
II. Jalandhar										
K. Jyoti	0.577	17.10	0.526	70.00	1.996	418.24	7.68	1195.54	10.78	1700.88
K. Pukhraj	0.421	14.70	0.279	66.27	0.98	251.00	3.38	739.42	5.06	1071.39
K. Badshah	0.037	2.18	0.038	5.28	0.146	24.30	0.395	67.34	0.616	99.1
K. Khyati	0.022	0.71	0.033	4.87	0.14	33.00	0.604	122.45	0.799	161.03
K. Surya	0.015	0.06	0.013	1.13	0.014	3.50	-	-	0.042	4.69
K. Himalini	0.049	4.01	0.072	9.34	0.187	44.19	0.322	87.75	0.63	145.29
K. Chipsona-1	0.018	0.20	0.027	2.54	0.10	12.93	-	-	0.14	15.67
Total	1.139	38.96	0.988	159.43	3.563	787.16	12.381	2212.50	18.07	3198.05
III. Gwalior										
K. Chandramukhi	0.09	5.87	0.22	42.50	0.86	84.50	2.85	463.21	4.02	596.08
K. Jyoti	0.12	6.44	0.22	44.00	0.83	127.00	3.73	735.00	4.9	912.44
K. Sindhuri	0.08	4.19	0.20	39.50	1.20	105.00	4.62	928.00	6.1	1076.69
K. Lauvkar	0.09	5.22	0.16	28.50	0.46	61.00	0.96	177.00	1.67	271.72
K. Chipsona-1	0.11	6.93	0.28	43.50	1.04	245.50	9.43	2212.50	10.86	2508.43
K. Chipsona-3	0.08	5.13	0.19	36.50	0.53	92.50	2.60	383.00	3.40	517.13
K. Surya	0.09	6.75	0.22	48.34	0.57	149.00	2.69	501.00	3.57	705.09
K. Pukhraj	0.09	5.64	0.18	51.00	0.56	50.50	-	-	0.83	107.14
K. Khyati	0.07	4.15	0.04	13.00	-	-	-	-	0.11	17.15
K. Bahar	0.01	0.51	-	-	-	-	-	-	0.01	0.51
K. Lima	0.03	2.07	0.01	1.60	-	-	-	-	0.04	03.67
K. Thar-2	0.02	1.85	0.01	1.94	-	-	-	-	0.03	03.79
K. Sangam	0.02	1.14	0.01	0.38	-	-	-	-	0.03	01.52
Total	0.90	55.89	1.74	350.76	6.05	915.00	26.88	5399.71	35.57	6721.36
IV Patna										
K. Himalini	0.012	1.00	0.0225	4.00	0.06	16.00	0.20	66.80	0.29	87.80
K. Jyoti	0.015	1.50	0.045	6.30	0.13	42.50	0.75	114.90	0.94	165.20
K. Kanchan	0.003	0.35	0.0175	2.00	0.03	4.50	-	-	0.050	6.85
K. Kesar	0.012	1.50	0.0425	7.90	0.15	24.50	0.14	13.25	0.344	47.15
K. Khyati	0.015	1.50	0.0475	12.50	0.15	36.00	1.30	205.50	1.51	255.50
K. Lailt	0.012	1.00	0.030	7.50	0.13	29.00	0.55	9.80	0.72	47.30
K. Manik	0.006	0.25	0.0025	0.15	-	-	-	-	0.0085	0.40
K. Neelkanth	0.006	0.500	0.035	1.00	-	-	-	-	0.041	1.50
K. Pukhraj	0.012	1.50	0.0275	4.50	0.12	23.00	0.70	13.50	0.86	42.50
K. Sindhuri	0.006	1.00	0.030	6.70	0.06	15.00	0.50	53.30	0.60	76.00
Total	0.099	10.1	0.3	52.55	0.83	190.5	4.14	477.05	5.37	730.20
Plains' Total	3.117	198.95	6.365	958.59	18.443	3616.46	75.151	15637.26	102.44	20411.26

1. 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

1166.64 qtls. was achieved in G-I from an area of 6.07 ha with an average production of 176.69, 237.04, 150.89 and 318.68 qtls/ha at Modipuram, Jalandhar,

Gwalior and Patna, respectively (Table-3).

- (ii) **Generation-2:** A total production of 6440.43 qtls. was achieved in G-2 from an area of 28.96ha with an average production

of 238.53, 211.57, 193.40 and 197.15 qtls/ha at Modipuram, Jalandhar, Gwalior and Patna, respectively (Table-3).

Table 3: Station & variety-wise area and production (Qts.) in Hi-Tech system 2022 (Plains)

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
I. Modipuram						
K. Chipsona-1	1.23	209.50	5.20	1190.50	6.43	1400.00
K. Chipsona-3	0.30	38.00	1.20	315.00	1.50	353.00
K. Frysona	0.10	13.80	0.20	62.00	0.30	75.80
K. Ganga	0.15	48.20	1.00	282.50	1.15	330.70
K. Khyati	0.70	89.00	1.25	319.50	1.95	408.50
K. Mohan	1.20	170.00	3.50	828.50	4.70	998.50
K. Pukhraj	0.20	64.50	0.80	190.00	1.00	254.50
K. Surya	0.25	51.50	1.10	211.00	1.35	262.50
K. Sukhyati	0.30	96.00	-	-	0.30	96.00
K. Lima	0.01	04.00	-	-	0.01	4.00
Total	4.44	784.50	14.25	3399.00	18.69	4183.50
II Jalandhar						
K.Chandramukhi	0.094	30.90	1.65	342.01	1.744	372.91
K. Jyoti	0.032	13.50	1.562	229.41	1.594	242.91
K. Badshah	0.032	08.70	0.263	42.77	0.295	51.47
K. Pukhraj	0.338	57.85	3.72	827.98	4.058	885.83
K. Chipsona-1	0.032	06.89	1.414	263.03	1.446	269.92
K. Khyati	0.076	22.85	0.086	22.30	0.162	45.15
K. Himalini	0.121	33.20	1.28	371.51	1.401	404.71
K. Gaurav	0.043	11.30	0.03	08.91	0.073	20.21
K. Surya	-	-	0.047	11.42	0.047	11.42
K. Karan	0.090	16.58	0.12	32.71	0.21	49.29
K. Sukhyati	0.032	12.23	-	-	0.032	12.23
K. Pushkar	0.011	1.79	-	-	0.011	1.79
K. Himsona	0.022	3.00	-	-	0.022	3.00
Total	0.923	218.79	10.172	2152.05	11.095	2370.84
III Gwalior						
K. Ganga	0.14	21.25	-	-	0.14	21.25
K. Neelkanth	0.14	21.00	-	-	0.14	21.00
K. Chipsona-1	-	-	0.24	55.00	0.24	55.00
K. Pukhraj	-	-	0.22	52.00	0.22	52.00
K. Khyati	-	-	0.29	48.50	0.29	48.50
K. Himalini	-	-	0.26	54.20	0.26	54.20
K. Garima	-	-	0.22	44.00	0.22	44.00
K. Karan	-	-	0.28	38.33	0.28	38.33
Total	0.28	42.25	1.51	292.03	1.79	334.28

Variety	G1		G2		TOTAL	
	Area	Production	Area	Production	Area	Production
IV Patna						
K. Ashoka	0.012	3.00	-	-	0.012	03.00
K. Chipsona-1	0.02	4.00	-	-	0.02	04.00
K. Chipsona-3	-	-	0.30	49.50	0.30	49.50
K. Himalini	0.14	37.0	0.35	30.60	0.49	67.60
K. Kesar	-	-	0.13	32.90	0.13	32.90
K. Khyati	0.04	4.8	1.45	309.30	1.49	314.10
K. Mohan	-	-	0.19	34.80	0.19	34.80
K. Neelkanth	0.08	29.00	0.33	48.95	0.41	77.95
K. Pukhraj	0.02	5.30	0.15	35.80	0.17	41.10
K. Sindhuri	0.06	13.00	-	-	0.006	13.00
K. Surya	0.008	25.00	0.13	55.50	0.138	80.50
Total	0.38	121.10	3.03	597.35	3.41	718.45
Plains Total	6.023	1166.64	28.962	6440.43	34.98	7607.07

3. Total supply of breeder seed

During 2022, a total of 22294.52 qtls of breeder seed was supplied to various government and private agencies, from plains Table-4 (A & B).

Table 4 (A): Station and variety-wise supply (qtls) during 2022

S. No	Variety	Stations				Total (q)
		Modipuram	Jalandhar	Gwalior	Patna	
1.	Kufri Anand	532.20	-	-	-	532.20
2.	Kufri Bahar	3176.25	-	-	-	3176.25
3.	Kufri Badshah	-	110.11	-	-	110.11
4.	Kufri Chipsona-1	1638.20	244.33	2173.05	-	4055.58
5.	Kufri Chipsona-3	540.00	-	364.50	49.50	954.00
6.	Kufri Chandramukhi	-	348.66	463.21	-	811.87
7.	Kufri Frysona	456.30	-	-	-	456.30
8.	Kufri Gaurav	-	8.91	-	-	8.91
9.	Kufri Garima	-	-	44.00	-	44.00
10.	Kufri Ganga	285.05	-	-	-	285.05
11.	Kufri Himalini	-	465.835	54.20	97.40	617.435
12.	Kufri Jyoti	-	1419.675	735.00	114.90	2269.575
13.	Kufri Khyati	1192.20	166.25	48.50	514.80	1921.75
14.	Kufri Karan	-	32.71	38.33	-	71.04
15.	Kufri Mohan	1741.30	-	-	34.80	1776.10
16.	Kufri Neelkanth	-	-	-	62.45	62.45
17.	Kufri Lalit	-	-	-	73.30	73.30
18.	Kufri Lauvkar	-	-	177.00	-	177.00
19.	Kufri Pukhraj	1282.40	1559.20	52.00	49.30	2942.90
20.	Kufri Surya	410.65	11.245	501.00	55.50	978.395
21.	Kufri Sindhuri	-	-	917.00	53.30	970.30
	Total	11254.55	4366.925	5567.79	1105.25	22294.52

B. Hills

- Multiplication of basic material maintenance of mother stock:** During the year, 38 pots of 19 varieties were planted and tested with ELISA/PCR against different potato viruses. After carrying out a series of testing through PCR/ELISA, all healthy varieties were shifted *in vitro* & were included in the micro-plants multiplication and supply chain. In total, 16250 culture tubes of 45 varieties were multiplied in tissue culture. In aeroponics, 51236 mini tubers of different varieties/ diploids/ advanced hybrids were harvested.

- Maintenance of buffer stock in the field at CPRS, Kufri:** On account of interception of Potato Cyst Nematode (PCN) at Kufri and Fagu farms and subsequent imposition of quarantine by Govt. on India during Nov./Dec. 2018; the nucleus and breeder seed potato production of CPRS Kufri-Fagu Unit has been suspended since 2018. However, as

per the approved scheme, a limited quantity of buffer seed stocks of varieties viz., K. Jyoti, K. Himalini, K. Girdhari, K. Giriraj, K. Shailja, K. Kanchan, K. Himsona and K. Karan under different seed stages of Conventional and Hi-tech systems are being maintained. The produce obtained from such buffer seed stages was used in planting the trap crop (as a measure to eradicate the PCN from farms) and as a seed for planting buffer seed stages during the following year. The surplus quantities, if any, are disposed of in the local sabzi market as ware potatoes.

C. Supply of Microplants to Different Seed Agencies

A total of 224 virus-free *in vitro* culture tubes of basic seed material of 31 varieties (Fig 1) were supplied to 31 seed-producing organizations in India (Table-5), and a revenue of Rs. 11,20,000/- has been generated. An amount of Rs.1,00,000 was received as a registration fee @Rs. 10,000/firm valid for a period of five years.

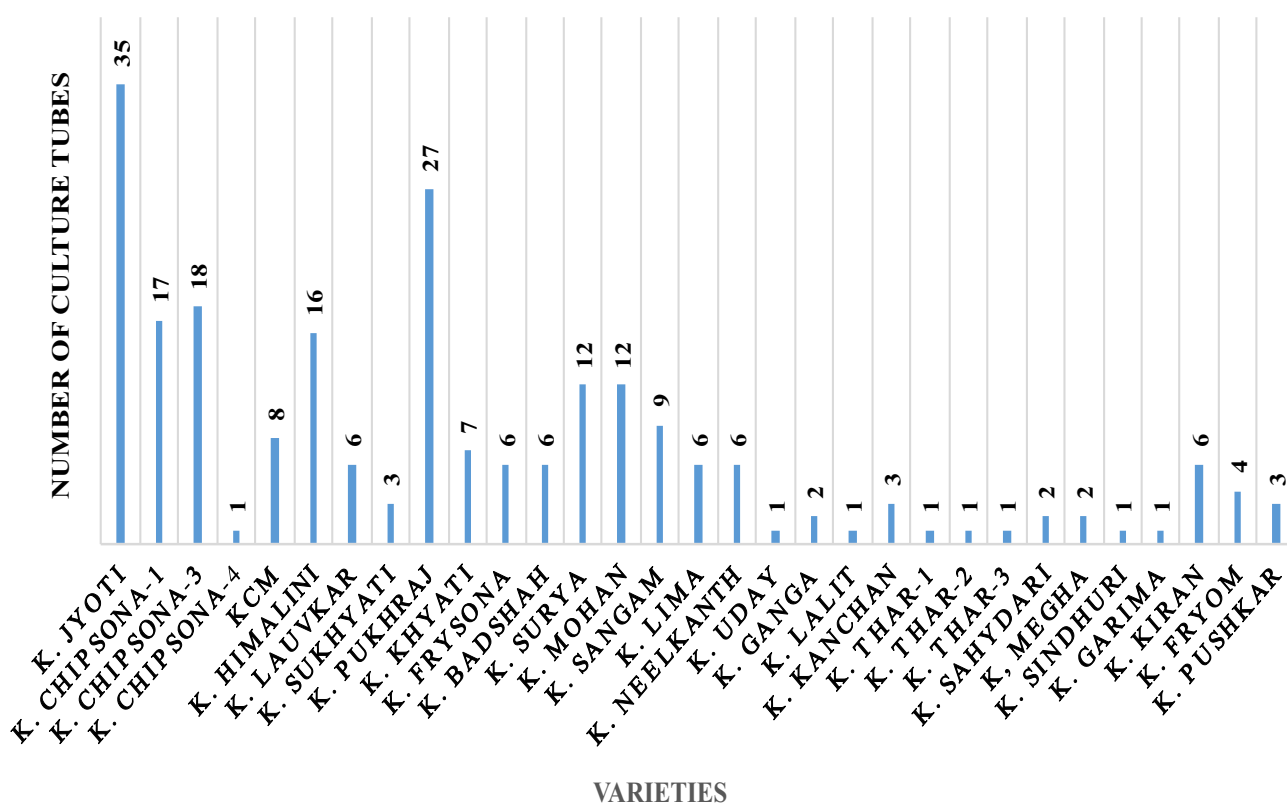


Fig. 1: Variety-wise supply to different seed organizations

Table 5: Microplants supply to different Seed Producing Organizations

S. N.	Firms	Varieties Supplied
1.	M/s Merino Industries Ltd, Village-Achheja, PO- Hapur, UP	K. Chipsona-1, K. Jyoti,
2.	Deputy Director Horticulture, Potato Technology Centre, (PTC) Shamgarh, Karnal, Haryana	K. Pukhraj, K. Mohan, K. Lima, K. Neelkanth, K. Pushkar, K. Sangam, K. Udhay
3.	M/s The Energy & Resources Institute, TERI-GRAM, Gurgaon, Haryana	K. Chip-1, K. Chip-3, K. Pukhraj, K. Surya, K. Neelkanth, K. Mohan, K. Sangam, K. Lima, K. Thar-2
4.	Dr. Rajendra Prasad Central Agricultural University, Pusa, Samstipur, Bihar	K. Khyati, K. Mohan, K. Ganga, K. Surya, K. Jyoti, K. Pukhraj, K. Lalit, K. Neelkanth, K. Chip-3, K. Chip-4,
5.	M/s Sekhon Biotech Pvt. Ltd, Ropar, Punjab	K. Jyoti, K. Lauvkar, K. Pukhraj, K. Khyati, K. Sukhyati, K. Frysona, K. Chip-1, K. Chip-3, KCM, K. Himalini, K. Badshah, K. Surya, K. Mohan, K. Sangam
6.	M/S Avika Water Solutions, Nasirpur Farms, Patiala, Punjab	K. Jyoti, K. Lauvkar, K. Chandramukhi
7.	M/s Utkal Tubers India Pvt. Ltd., Whitefield Road, Garudacharapalya, Bangalore	K. Chipsona-1, K. Chipsona-3, K. Frysona
8.	M/s Madhav Agri Tech, Bhagwati Nagar, Station Road, Tunda, Firozabad UP	K. Sangam, K. Mohan, K. Neelkanth, K. Sukhyati, K. Pukhraj, K. Khyati, K. Chipsona-3, K. Thar-1
9.	M/s Centre of Excellence for Potato, Dhogri, Distt-Jalandhar, Punjab	K. Himalini, K. Jyoti, K. Pukhraj, K. Mohan
10.	M/s Sheel Biotech Ltd, Sheel House, Main Jagdamba Road, Tughlakabad, New Delhi	K. Jyoti, K. Pukhraj, K. Himalini, K. Lima, K. Chipsona-1, K. Mohan, K. Sangam, K. Kanchan
11.	Uttar Banga Krishi Vishwavidyalaya, Pundipari, West Bengal	K. Jyoti, K. Himalini, K. Pukhraj, K. Chandramukhi, K. Khyati, K. Lima, K. Kanchan, K. Mohan, K. Neelkanth, K. Surya, K. Sangam, K. Lauvkar, K. Sukhyati, K. Ganga, K. Chip-3
12.	M/s Dayal Seeds Pvt Ltd, Partapur, Meerut, U.P	K. Sangam
13.	Director Research, Assam Agriculture University, Jorhat, Assam	K. Himalini, K. Surya, K. Chipsona-3
14.	M/s Jain Irrigation Systems Ltd, Jalgaon, Maharashtra	K. Jyoti, K. Badshah, K. Pukhraj, K. Chipsona-3, K. Khyati, K. Frysona
15.	M/s SF Agritech Pvt. Ltd, Itwah, Uttar Pradesh	K. Himalini, K. Chipsona-1, K. Chipsona-3, K. Fry Om, K. Pushakar
16.	Sh. Chamkaur Singh, VPO- Tohra, Patiala	K. Chip-1, K. Pukhraj, K. Kiran, K. Surya
17.	Mr. Vishwas Yadav, M/s Shamanur Agritech Pvt Ltd, Karnataka	K. Jyoti, K. Pukhraj, K. Chipsona-1, K. Chipsona-3
18.	The Assistant Director, Horticulture Research Complex, Nagicherra, West Tripura	K. Jyoti, K. Chandramukhi, TPS-67, TPS-13, TPS-07, MF-1, MF-2
19.	Mr. Neeraj Sharma, Elisha Hortiagro Pvt. Ltd, Aligarh, UP	K. Sangam, K. Lauvkar, K. Surya, K. Chipsona-1, K. Mohan

20.	M/s Technico Agri Sciences Ltd Tehsil- Baddi, Solan	K. Sahyadri
21.	M/s Kalandi Agro Biotech Ltd Laltapur, Indistrial Area, Dehradun	K. Frysona, K. Jyoti, K. Lauvkar, K. Chipsona-, K. Surya
22.	M/s GMS Agritech Pvt Ltd, Kolkata	K. Jyoti, K. Himalini, K. Pukhraj
23.	M/s Shashanka Agro-tech Pvt. Ltd., Ranchi, Jharkhand	K. Sindhuri, K. Sahyadri, K. Thar-3, K. Garima, K. Jyoti
24.	International Potato Centre, Shillong	K. Megha, K. Himalini, K. Jyoti, K. Chipsona-3
25.	M/s Dauladhar Bioplants, P.O- Bajarerh, Tehsil- Shahpur, Distt- Kangra, HP	K. Jyoti, K. Lauvkar, K. Chandramukhi, K. Sukhyati, K. Pukhraj
26.	M/s SK Cold Storage, Ahmedabad, Gujrat	K. FryOm, K. Kiran
27.	M/s Kavya Agro Potato Seeds Distt.- Bulandshahar, UP	K. Sangam, K. Kiran, K. Chipsona-1, K. Surya
28.	International Potato Centre, Karnataka	K. Himalini, K. Jyoti
29.	M/s Saveer Biotech Ltd, New Delhi	K. Jyoti, K. Sindhuri, K. Badshah, K. Neelkanth, K. Himalini, K. Pukhraj, K. Chipsona-1, K. Chipsona-3, K. Chandramukhi, K. Surya
30.	M/s Bhatti Tissue Tech. Vill.-Alipur, PO-Mithapur, The & Distt.- Jalandhar, PB	K. Jyoti
31.	M/s West Bengal State Seed Association, Beej Bhawab Paschim Medianpur WB	K. Jyoti, K. Himalini, K. Pukhraj, KCM, K. Khyati, K. Lima, K. Kanchan, K. Mohan, K. Neelkanth, K. Surya, K. Sangam, K. Lauvkar, K. Sukhyati

Last year, 1183 culture tubes of 29 varieties were supplied to different seed production stations/ centers i.e., Modipuram, Jalandhar, Patna, Shillong and Gwalior.

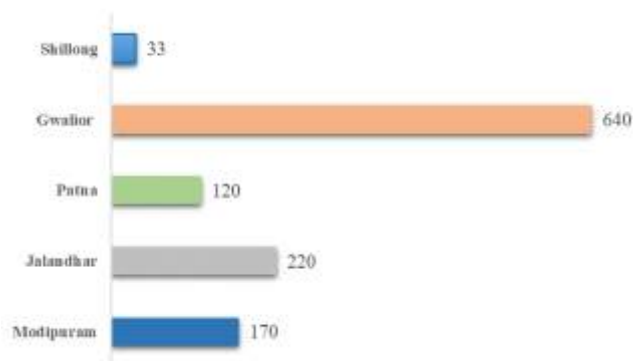


Fig 2. Station - wise micro plant supply to different seed centers

D. Production and supply of quality seed

Production of quality seed during spring 2022

(Ooty): In total, 44.77 tons of quality seed was produced from an area of 2.56 ha during all three crop seasons (spring/summer/autumn) in 2022. Out of which 5745 Kg of quality seed was supplied to the farmers, 16749 Kg to govt. organization and 825 Kg was disposed of as table potatoes and miscellaneous to the ICAR- CPRS staff/ market. A total of **Rs. 9,51,423/-** unsold revenue was generated, including the last year's seed sold during this financial year.

Table 6: Details of quality seed produced during 2022

Variety	Area (ha)	Quantity harvested (t)	Average yield (t/ha)
Kufri Swarna	0.55	9.60	17.45
Kufri Sahyadri	0.65	10.80	16.61
Kufri Girdhari	0.51	9.30	18.23
Kufri Karan	0.65	12.07	18.56
Kufri Himalini	0.20	3.00	15.00
Total	2.56	44.77	17.48

Production of quality seed during 2022

(Shillong): For quality seed production, Kufri Himalini was planted on 1st Feb 2022 and the remaining varieties K. Jyoti, K. Girdhari, K. Giriraj, K. Megha, K. Kanchan, K. Chipsona-1, Chipsona-3 and K. Lauvkar were planted in

March 2022. In total, 17.61 tons of quality seed was produced from a 2.00 ha area (table 7). Out of 17.61 tons of total yield, after grading and sorting of wounded and diseased tuber, around 4 tons is kept for use in experiments, FLD, and other plantings. A total of 10.38 tons has been supplied to various stakeholders.

Table 7 : Quality seed production (tons) at CPRI RS, Shillong to various states (2021-2022)

Variety	Area (ha)	Quantity harvested (tons)	Average yield (tons/ha)
Kufri Jyoti	0.40	3.85	9.63
Kufri Girdhari	0.40	2.20	5.5
Kufri Giriraj	0.30	2.20	7.33
Kufri Megha	0.30	1.56	5.2
Kufri Himalini	0.40	6.59	16.48
Kufri Chipsona 1	0.05	0.11	2.2
Kufri Chipsona 3	0.05	0.29	5.8
Kufri Kanchan	0.07	0.64	9.14
Kufri Lauvkar	0.03	0.17	5.67
Total	2.00	17.61	8.81

Production of rooted cuttings (transplants) originating from tissue culture plantlets was carried out at CPRI-RS, Shillong, from Feb up to Nov 2022 batch-wise for the production of seed

tubers during the Summer, Autumn, and Winter seasons. A total of **1,15,405** numbers of cuttings were produced during the year.

Table 8: Production of rooted cuttings at CPRI RS, Shillong, during 2022

Variety	No.
K. Himalini	29550
K. Girdhari	4590
K. Megha	18783
K. Chip 3	7274
K. Giriraj	17234
K. Lima	2109
K. Karan	26472
K. Badami	1207
K. Jyoti	2995
K. Kanchan	5191
Total	1,15,405

Table 4: (B) Variety/ stage & agency-wise breeder seed supply from plains (qtls) during 2022

S.N.	Variety	BR*	CG*	HP*	J&K*	MP*	ML*	PB*	UK*	UP*	WB*	NHRDF*	NSC*	Uni.*	ICAR	Auctioned	Farmers/Pvt.	Total
1.	K. Anand	-	-	-	-	-	-	-	-	403.00	-	-	-	-	19.50	12.20	97.50	532.20
2.	K. Badshah	-	-	-	35.50	-	-	-	-	61.00	-	-	-	-	-	-	13.61	110.11
3.	K. Bahar	-	38.75	-	-	-	-	-	-	2309.50	23.50	-	-	-	-	677.00	127.50	3176.25
4.	KCM	-	50.00	200.00	105.00	-	-	9.00	-	-	143.00	60.00	-	-	10.50	-	234.37	811.87
5.	K. Chipsona-I	-	-	-	25.00	150.00	-	18.00	-	2423.79	-	-	-	505.80	73.00	48.70	811.29	4055.58
6.	K. Chipsona-3	3.50	-	-	90.00	300.00	-	-	-	300.00	-	-	-	-	30.00	16.50	214.00	954.00
7.	K. Frysona	-	-	-	25.00	-	-	-	-	120.00	-	-	-	-	211.00	10.30	90.00	456.30
8.	K. Garima	-	5.00	-	-	-	-	-	-	27.00	-	-	-	-	01.00	-	11.00	44.00
9.	K. Gaurav	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.91	8.91
10.	K. Ganga	-	47.60	-	-	-	-	-	9.50	176.25	-	-	-	-	5.00	31.70	15.00	285.05
11.	K. Himalini	7.00	-	27.00	80.50	-	30.00	100.00	21.50	-	56.00	23.00	27.00	-	19.00	-	226.435	617.435
12.	K. Jyoti	3.00	-	175.00	208.00	-	-	415.41	50.00	-	271.00	27.50	110.00	15.00	16.00	-	978.665	2269.575
13.	K. Karan	-	-	-	-	-	-	-	39.50	-	-	-	-	2.71	05.50	-	23.33	71.04
14.	K. Khyati	15.00	-	-	35.00	-	-	46.50	-	905.19	327.31	129.50	-	-	45.00	176.20	242.05	1921.75
15.	K. Lauvkar	-	-	-	-	-	-	-	-	-	-	-	-	-	04.00	-	173.00	177.00
16.	K. Lalit	5.00	-	-	-	-	-	-	-	-	2.50	-	-	-	63.50	-	2.30	73.30
17.	K. Mohan	3.50	200.00	-	-	-	-	268.00	-	300.00	140.00	200.00	117.00	6.00	85.00	246.80	209.80	1776.10
18.	K. Neelkanth	12.50	-	-	-	-	-	-	-	16.70	4.10	-	-	-	13.50	-	15.65	62.45
19.	K. Pukhraj	45.00	-	-	174.10	-	60.00	450.00	12.50	660.00	210.00	150.00	-	32.00	240.00	242.40	666.90	2942.90
20.	K. Sindhuri	45.00	50.00	-	80.00	-	-	54.00	-	500.00	-	30.00	-	140.00	2.00	-	69.30	970.30
21.	K. Surya	7.00	37.50	-	20.00	-	-	-	-	558.00	-	-	76.00	0.52	64.95	20.70	193.725	978.395
Total		146.5	428.85	402.00	878.10	450.00	90.00	1360.91	133.00	8760.43	1177.41	620.00	330.00	702.03	908.45	1482.5	4424.335	22294.52

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

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

1. Production behavior of aeroponic tubers grown during two different seasons

Two crops can be taken up successfully in a year for faster multiplication and effective utilization of aeroponic potato units. However, such aeroponic seed potato tubers obtained from both seasons can only be multiplied during the next potato crop season. To know the production behavior of such aeroponic tubers, a comparative study with 15 months old (harvested during Feb. 2021) and 08 months old (harvested during Sep. 2021) aeroponic tubers was conducted during *Kharif* 2022 using <3g of aeroponic tubers of two

potato varieties *viz.* Kufri Karan and K. Himalini. The number of tubers/m² was significantly affected by both factors. No. of tubers /m² were higher with older seed tubers in potato cultivar K. Karan. However, the yield /m² was more (1.97 kg/m²) with young aeroponic tubers than the older tubers (1.73 kg/m²). Among the cultivars, the yield was slightly higher in K. Karan than in K. Himalini (**Table 1**). The average number of tubers /plant was higher with older (15 months) seed tubers and potato cultivar K. Karan. Therefore, one-year older aeroponic tubers can also be used successfully as a seed source without a doubt. The finding will prove to be a boon in fulfilling the everlasting shortages of seed potatoes and will avoid the wastage of precious planting material.

Table 1: Production behaviour of aeroponic tubers from two seasons.

S. No.	Variety	No. of tubers/m ²			Yield (Kg/m ²)			No. of tubers/plant		
		Feb. harvest (15 months old)	Sep. harvest (08 months old)	Mean	Feb. harvest (15 months old)	Sep. harvest (08 months old)	Mean	Feb. harvest (15 months old)	Sep. harvest (08 months old)	Mean
1	K. Karan	125.0	124.9	125.0	1.77	2.00	1.89	4.7	4.5	4.6
2	K. Himalini	68.3	57.6	62.9	1.69	1.94	1.81	2.6	2.1	2.4
Mean		96.6	91.3		1.73	1.97		3.6	3.3	
CD 0.05										
Variety (V)			3.2		0.08			0.3		
Seed type (S)			3.2		0.08			0.3		
V X S			4.6		N.S.			N.S.		

2. Standardization of planting geometry for extremely small mini-tubers in the flat bed method of planting

Since every potato genotype/cultivar is known to behave differently in its production behavior, it becomes necessary to standardize the agronomy for each and every cultivar to harness its maximum production potential. Keeping this in view, an experiment was conducted to standardize the geometry for planting extremely small mini-tubers of the new potato cultivar K. Karan in Gen. 1 during the *Kharif* 2022 at Fagu farm. The results revealed that percent emergence (50 DAP) was slightly higher in large (3-10g) tubers but was significantly higher at 60x20cm than closer intra-row spacing. Ground cover at 50 DAP was only affected by the size of the seed

tuber and not by the planting geometry. However, 70 DAP, both factors affected ground coverage significantly and were higher with large (3-10g) seed tubers and at closer plant spacing (60x15cm). The number of tubers and yield /ha were significantly affected by both factors, and their interactions were also significant (**Table 2**). Tubers and yield/ha were higher with large seeds (3-10g) and at closer planting (60x15cm). However, significant interactions reveal that the number of tubers was higher with <3g seed tubers at 60 x15 cm, which were statistically similar for large seed tubers at both the planting geometries. With 3-10g seed tubers, yield/ha was significantly higher at 60x20cm and with <3g seed tubers at 60x15cm geometry.

Table 2: Production behavior of extremely small mini-tubers of K. Karan in flat bed planting under field conditions

S. No.	Size of mini-tuber	Plant height (cm)			No. of tubers (lakh/ha)			Yield (q/ha)		
		60x20cm	60x15cm	Mean	60x20cm	60x15cm	Mean	60x20cm	60x15cm	Mean
1	3-10g	68.5	70.5	69.5	8.50	8.48	8.49	387.0	352.7	387.0
2	<3g	59.2	70.2	64.7	6.69	9.35	8.02	259.5	371.2	259.5
Mean		63.8	70.4		7.59	8.92		323.3	361.9	
CD 0.05										
Seed size (S)			2.2		0.38		6.9			
Geometry (G)			2.2		0.38		6.9			
S xG			3.1		0.54		9.7			

3. Standardization of variety-specific nutrient solution for mini tuber production under aeroponic

Nutrient optimization is critical for producing high-quality, clean potato seed in a soilless culture like aeroponics. Each crop has an optimum nutritional requirement. Each potato cultivar may require a specific nutrient solution in an aeroponics unit. Therefore, a nutrient optimization experiment was conducted to study the effect of different nutrient solution levels on the yield of potato mini-tubers. The treatments

were three different nutrient solutions of macro and micronutrients. Feeding the plants with Solution-III produced the highest number of mini tubers/plants in Kufri Jyoti (27), Kufri Himalini (36) and Kufri Pukhraj (52). Feeding the plants with Solution-III doubled yield/plant in Kufri Pukhraj and Kufri Himalini (Fig 1). Besides producing more tuber number /plant compared to check treatment (Solution-I), solution-II and Solution-III economized the N and K use by more than 90% and P by 45%. The study will be repeated in the next season.

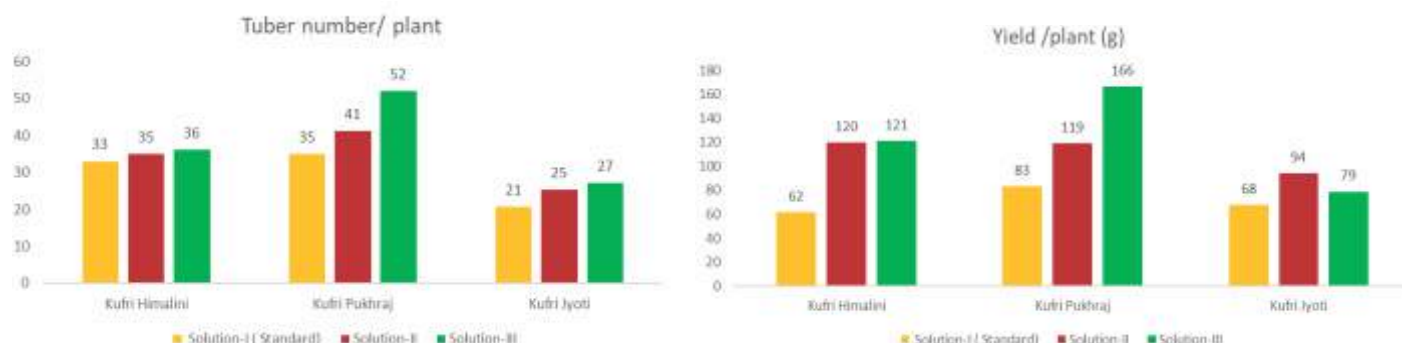
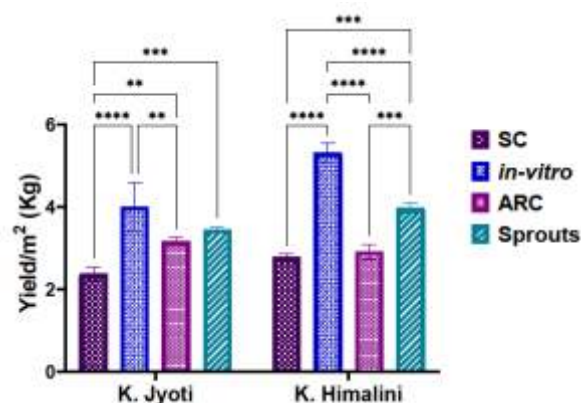
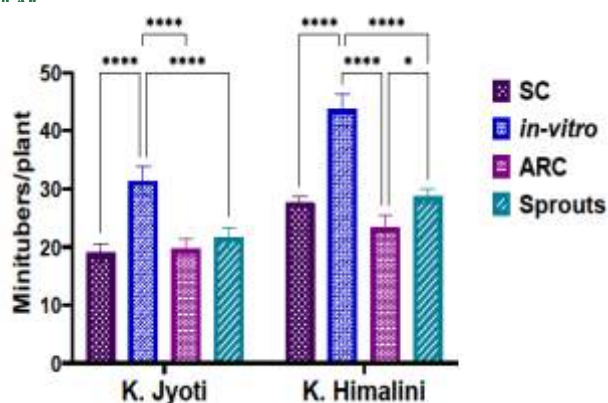


Fig. 1: Effect of different nutrient solution levels on the number and yield of potato mini-tubers.

4. Effect of different plant sources for mini tuber production under aeroponics

The objective of this study was to evaluate the performance of potato varieties (K. Jyoti, K. Himalini) derived from four plant sources (stem cuttings, in vitro plants, tissue culture, apical rooted cuttings and sprouts from mini tubers) grown under aeroponics to establish their potential as a source of seed potato. Results revealed a strong influence of the type of planting material (plant origin) and genotype (cultivar) on the total number of mini tubers produced by the

plant, mini tuber mass, and total yield of potatoes grown in aeroponics (Fig 2). Though the early tuberization was recorded in all the plant sources except *in vitro* plants however, most of the productive traits i.e., no. of tubers per plant and no. of harvests, were significantly higher in micro plants which ultimately resulted in harnessing the full potential of plants for mini tuber production under aeroponics. The distribution pattern of mini-tuber production among the varieties varied as per the plant sources. This indicates that *in vitro* plantlets can give a viable material for seed potato tuber production under aeroponics.



(* Significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$)

Fig. 2: Minutubers/plant and yield as influenced by plant origin

5. Standardization of planting geometry for the multiplication of different grades of mini-tubers of new potato cultivar Kufri Karan in Gen.1 under field conditions

03 grades of mini-tubers (20-40g, 10-20g and 3-10g) and 03 geometries (60x10cm, 60x15cm & 60x20cm) were used. The results revealed that the factors, viz. size of mini-tuber and planting geometry, significantly affected the number of tubers/ha. The increasing size of seed tubers and decreasing intra-row spacing gradually increased the number of tubers/ha. The number of tubers/ha was significantly higher with 20-40g seed tubers (8.33 lakh/ha) than with smaller grades. Among the different planting geometries, the number of tubers was significantly higher (8.49 lakh/ha) with a planting geometry of 60x10cm. The interaction between the size of the mini-tuber planted and planting geometry was

significant for the number of tubers/ha (Table 3). Like number, the yield /ha was also significantly affected by the mini-tuber's size and planting geometry. A gradual increase in yield/ha with increasing size of mini-tuber as well as with closer intra-row spacing was noticed. Like the number of tubers, yield/ha was also maximum with 20-40g mini-tubers and at 60x10 cm geometry. The significant interaction between the size of the mini-tuber and planting geometry revealed that yield/ha was maximum when 3-10g mini-tubers were planted at 60x10 cm, 10-20g at 60x15cm and 20-40g at 60x20 cm, respectively. The interaction between seed tuber grade and planting geometry was significant for undersized tubers but insignificant for oversized ones. Interaction effect reveals that undersize tubers were minimum when 3-10g min-tubers were planted at 60x20 cm and maximum with 20-40g mini-tubers at 60x10 cm planting geometry.

Table 3: Production behavior of different grades of mini-tubers of K. Karan at different planting geometries in Gen. 1.

Treatments	Total tubers/ha (lakh)			Mean	Total yield (q/ha)			Mean
	60x20cm	60x15cm	60x10cm		60x20cm	60x15cm	60x10cm	
20-40g	7.46	8.05	9.49	8.33	349.5	339.6	334.8	341.3
10-20g	6.82	7.57	8.43	7.61	324.4	347.9	329.5	333.9
3-10g	6.05	7.05	7.56	6.88	317.9	319.6	325.3	320.9
Mean	6.78	7.56	8.49		330.6	335.7	329.8	
CD _{0.05}								
Grade of mini-tuber (A)			0.24	2.7				
Planting Geometry (B)			0.24	2.7				
A x B								

6. Agronomical manipulations for effective field multiplication of potato aeroponic mini tubers of newly released varieties

At Gwalior, an experiment was conducted with 8 popular varieties viz Kufri Ganga, Kufri Himalini, Kufri Lima, Kufri Pukhraj, Kufri Jyoti,

Kufri Chipsona-1, Kufri Khyati and Kufri Mohan and two spacing combinations 30x10 cm (333333 plants/ha) and 30x15 cm (222222 plants/ha). The experiment was planted in factorial RBD with 3 replications. No significant difference was recorded among varieties for germination and

among spacing. A significantly higher total number of tuber (000/ha) was recorded in Kufri Ganga (1610), Kufri Pukhraj (1285) and Kufri Mohan (1299) and Kufri Jyoti (1047) over Kufri Lima (829)-fig. 3. Among spacing, 30 x 10 cm recorded significantly higher total tuber number (1249 thousand/ha) over 30 x 15cm (940 thousand/ha) fig. 3. Among interaction Kufri Ganga with 30x10 cm spacing (1770 thousand/ha) recorded significantly highest total tuber number among other treatment combinations. For weight, Kufri Pukhraj (18.67t/ha) recorded significantly higher total tuber weight, followed by Kufri Khyati (18.54), Kufri Himalini (15.66), Kufri Mohan (13.94) and Kufri Ganga (13.50) over

Kufri Chipsona-1 (10.06t/ha)- fig 3. For spacing, 30×10 cm spacing (15.03 t/ha) recorded non-significantly higher total tuber weight over 30×15 cm spacing (14.03 t/ha). Kufri Ganga recorded the highest <3g mini tuber % (48.64 by number and 6.19 by weight). Similarly, 30×10 cm spacing (34.33% by number and 4.05 by weight) recorded significantly higher <3g minituber% over 30×15 cm spacing (29.68 by number and 3.09 by weight). Kufri Khyati by number (15.00) and Kufri Lima (40.06) by weight recorded the highest 41-80g mini tuber % over other varieties. 30×15 cm spacing (10.30% by number and 31.47% by weight) recorded non-significantly higher 41-80g mini tuber over 30×10 cm spacing.

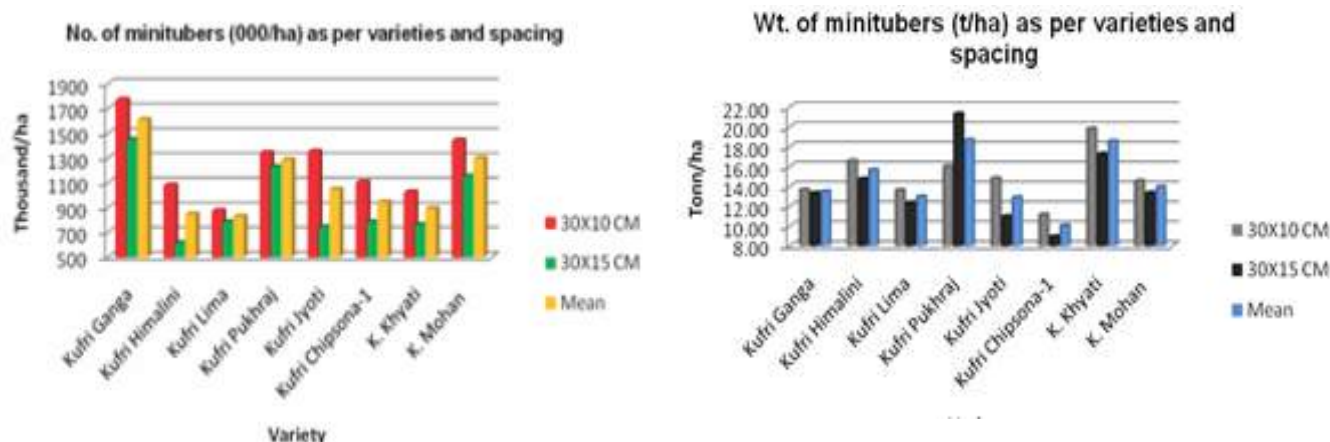


Fig. 3: Effect of spacings on the number and weight of mini tubers

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

1. Evaluation of potato varieties under different spacing and canopy management practices for the production of seed-size tubers

At Gwalior, a study was conducted with five spacing combinations viz S1-Ridge and furrow 60×20 cm, S2-Ridge and furrow 60×15cm, S3-Flat Bed Paired row 90 cm bed length (two rows 20 cm plant to plant spacing), S4-Flat bed Paired row 90 cm bed length (two rows 15 cm plant to plant spacing) and S5-Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) and two haulm killing dates viz H1-70 and H2-80 days with three replications in split plot design. The trial was planted on 05/11/2021 with Kufri Khyati. No significant differences were reported for days to initial emergence among spacing combinations and haulm killing and for 50% and final emergence among haulm killing days. An increasing trend was reported with the treatments in the 25-125g (seed size)

category of tubers and the significantly highest seed tubers were recorded in S5-Flat bed triple row 90 cm bed length (three rows 20 cm plant to plant spacing) 581 thousand tuber number and 31.93 t/ha seed size tuber yield. Significantly higher seed size tubers were reported in 80 days of haulm killing by number (507000/ha) and weight (28.92 t/ha). A similar trend was reported for total tuber number and weight. Non-significant differences were reported for seed size (25-125g) tuber % among spacing combinations and haulm killing days in number, but the highest was reported for S3 (61.30) fig 4 & 5. Non significantly higher tuber number % was recorded in 80 days' haulm killing (59.62) over 70 days haulm killing (56.64). But by weight, non significantly higher tuber weight% was recorded in S3 (67.18%) and 70 days' haulm killing days (66.07%). The trial was repeated and planted on 16/11/2022. All treatment combinations were replicated thrice in a split-plot design. The data on growth parameters is being recorded.

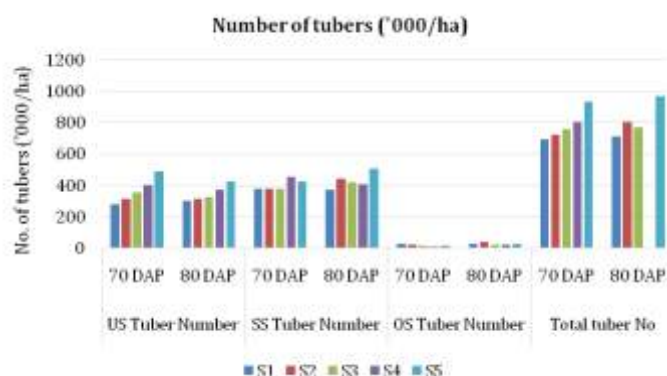


Fig. 4: Effect of different spacing combinations on number of tubers

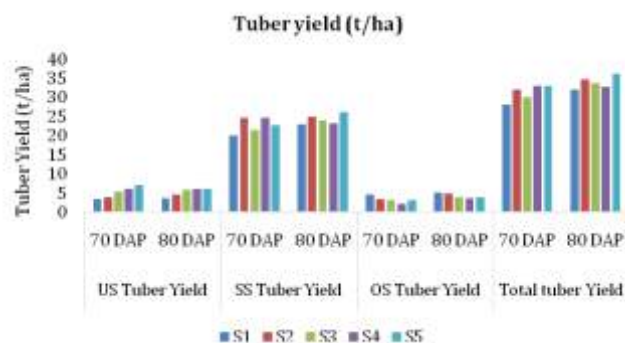


Fig. 5: Effect of different spacing combinations on total tuber yield

At Jalandhar, a study was conducted at ICAR-CPRS, Jalandhar, during 2021-22 to study the effect of different planting spacing and configurations, i.e., 60 cm x 20 cm (S1), 60 cm x 15 cm (S2), Paired two rows (S3) (30 x 20), Paired two rows (S4) (30 cm x 15 cm) and paired three rows (S5) (20 cm x 20 cm) and two haulm killing dates, i.e. 70 DAP and 80 DAP in Kufri Himalini variety. During the study, it was observed that flatbed paired rows (with three rows) resulted in the maximum total yield (t/ha) as well as total tuber number ('000/ha) with dehaulming at 80 DAP. The highest number and yield of seed-size tubers were also recorded in paired row planting with three rows when dehaulming was done at 80 DAP. The trial was planted on 09/10/2022. All treatment combinations were replicated thrice in a split-plot design. The data on growth parameters is being recorded.

2. Studies on the degeneration of potato seeds of different varieties under changing climate scenarios

At Gwalior, the experiment was conducted with 7 varieties viz V1.-K. Chandramukhi (Early), V2.-K. Lauvkar (Early), V3.-K. Surya (Early), V4.-K. Jyoti (Medium), V5.-K. Chipsona-1 (Mid-late), V6.-K. Chipsona – 3 (Mid-late) and V7.-K. Sindhuri (late) and 3 seed type viz S1.- Fresh breeder seed used as control every year, S2.- Carry over breeder seed 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. Carry over breeder seed in which no roguing and plant protection measures are raised in this treatment and the seed will be carried forward for next year. The experiment was replicated three times with a split plot design. A significantly

higher emergence % was recorded in fresh breeder seed (94.15) over COSPT (92.72) and COWSPT (92.89) seed types. Non-significant differences were reported for varieties for emergence. Fresh breeder seed (648000 and 33.50t/ha) reported significantly higher total tuber number and weight, followed by CO SPT (621000 and 30.71t/ha) over COWSPT (51900 and 26.33 t/ha). Variability was recorded for the number and weight of tuber/ha. Among varieties, Kufri Sindhuri (913000 and 31.97) recorded significantly the highest total number and weight of tuber and the least was in Kufri Lauvkar (455000 and 28.0 t/ha). The trial was carried out in 2022 and planted for the third year as per methodology with 7 varieties and 3 seed types. Data on growth vectors and health parameters are being recorded.

3. Effect of crop duration on the production behavior of potato cultivars of hills

At Fagu, to confirm last year's findings, the experiment on the production behavior of popular and new potato cultivars of hills viz. Kufri Jyoti, Kufri Himalini, Kufri Karan and Kufri Girdhari with three crop durations viz. 100, 120 and 140 days were repeated during Kharif 2022 at Fagu in RBD (2f) using three replications. Planting was done on 29th April and haulms were cut as per the crop durations. Among the cultivars, the average yield was maximum in Kufri Himalini, followed by Kufri Jyoti and minimum in Kufri Karan (Table 4). Yield in Kufri Jyoti and Kufri Himalini was found to be maximum after 120 days of planting and in Kufri Karan and Kufri Girdhari after 140 days. This may be due to the fact that some losses have occurred beyond 120 days on account of tuber rotting due to late blight in both these cultivars,

whereas; the maximum yield after 140 days in Kufri Karan and Kufri Girdhari is due to their high resistance against late blight. The proportion of undersized (<20g) and oversize (>120g) tubers were also affected significantly by the varying crop durations as well as genotypes. Among the cultivars Kufri Jyoti and Kufri Himalini had the maximum proportion of oversize tubers (about 17%) and a minimum number of undersized tubers. In contrast, Kufri Girdhari had maximum undersized tubers (about 30%) and minimum oversize tubers (about 8.0%). The cultivar affected

the proportion of seed-size tubers (20-80g), not crop duration. Seed size tubers were almost similar in three potato cultivars except for K. Himalini, which had a minimum proportion of seed size tubers (38.5%). The results conform to the last year's findings. From the results, it can be concluded that for obtaining maximum yields, the crop duration in Kufri Jyoti and Kufri Himalini should be 120 days and for Kufri Karan and Kufri Girdhari, the optimum crop duration should be 140 days.

Table. 4 Effect of crop duration on production behavior of potato cultivars

	Total yield (q/ ha)				% Undersize (<20g) tubers			
	Crop duration			Mean	Crop duration			Mean
	100 days	120 days	140 days		100 days	120 days	140 days	
K. Jyoti	375.4	380.9	375.7	377.3	26.7	24.9	23.5	25.0
K. Himalini	391.2	398.3	395.7	395.0	24.2	21.7	18.7	21.5
K. Karan	356.2	359.8	371.9	362.6	29.1	28.1	24.5	27.2
K. Girdhari	357.7	366.5	389.7	371.3	33.4	29.7	25.1	29.4
Mean	370.1	376.4	383.2		28.3	26.1	22.9	
CD 0.05								
Cultivar (A)		8.9		1.9				
Crop duration (B)		7.7		1.6				
A x B		NS		NS				

4. Manipulation of seed tuber size in potato with foliar application of N fertilizer in seed potato production

An experiment was conducted with variety Kufri Mohan at Gwalior and Kufri Jyoti at Patna to manipulate seed tuber size in potatoes. A total of nine treatments *viz.* T1- Control RDF (50% basal N+ 50% top dressing at 25 DAP), T2- 50% basal N + 25% top dressing at 25 DAP, T3- 25% basal N + 25% top dressing at 25 DAP, T4- 50% basal N + 25% top dressing at 25 DAP+ one foliar spray @ 2% urea at 40 DAP, T5- 25% basal N + 25% top dressing at 25 DAP+ one foliar spray @ 2% urea at 40 DAP, T6- 50% basal N + 25% top dressing at 25 DAP + two foliar spray @ 2% urea at 40 & 55 DAP, T7- 25% basal N + 25% top dressing at 25 DAP + two foliar spray @ 2% urea at 40 & 55 DAP, T8- 50% basal N + three foliar spray @ 2% urea at 25, 40 & 55 DAP and T9- 25% basal N + three foliar spray @ 2% urea at 25, 40 & 55 DAP were tried with 3 replications in RBD design. Observations on the vegetative and yield-attributing aspects are being recorded at suitable intervals.

5. Effect of irrigation method, irrigation scheduling and mulching on seed tuber yield and quality (seed size distribution)

At Jalandhar, four irrigation scheduling strategies, *viz.*, furrow irrigations at IW: CPE 2.5 (M1), 2-week interval upto 70 DAP (M2), at 2-weeks interval upto 56 DAP (M3) and drip irrigation at 100% open pan evaporation rate (M4) were compared. Each scheduling strategy was further evaluated against two different rates of paddy straw mulching applications i.e. @ 2.5 t ha⁻¹ and 5.0 t ha⁻¹ and without mulch. Seed tuber (25-125 g) yield was significantly higher in drip irrigation @100 % OPE than others. Among furrow irrigations, early withdrawal at 56 DAP resulted in the highest seed yield followed by IW: CPE 2.5 and the least in irrigation up to 70 DAP. The number of oversized tubers was the least in early irrigation withdrawal (M3), followed by drip treatment. Under each irrigation scheduling strategy, application of paddy straw mulch @ 5 t ha⁻¹ resulted in higher total tuber numbers than the control (without mulch), and in the case of M1 (IW: CPE 2.5), the above difference was significant (Fig 7 & 8).



a



b

Fig. 6: Experimental seed potato crop under drip (a) and (b) furrow irrigation systems (25 DAP)

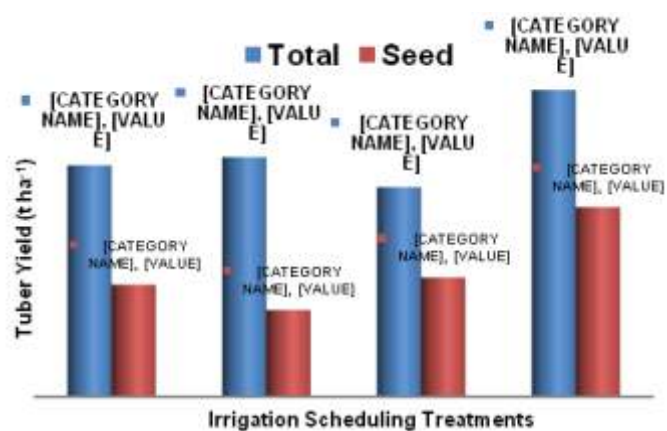


Fig. 7: Total and seed-grade tuber yields under various irrigation scheduling treatments

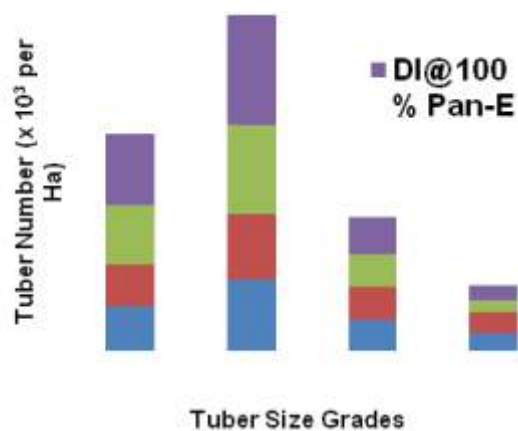


Fig. 8: Tuber size distribution under various irrigation scheduling treatments



DIVISION OF CROP PRODUCTION

PROGRAMME: VULNERABILITY AND RESILIENCE TO CLIMATE CHANGE FOR SUSTAINABLE POTATO PRODUCTION

Climate change and agriculture are highly correlated and a slight change in climatic parameters affects the agriculture production drastically. It is reported that climate change impact on agriculture leads to 1.5% loss in India's GDP. Potato crop is highly vulnerable to climatic parameters, particularly temperature, relative humidity as well as extreme events. The research work initiated on climate change in the Institute focused on its impact on potato productivity and to develop sustainable adaptation strategies to reduce the impact. The progress report presented herein includes the research work carried out during 2022 under the programme “Vulnerability and resilience to climate change for sustainable potato production” (initiated from April, 2021).

Project-I: Climate change impact assessment and devising suitable adaptation strategies for potatoes

Implementation of modelling and GIS tools (Drs V.K. Dua, Paresh Chaukhande, Anil K. Chaudhary, Jagdev Sharma)

The potato tuber yield is likely to be impacted negatively under the future climate scenario. However, with proper adaptation strategy, the loss may be minimized or even a gain may also be achieved. A simulation study was carried out for West Bengal using INFOCROP - Potato model to develop adaptation strategies i.e. the agronomic practices, in order to minimize/offset the negative impact of climate change on potato. For this study, five districts of West Bengal were

selected (Bankura, Hooghly, Jalpaiguri, Malda and Midnapur), three potato varieties were used; Kufri Badshah (Long duration), Kufri Jyoti (Medium duration) and Kufri Pukhraj (Early bulking). The simulation was done for two climatic scenarios; RCP 4.5 and RCP 6.0 of IPCC AR5, for three time slices (2030s, 2050s and 2080s).

Under RCP 4.5, scenario the mean tuber yield for Kufri Jyoti, across the location, is likely to reduce by 7.5, 10.4 and 13.3% under farmer's practice (50 mm irrigation at 8 days interval and 200 kg N/ha in two equal splits at 0 and 26 days after planting) during 2030, 2050 and 2080 future climate scenario of temperature and CO₂ fertilization, respectively (Fig. 1). Similar values were 8.6, 11.7 and 13.7% for Kufri Badshah and 7.6, 11.2 and 13.2% for Kufri Pukhraj, respectively. The simulation study has shown that by adapting a simple agronomic practice of reducing the irrigation interval from 8 days to 5 days i.e. increased frequency by 60% alone can reverse the negative impact to the positive over the baseline year (2000). It is expected that this agronomic practice (50 mm irrigation at 5 days interval and 200 kg N/ha in two equal splits at 0 and 26 days after planting) might increase the yield of Kufri Jyoti by 5.3, 3.8 and 2.3% during 2030, 2050 and 2080, respectively, over the baseline. The corresponding figures for Kufri Badshah are; 5.3, 2.6 and 1.0% and for Kufri Pukhraj are; 6.3, 5.0 and 3.1%, respectively (Fig. 1).

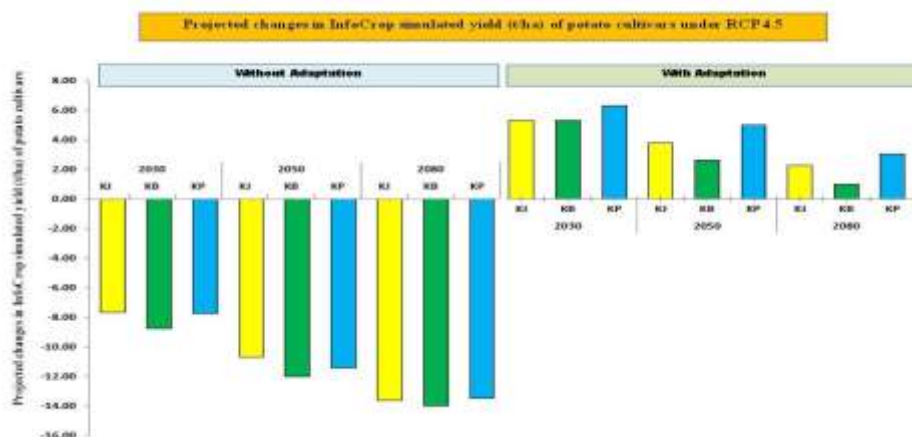


Fig. 1: Projected changes in InfoCrop simulated yield (t/ha) of potato cultivars under RCP 4.5 West Bengal without adaptation i.e. farmers' practice (50 mm irrigation at 8 days interval & 200 kg N/ha in two equal splits at 0 and 26 days after planting) & with adaptation (reducing irrigation interval from 8 days to 5 days, & 200 kg N/ha in two equal splits at 0 and 26 days after planting). [Note: KJ: Kufri Jyoti; KB: Kufri Bahar; KP: Kufri Pukhraj]

The simulation study carried out for RCP 6.0 shows that under the farmer's practice (50 mm irrigation at 8 days interval and 200 kg N/ha in two equal splits at 0 and 26 days after planting), as described above, the yield of Kufri Jyoti is likely to reduce by 8.0, 7.1 and 8.3% during 2030, 2050 and 2080, respectively, over the baseline (Fig. 2). Similarly, during these 3 timeframe-slices, the yield of Kufri Badshah is likely to reduce by 9.3, 8.1 and 8.9% and of Kufri Pukhraj by 8.5, 7.3 and 7.9%. Like RCP 4.5, the adaptation strategy of increasing irrigation frequency by 60% is also likely to impact the potato productivity in positive way under RCP 6.0 for all the 3 varieties and 3 climatic scenarios. A simple adaptation in case of irrigation to be given at 5 days interval (50 mm

irrigation at 5 days interval and 200 kg N/ha in two equal splits at 0 and 26 days after planting) against the farmer's practice of 8 days interval (50 mm irrigation at 8 days interval and 200 kg N/ha in two equal splits at 0 and 26 days after planting) has shown to increase the yield of Kufri Jyoti by 5.2, 6.8 and 6.6%, across the location, during 2030, 2050 and 2080, respectively, over the baseline. The corresponding figures for the Kufri Badshah are; 5.5, 6.4 and 5.84 and for Kufri Pukhraj; 5.6, 7.9 and 7.6%. overall, the simulation studies have shown that employing/ adjusting agronomic practices can lead to adaptation against climate change to a greater extent, thus, minimizing the losses in yield and sustaining the productivity.

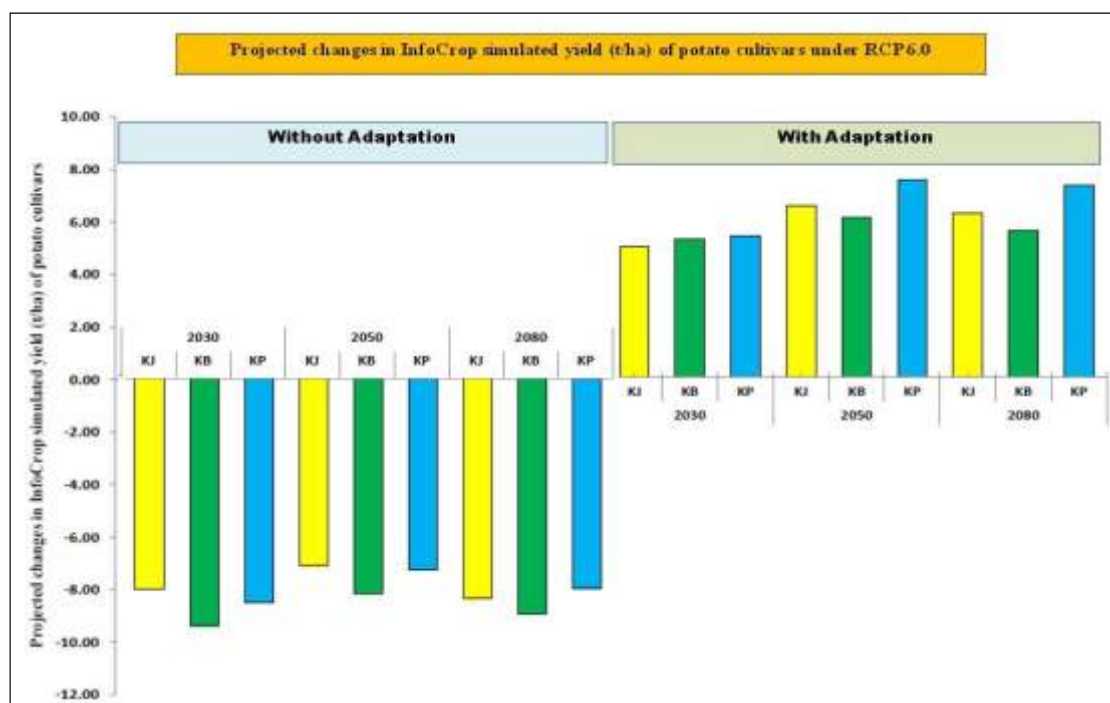


Fig. 2: Projected changes in InfoCrop simulated yield (t/ha) of potato cultivars under RCP 6.0 in West Bengal without adaptation i.e. farmers' practice (50 mm irrigation at 8 days interval & 200 kg N/ha in two equal splits at 0 and 26 days after planting) & with adaptation (reducing irrigation interval from 8 days to 5 days, & 200 kg N/ha in two equal splits at 0 and 26 days after planting). [Note: KJ: Kufri Jyoti; KB: Kufri Bahar; KP: Kufri Pukhraj].

Project-II: Carbon fraction dynamic and Budgeting under elevated CO₂ and temperature (PI: Dr. Anil Sharma)

In order to study the impact of elevated temperature on tuber yield and soil organic carbon status and to suggest management option to reduce the impact of elevated temperature a study was carried out in OTCs at CPRI RS Jalandhar. It was observed that tuber yield decreased with temperature elevation of 3°C (approx.). The decrease was statistically non-significant in case of paddy straw incorporation

but the same was significant in case of vermicompost application (Fig. 3). The extent of decrease in tuber yield due to temperature elevation was less in soils where paddy straw was incorporated (-5.72%) compared to vermicompost application (-9.46%) and no amendment (-13.02%). So far as soil organic carbon is concerned it was observed that under elevated temperature scenario the soil organic carbon decreased in all the three amendments, but this decrease was less in case of paddy straw incorporation (Fig. 4).

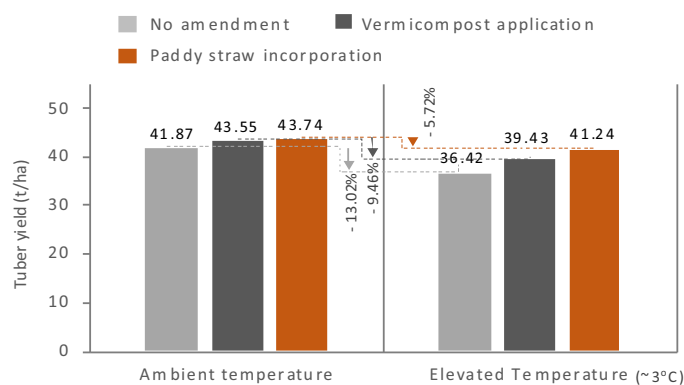


Fig. 3: Tuber yield as influenced by different amendments under elevated temperature

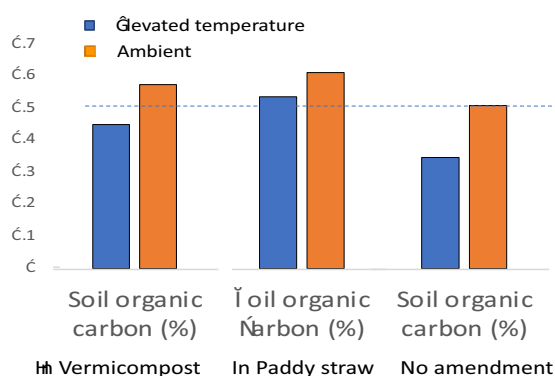


Fig. 4: Extent of decrease in soil organic carbon as influenced by different amendments under elevated temperature

Project-III. Carbon footprint estimation of potato production under different agro-ecological zones

(Drs. Anil K. Choudhary, VK Dua, Jagdev Sharma)

Carbon footprint estimation of potato production under different agro-ecological zones was studied and it was observed that the integrated crop management (ICM) in Himachal Pradesh resulted in slightly higher carbon footprints (0.08 kg CE kg⁻¹ fresh potato tuber yield) compared to farmers' practice (FP) (0.069 kg CE kg⁻¹ fresh potato tuber yield) due to higher carbon inputs used in balanced plant nutrition, crop management and plant protection measures under ICM (Fig. 5). The ICM technology imbedded with improved potato varieties like Kufri Shailja and Kufri Giriraj; had higher productivity (27.8%) compared to FP. Total carbon output under ICM was ~31.3% higher over FP, indicating that ICM adoption may be a possible mitigation strategy to climate change. Overall, ICM is a better option over FP w.r.t. potato productivity and carbon output in diverse potato production systems of wet-temperate NW Himalayas.

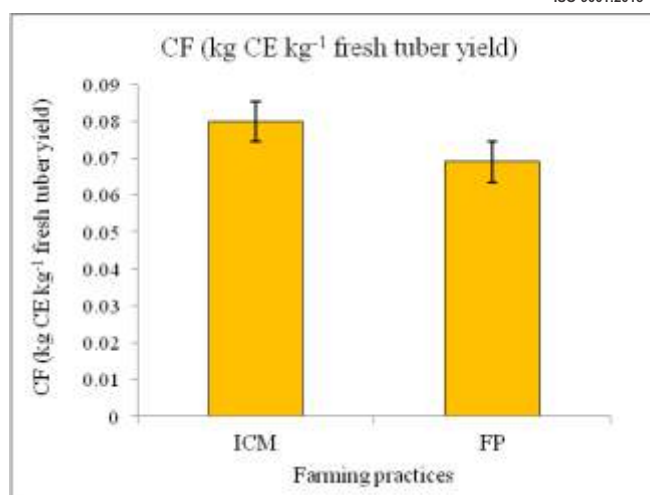


Fig. 5: Carbon footprints for potato production in wet-temperate region of Himachal Pradesh. [Note: ICM; Sowing time: March-April; Sowing method: In furrows (50×20 cm); seed rate: 2.5 t/ha; FYM @ 20 t/ha; NPK @ 120:80:60 kg/ha; Weed management: Isoproturon 75WP @ 1.0 kg a.i./ha or Oxiflorfen (Goal 23.5 EC) @ 0.5 kg a.i./ha + two hand-weeding & earthing-up at 30 & 50 DAP; Pest management (White grub): Furadan 3 G @ 2.5 kg/ha; Disease management (Late blight): Two sprays of Redomil MZ-72 WP or Metamyl 0.25% at 15 days interval followed by 4 sprays of Indofil M-45 @ 0.25% at weekly interval). FP; Sowing time: March-April; Sowing method: In furrows (50×20 cm); seed rate: 2.0 t/ha; FYM @ 10 t/ha; NPK @ 60:60:30 kg/ha; Weed management: One hand-weeding + earthing-up at 40-45 DAP; Pest management (White grub): None; Disease management (Late blight): Use of non recommended fungicides 2 sprays].

Project-IV: Impact of climate change on black scurf and early blight disease (PI: Dr. Mehi Lal)

Effect on early blight severity on different level of resistance cultivars at different dates of planting was studied. This experiment was conducted using two sets of varieties (Resistant/moderately resistant and susceptible). In resistant group (Kufri Sindhuri, K. Pukhraj & K. Khyati) and susceptible (Kufri Chandramukhi, K. Lavkar & K. Deva) were planted during Rabi season 2021-22 to know how these varieties would behave against *Alternaria* spp under different environmental condition. In this context, three dates of planting (17 Oct, 2 Nov and 17 Nov, 2021) were done at 15 days interval. On 17 Oct, 2021 date of planting, under susceptible group highest AUDPC (Area Under Disease Progress Curve) was recorded on cv. K. Lavkar (1288.3) followed by K. Chandramukhi (125.3) and under resistant group highest AUDPC was on cv K. Khyati (94.3) followed by K. Sindhuri (40.0) and K. Pukhraj (21.8) Fig 1. On 2 Nov date of planting, highest

disease severity was recorded on K. Lavkar (6.5% DS) and K. Chandramukhi (3.5% DS). Effect on black scurf disease incidence on different level of resistance cultivars at different dates of planting was also studied. In this experiment, two sets of varieties (Resistant and susceptible) were evaluated to know behaviour against *Rhizoctonia solani* at three dates of planting (17 Oct, 2 Nov and 17 Nov, 2021) were done at 15 days interval. In resistant group (Kufri Sherpa & K. Deva) and susceptible (Kufri Sindhuri & Atlantic) were selected. Result revealed that on 2 Nov planting maximum disease incidence of black scurf was recorded on both the sets of varieties i.e. Kufri Sindhuri (28.89% DI), K. Deva (22.11% DI); except Atlantic and Kufri Sherpa. These two varieties recorded maximum disease incidence (Atlantic- 28.89% DI, Kufri Sherpa-22.96% DI) on 17 Nov date of planting. While on 17 Oct, lowest disease incidence of black scurf was recorded (Fig. 6). Date of planting and varieties have statistically significant while their interaction was non-significant

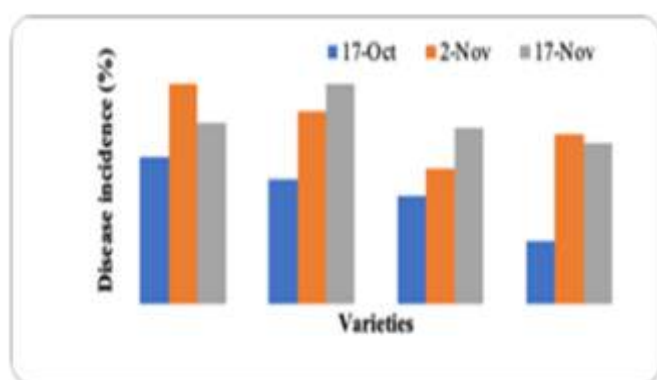


Fig. 6: Impact on black scurf disease incidence on different sets of varieties at 17 Oct, 2 Nov and 17 Nov date of planting [CD (p0.05) DOP: 3.76, Variety: 4.34, DOPxVariety: NS]

Project-V: Biology and management of potato insect pests under climate change (PI: Dr. Subhash S)

The population of aphids, whiteflies and leafhoppers were monitored at weekly interval in unsprayed potato fields in the early planted (DOP- Sep 25th; K. Pukhraj) and main crop (DOP- Nov 3rd; K. Bahar) at Modipuram. It was observed that in the early crop, aphids first

appeared on the potato plants in the 2nd week of October and in the main crop 3rd week of November. The results further showed that, 3rd week of November to 2nd week of December would be the critical time period for aphid management. Favorable temperature for population buildup of aphids is 20 to 26°C (Fig. 7). In both the early and main crop, the population of whitefly showed a general decline in population over time which begun high initially. The interactive effect of host plant age and temperature is playing a role in the buildup of whiteflies population and whiteflies population can buildup in the temperature ranges from 20 to 33°C (Fig. 8). In the early crop, the population of leafhoppers was very high with steady increase throughout the crop growth whereas the population on main crop was very low (Fig. 9). The population buildup of leafhoppers was temperature dependent. Favorable temperature for population buildup of leafhoppers was 23 to 28°C with relative humidity 92%. Effect of sowing dates on incidence of aphids, whiteflies and leaf hoppers in unsprayed potato crop showed that there was no statistically significant difference in the incidence of aphids, whiteflies and leafhoppers among different sowing dates however there is a huge variation in the mean population densities among different sowing dates. The results further showed that, higher incidence of whiteflies and aphids on the crop sowed during September and high occurrence of leafhoppers on both September and October sowed crop. From management perspective, it is necessary to do seed treatment and application of insecticides after emergence of crop in the September planted crop.

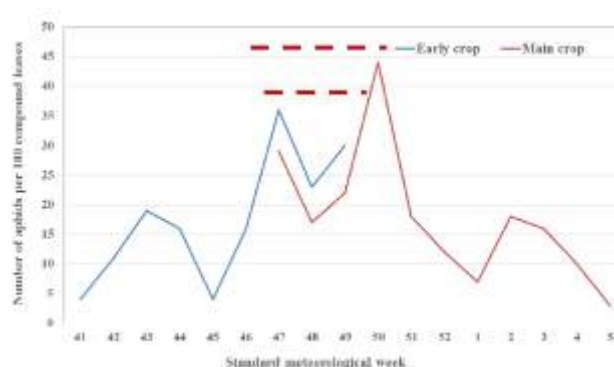


Fig. 7: The population of aphids per 100 compound leaves observed in early planted and main potato crop at different standard meteorological week during rabi crop 2021-22 at Modipuram

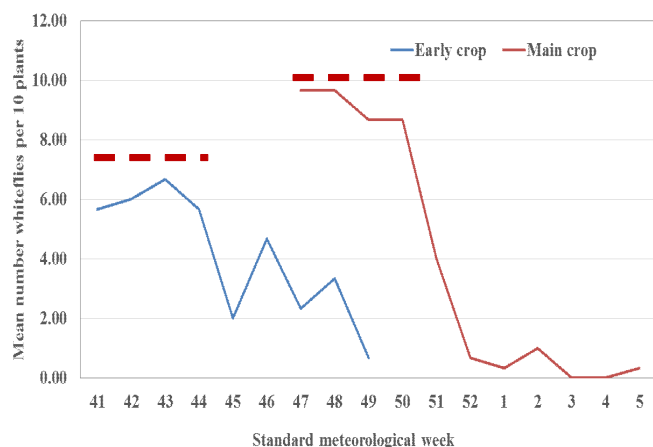


Fig. 8: The population of whiteflies per 10 plants observed in early planted and main potato crop at different standard meteorological week during rabi crop 2021-22 at Modipuram

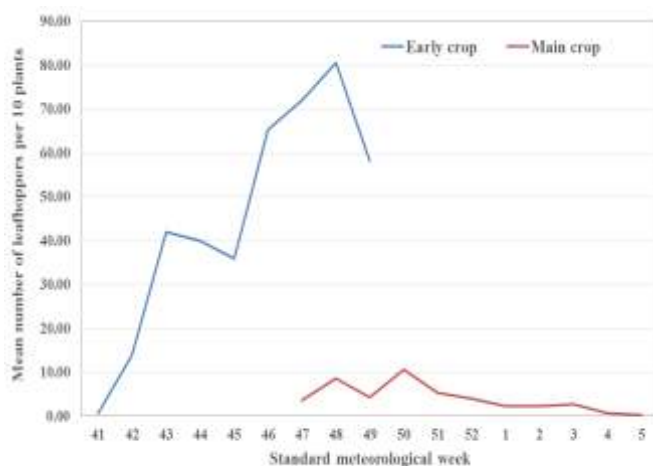


Fig. 9: The population of leafhoppers per 10 plants observed in early planted and main potato crop at different standard meteorological week during rabi crop 2021-22 at Modipuram

Project-VI: Evaluating Aquacrop simulation model for forecasting the potato productivity under changing climatic conditions (PI: Dr. S. Saha)

Experiments were laid down to generate data for calibrating & validating Aquacrop simulation model for determining crop water productivity under changing climatic conditions. It was observed that tuber Yield at harvest increased with water application rate from 50 to 150% of E_{Tref} under both mulch and no mulch condition. Paddy straw mulching (@ 5 t ha⁻¹) lead to maximum increase in tuber yield under most water-limited environment (28.3% higher) whereas under non-limiting water condition, yield gain was only 4.3%. Among the dynamic plant parameters, plant height under paddy straw mulch treatment was significantly higher ($p < 0.05$) as compared to control during early as well as late tuber bulking phases. Periodic tuber growth from early bulking stage to haulm cutting, showed consistently higher values under mulch across water application gradient.

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

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

Nutrient management using crops, organic and inorganic sources of fertility and micro irrigation methods: The field experiment was laid out at Modipuram during 2021-22 to study the effect of different nutrients management options using crops of green manure and pulses, organic & inorganic sources of nutrition under drip, sprinkler and conventional furrow irrigation methods for enhancing water and nutrient use efficiency. Potato (cv. Kufri Bahar) was taken up in autumn season and each treatment was

replicated four times in split plot design. The results revealed that drip irrigation gave maximum tuber yield (32.1 t/ha) and tuber numbers (656 000/ha) against furrow irrigation attaining tuber yield (27.8 t/ha) and numbers (653 000/ha). Sprinkler irrigation was found intermediate in category having tuber yields of 29.0 t/ha. Nutrition (100% NPK) recorded highest tuber yields under drip (37.6 t/ha), sprinkler (35.7 t/ha) and furrow (34.0 t/ha) in comparison to other fertility levels. Similar trend was also noticed in case of medium size tuber yields. Recommended 100% NPK dose had higher mean tuber yield (35.9 t/ha) than other treatments across all irrigation methods (Table 1).

Table 1: Effect of irrigation methods & nutrient management options on potato (Modipuram)

Treatments	Tuber yield (t/ha)				Number of tubers (000/ha)			
	Drip	Sprinkler	Furrow	Mean	Drip	Sprinkler	Furrow	Mean
100 % NPK	37.6	34.6	35.7	35.9	760	696	625	693
75 % NPK +Pulse	32.9	31.1	30.6	31.5	662	644	588	631
75 % NPK+GM	35.4	32.1	33.0	33.5	699	653	619	657
50 % NPK+15 t FYM/ha	37.6	30.9	25.8	31.4	631	703	595	643
15 t FYM/ha +CR+BF	17.1	16.3	13.8	15.7	517	584	547	549
Mean	32.1	29.1	27.8	-	654	656	595	-
CD _{0.05}	I=1.2	F=1.6	I X F=NS		I=36	F=46	I X F=NS	

In another trial at Modipuram during 2021-22, an attempt was made to economize irrigation water and N nutrition through agronomic manipulations in potato crop for developing low cost production technology. Variety Kufri Bahar was taken up and each treatment was replicated four times in a randomized block design. The spray of urea was done @2% as per treatments at different crop growth stages. Application of 180 kg N/ha and recommended irrigations (TWA 334 mm) produced significantly higher tuber yield (36.9 t/ha) and numbers (998 000/ha) followed by tuber yield (34.4 t/ha) and numbers (889 000/ha), respectively when irrigations was applied at critical stages of crop (284 mm water) and nutrition of 15 t FYM+ 180 kg N/ha thus saving 26% of irrigation water.

Optimizing macro-nutrient and water requirement of variety Kufri Thar-3: A field study was conducted in split plot design to work out the water and NPK requirement of potato cv. Kufri Thar-3 at Modipuram. Treatments replicated four times were three main plots (irrigation levels: I₁= 20 mm CPE, I₂= 25 mm CPE & I₃= 30 mm CPE) and five sub-plots (nutrients: F₁= 100% NPK, F₂= 75% N+ 100% PK, F₃= 75% P+ 100% NK, F₄= 75% K+ 100% NP, F₅= 75% recommended NPK as control). Irrigation at 20 mm CPE produced significantly higher tuber yield (29.9 t/ha) and numbers (902 000/ha) which were at par with treatment of 25 mm CPE (29.4 t/ha). Similar trend was noticed at all NPK levels. Nutrient dose of 100% NPK recorded higher tuber yield (30.5 t/ha) and numbers (961 000/ha) remaining comparable to treatment 75% P+100% NK (30.2 t/ha). Tuber numbers also followed similar trend (Fig. 1).

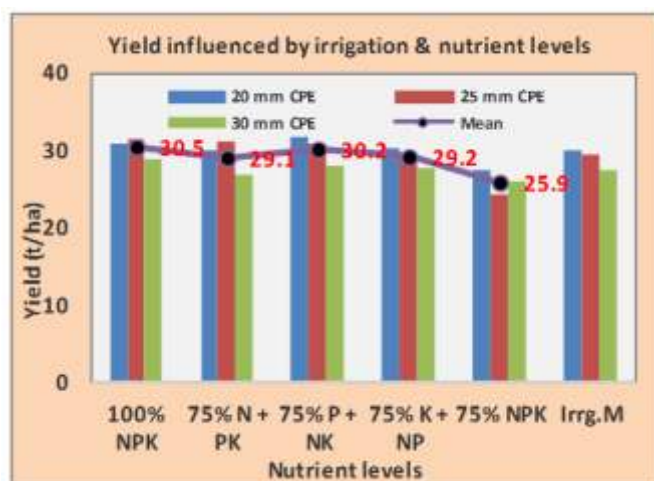


Fig.10: Effect of irrigation and nutrient levels on potato crop at Modipuram

At Gwalior, maximum tuber yield (32.2 t/ha) of Kufri Jyoti was obtained with application of 75% RDF NPK along with *Sesbania* spp. green manuring followed by 50% RDF NPK+15 t FYM/ha (32.0 t/ha) and 100% RDF NPK (31 t/ha). Similar trend was observed for tuber numbers as 75% RDF NPK and green manuring of *Sesbania* spp. produced highest tuber numbers (440 000/ha) followed by 50% RDF NPK+15 t FYM/ha (415 000/ha) and 100% RDF NPK (415 000/ha). In case of irrigation, the highest tuber yield (30.9 t/ha) and numbers (422 000/ha) were obtained with drip irrigation method followed by sprinkler irrigation method (30.3 t/ha and 405 000/ha) and subsequently furrow irrigation (28.6 t/ha and 383 000/ha, respectively). Similar trend was also noticed in case of marketable tuber yields. Drip irrigation recorded highest water-use efficiency (91 kg/ha-mm) followed by sprinkler irrigation which recorded 86 kg/ha-mm in Kufri Jyoti (Fig. 11). Among fertility treatments, highest

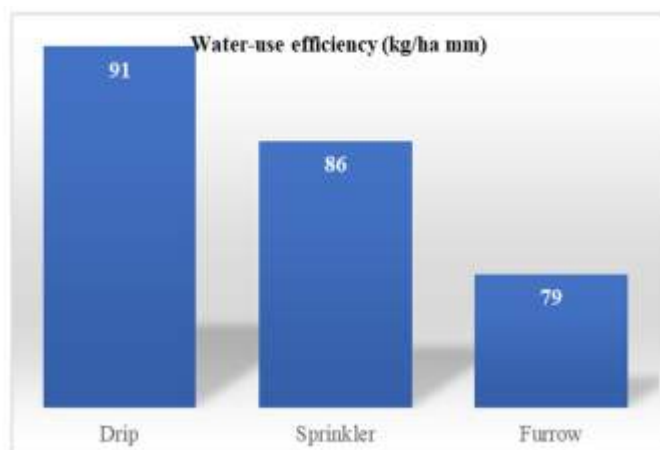


Fig. 11: Variation in WUE among different irrigation sources at Gwalior

water use efficiency (92.4 kg/ha-mm) was recorded with *Sesbania* spp.- potato (75% RDF NPK). Highest N (69 kg/ha), P (14 kg/ha) and K (109 kg/ha) uptake in tuber was recorded under drip irrigation method (Fig. 12). Highest N (72kg/ha), P (15 kg/ha) and K (114 kg/ha) uptake in tuber was recorded with *Sesbania* spp.- potato (75% RDF NPK).

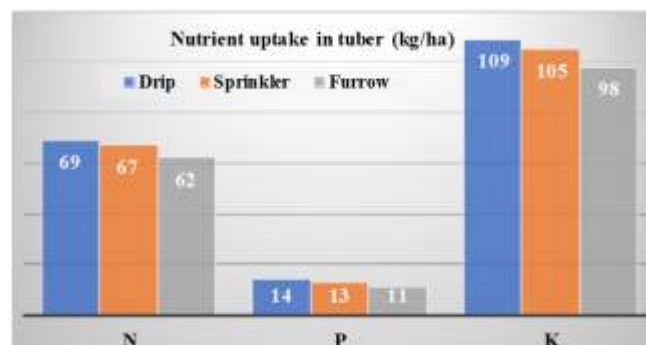


Fig. 12: Variation in nutrient uptake among different irrigation sources at Gwalior

Assessment of consumptive water use pattern and exploring water efficient technologies for potato under changing hydro-climatic regimes (PI: Dr. Sunayan Saha)

Improving water-use efficiency for potato crop:

A field experiment was conducted in split plot design with 4 replications at Jalandhar during 2021-22 to assess different irrigation scheduling strategies as main plot (M1: drip irrigations at 50% of ETref rates; M2: crop-stage adjusted variable rate drip irrigation on 100 % ETref; M3: 100% of ETref rates and M4: 150% of ETref rates); foliar sprays of various chemicals (Thiourea @ 400 ppm; KNO₃ @ 10 g/l and Salicylic acid @ 10 µM/l) at critical stages of 25, 40 and 60 days, and paddy straw mulching @ 5 t/ha in enhancing yield or tuber quality of table potato cv. *Kufri Jyoti* at recommended fertilizer dose of 240 N+ 100 P₂O₅+ 150 K₂O Kg/ha. Irrigation schedule was implemented after crop establishment and the total amount of water received under various treatments that includes effective rainfall too were 158 mm, 190 mm, 194 mm and 228 mm, in M1, M2, M3 and M4, respectively.

Amongst the four irrigation scheduling strategies, mean values of total as well as marketable tuber yields were highest in M4 (32.6 and 30.5 t/ha, respectively) which was closely followed by M2 (32.2 and 29.9 t/ha). The above yields were

lowest in M1 (30.5 and 27.9 t/ha) (Fig. 13). However, the above differences were statistically non-significant ($p < 0.05$). In contrast to yield, mean value of water use efficiency (WUE) was the highest in M1 *i.e.* lowest water application and decreased as the amount of water application increased. Overall, salicylic acid (184 kg/ha-mm) and thio-urea (182 kg/ha-mm) applications resulted in higher WUE compared to control *i.e.* no application of mulch or any chemical spray (170 kg/ha-mm) or KNO₃ or paddy mulch treatments. With regard to total tuber yields under the least water treatment (M1), application of thio-urea (31.4 t/ha) and salicylic acid (31.4

t/ha) improved the tuber yield slightly compared to control (30 t/ha). Whereas for marketable tuber (>25 g) yields, thio-urea (28.8 t/ha), KNO₃ (27.5 t/ha), salicylic acid (29.0 t/ha) and paddy mulch application (27.5 t/ha) resulted in better yields than control (26.8 t/ha) (Fig. 14). Foliar sprays of the chemicals or paddy mulch cover did not improve the yield /WUE significantly during this harvest season. However, percentage of cracked tubers within marketable category (>25 g) was lowest in minimal water application (M1: 6.6%) and highest in maximum water application (M4: 16.9%) and these two were significantly different ($p < 0.01$).

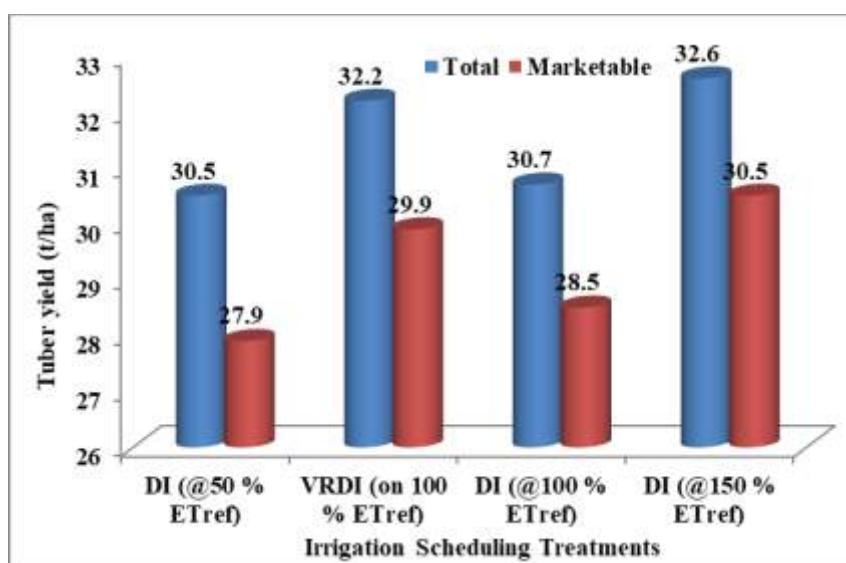


Fig. 13: Total and marketable tuber yield under various irrigation scheduling regimes

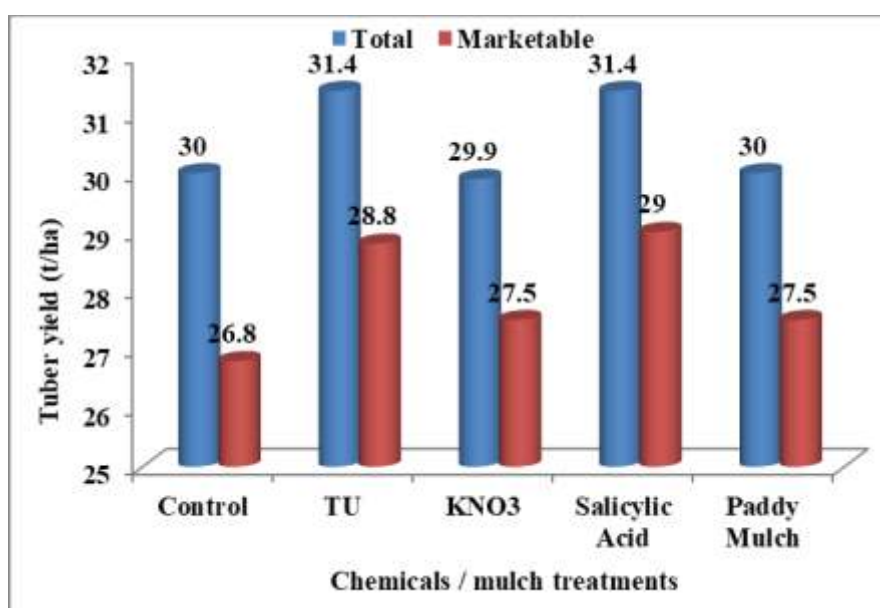


Fig. 14: Total and marketable tuber yield in response to various chemicals and paddy straw mulch application under limited irrigation

At Gwalior, performance of Kufri Jyoti was assessed under four irrigation scheduling strategies (I1: drip irrigations at 50%, I2: 75% and I4: 100% of ET_{ref} rates and I3: crop-stage adjusted variable rate drip irrigation on 100% ET_{ref}) along with foliar sprays of various chemicals (Thio-Urea @ 400 ppm, KNO₃ @ 10 g/l and Salicylic acid @ 10 µM/l) at critical stages of 25, 40 and 60 days and paddy straw mulching @ 5 t/ha at planting. Total tuber yield was maximum in I4 remaining significantly higher than that of I1 as well as I3 treatment. Paddy straw mulching resulted in significantly higher tuber yield as compared to control and yield under three different chemical applications. Maximum WUE was observed in lowest water application (I1) and minimum in case of 100 % ET_{ref} (I4), which was also significantly different ($p < 0.05$). There was no significant difference in WUE between scheduling at 75% ET_{ref} (I2) and VRDI (I3). Paddy straw mulching had significant positive impact in enhancing WUE over control as well as to other tested chemicals.

Soil management for improving nutrient availability in low pH soil (Drs. Divya K Lekshmanan, P Janani, Priyank Mhatre, Jagdev Sharma, Anil K. Choudhary)

Effect of biochar on yield improvement in Potato: A pot experiment was conducted to investigate the effect of bamboo biochar on growth and yield of potato in acidic soil of Meghalaya. The treatments included five levels of biochar; 0, 5, 10, 15 and 20 t ha⁻¹ as well as two levels of RDF (NP₂O₅K₂O); 0 and 140:120:60 kg/ha. The application of biochar and RDF significantly increased plant growth compared to the control and biochar alone. With the addition of biochar, the yield of potato tubers significantly increased (Table 2). The lowest yield (46.08 g plant⁻¹) was recorded in the untreated control whereas Biochar 20 t ha⁻¹ + RDF recorded the highest tuber yield (202.80 g plant⁻¹). RDF application along with biochar-amended treatments increased tuber yield by 30.57% when compared to the biochar-amended treatments alone. Biochar application increased soil pH (5.5-5.7) compared to the no biochar application (4.7). The application of biochar as a soil amendment enhances plant growth and potato under the acidic soil of Meghalaya.

Table 2: Tuber yield as influenced by the doses of Biochar

Treatments	Treatment details	Tuber yield (g/plant)
T ₁	Control	46.08 ^e
T ₂	Biochar 5 t ha ⁻¹	125.26 ^d
T ₃	Biochar 5 t ha ⁻¹ + RDF	161.96 ^{bc}
T ₄	Biochar 10 t ha ⁻¹	134.83 ^d
T ₅	Biochar 10 t ha ⁻¹ + RDF	169.13 ^{bc}
T ₆	Biochar 15 t ha ⁻¹	136.22 ^d
T ₇	Biochar 15 t ha ⁻¹ + RDF	177.13 ^b
T ₈	Biochar 20 t ha ⁻¹	148.22 ^{cd}
T ₉	Biochar 20 t ha ⁻¹ + RDF	202.80 ^a

Effect of button spent mushroom substrate (SMS) on yield of potato

In a field experiment at Shillong in 2022, the effect of button-spent mushroom substrate (SMS) on potato growth and production was examined (summer season). The SMS collected from the Mushroom Development Centre, Upper Shillong, was used as manure. SMS was decomposed by natural weathering processes in pits for 3 (SMS3) and 6 months (SMS6). Treatments including naturally composted SMS of different ages (3 and 6 months old) added @ 2.0 kg/m² along with RDF) were compared with recommended doses of fertilizers (N:P₂O₅:K₂O @ 140:120:60 kg/ha) + 15 t FYM per ha. The manures used in the study varied in their nutrient content. Naturally weathered SMS3 contained 1.82% N, 0.86% P and 1.37% K, SMS6 contained 2.48% N, 0.78% P and 1.89% K and FYM contained 0.55% N, 0.29% P and 0.61% K. Application of six-month-old naturally weathered SMS @ 20 t ha⁻¹ + RDF significantly improved potato vegetative growth and yield over the other treatments. The total and marketable tuber yield of potato was significantly higher in six-month-old naturally weathered (SMS6) SMS @ 20 t ha⁻¹ + RDF (22.02 and 14.59 t ha⁻¹) than FYM 15 t ha⁻¹ + RDF (14.98 and 9.50 t ha⁻¹) and absolute control (6.7 and 3.44 t ha⁻¹) (Fig. 15).

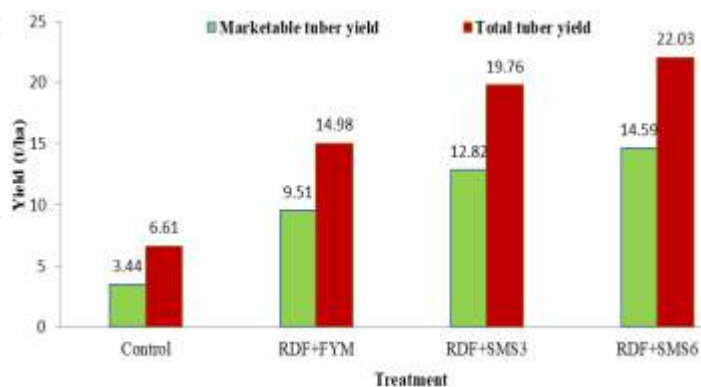


Fig. 15: Effect of spent mushroom substrate on potato production in acidic soil

Effect of biochar on potato cultivation in acidic soils: Biochar is a porous, carbonaceous material that is produced by pyrolysis of plant biomasses. Biochar addition has drawn remarkable consideration for soil improvements due to its enhanced soil fertility, nutrient immobilization and slow-release, carbon storage, which are some of the handful of benefits for soil amendments made with biochar. These enhanced properties are a result of the cumulative effects arising from the changes in the microbial activities in soils along with the agrochemical application. The effect of different doses of Biochar on growth and yield of potato variety, Kufri Sahyadri was studied at Ooty by conducting a pot experiment. Biochar was made from *Prosopis* sp. It contained 1.5% N, 1.06% P, 2.5% K with pH value 8.1. The treatments included six levels of Biochar viz., 0, 5, 10, 15, 20 and 30 t/ha were applied with and without RDF (90:130:90 kg NPK/ha) + FYM. The result showed that application of biochar significantly contributed to the potato yield (Table 3) and significant differences were observed between different treatments. The lowest yield was obtained in negative control. Application of Biochar 30t/ha along with RDF recorded highest tuber yield (379.72g /plant) and the yield increase over positive control was 24% respectively. This treatment was found on par with 20 t/ha biochar + RDF (352.18 g/plant) with an increase in yield of 38 % compared to negative control and 15% over positive control.

Table. 3: Effect of biochar on yield improvement in Potato

Treatments	Treatment Details	Tuber yield (g/ plant)
T ₁	Control (-ve control)	254.64 ^f
T ₂	RDF + FYM (+ve control)	305.34 ^{de}
T ₃	Biochar 5 t/ha	306.30 ^{de}
T ₄	Biochar 5 t/ha + RDF	318.90 ^{cde}
T ₅	Biochar 10 t/ha	335.09 ^{bcd}
T ₆	Biochar 10 t/ha + RDF	339.24 ^{bc}
T ₇	Biochar 20 t/ha	323.35 ^{bcd}
T ₈	Biochar 20 t/ha + RDF	352.18 ^{ab}
T ₉	Biochar 30 t/ha	291.89 ^c
T ₁₀	Biochar 30 t/ha + RDF	379.72 ^a

Effect of different doses of pressmud compost on yield improvement in Potato: It is used as a suitable fertilising agent since it is rich in micro and macro nutrients along with org-anic carbon. Pressmud is the compressed sugar industry waste produced from the filtration of the cane juice. The composition of raw press mud includes carbon, nitrogen, phosphorus, potash, calcium,

manganese, iron, silicon and wax. Press mud compost The composition varies significantly on the soil condition, cane varieties, period of supply of cane and geographical variation. A pot experiment was conducted to study the effect of different doses of sugarcane press mud compost on growth and yield of potato variety, Kufri Sahyadri in acidic soil of Ooty. The press-mud compost used for the study contained 1.9% N, 1.5% P and 1.83% K with a pH value of pH 6.1. Different levels of press mud compost tried were 0, 2.5, 5.0 and 10 t/ha and it was tried with and without recommended dose of fertilizer (90:130:90 kg NPK/ha). Significant difference was observed for the treatments studied and the results showed that application of press mud compost significantly improved the yield of potato cultivar Kufri Sahyadri (Fig. 16). Maximum tuber yield was obtained when press-mud was applied at 5t/ha (425.87 g /plant) and the lowest yield was obtained in untreated control.

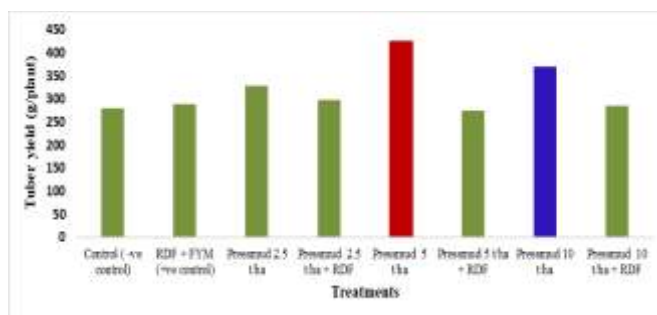


Fig. 16: Tuber yield as influenced by various doses of press mud levels

Developing sustainable strategies for improving P-use efficiency in potato (Drs. Jagdev Sharma, V.K. Dua, Manoj Kumar, Anil K. Choudhary, Anil Sharma, Prince Kumar, Janani P, Dharmendra Kumar)

Rice husk ash (RHA) is a primary agricultural product obtained from paddy. The husk is generally used as fuel in the rice mills to produce steam for boiling. This RHA may contain contains about 85–90% of amorphous silica. The chemical constituents include silica, calcium, magnesium, phosphorus, potassium, sodium, iron, carbon and small nitrogen. Amount of nutrients vary with the temperature and time which the husk is burnt. Being a rich source of silica its application has been reported to improve P uptake in rice okra and other crops. A pot experiment was also conducted to study the effect of RHA on plant growth. Application of RHA

significantly increased the above ground biomass (12.36%), plant height and root biomass (4.38%) significantly in a sand culture experiment (Fig. 17). Another experiment was conducted using graded doses of P at Jalandhar. Application of 20 ton RHA ha^{-1} significantly increased the tuber yield over control treatment (No P-application). Application of 20 t ha^{-1} RHA along with 75% P dose produced highest yield and it was significantly higher than 75% P alone treatment. Application of 20 t ha^{-1} RHA along with 50% P dose produced tuber yield equivalent to 100% P alone treatment (Fig. 18). The results revealed that rice husk improved the P use efficiency.



Fig. 17: Pot experiment to study the effect of RHA

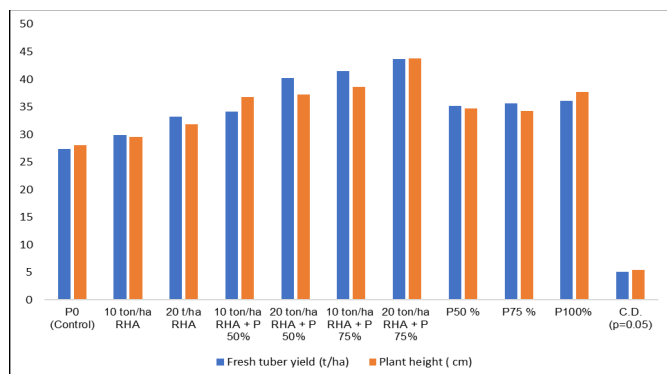


Fig. 18: Effect of RHA on tuber yield and plant height

In order to improve the productivity and P-use efficiency (PUE) in potato crop under Acid Alfisols, devising efficient P-management strategies with integration of soil applied P-fertilizers, biofertilizers and innovative approaches like foliar-P fertilization, may assume utmost importance. AM-fungi and PSB hold great potential in solubilization and mobilization of native and applied-P. Foliar P-fertilization has also shown positive influence on crop productivity and quality in many crops. Thus, foliar-P fertilization along with microbial inoculants like AM-fungi and PSB may prove as a low-cost technology in nutrient exhaustive crops

like potato to harness higher yield with higher PUE besides saving soil applied-P. Hence, a field experiment has been conducted during 2022 at ICAR-CPRI, Shimla (HP) comprising different P-levels as sole or in combinations with AM-fungi and PSB besides foliar-P fertilization. The results revealed that application of P_{20} + PSB + AMF, P_{20} +2FSP [Two foliar-P sprays of 2% mono-ammonium phosphate (MAP) applied at vegetative stage (VS) & tuberization stage (TS) in potato]; and P_{20} +PSB+AMF+2 FSP led to 14.2, 12.9 & 19.2% higher tuber productivity over sole use of P_{20} . On an average, application of P_{40} + PSB + AMF, P_{40} +2FSP; and P_{40} +PSB+AMF+2 FSP led to 9.5, 8.0 & 15% higher tuber productivity over sole use of P_{40} during experimentation (Fig. 19). It was also revealed that at lower doses of soil applied-P, the response of PSB + AMF or foliar-P was better (11.8–19.2%) over their application at the higher soil applied-P doses (8–15%). Hence, integrated P-use through soil applied-P, foliar-P and microbial inoculants like PSB + AMF, can be a low-cost crop management technology under low soil applied-P situations with mini tuber yield compromise in the acid Alfisols. An experiment on foliar application of P was also conducted at Jalandhar. Two foliar applications of MPP (5 g/l) resulted in a marginal (non-significant) increase of 8.59% over control (0 P level) and 7.07% at 75% P level. The results indicated that foliar application of phosphorus has the potential as a supplementary application only.

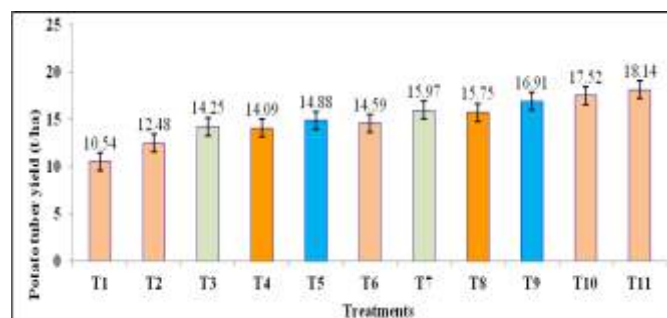


Fig. 19: Effect of P-fertilization practices on potato tuber yield (t/ha) in an acid Alfisol (Kharif 2022). [Note: T1: P_0 ; T2: P_{20} ; T3: P_{20} + PSB + AMF; T4: P_{20} + 2 foliar sprays of P through 2% MAP (2 FSP); T5: P_{20} + PSB + AMF + 2 FSP; T6: P_{40} ; T7: P_{40} + PSB + AMF; T8: P_{40} + 2 FSP; T9: P_{40} + PSB + AMF + 2 FSP; T10: P_{80} ; T11: P_{100}]. (The vertical bars represent $LSD_{0.05}$ values).

Plants have also developed some biotic interactions with diverse soil microorganisms that promote plant growth. Arbuscular mycorrhizal fungi (AMF) and plant growth-promoting bacteria (PGPB) especially the

phosphate-solubilizing bacteria subgroup (PSB), are known to curtail P-deficiency in plants. AMF perform a symbiotic relationship between a fungus and the roots of a plant and their inoculation has been found to increase the uptake of nutrients, growth of plants, improve yield quality, and enhance several abiotic stresses in many crops. Hence, a glass-house pot experiment was conducted during *Kharif*2020–2022 at CPRI-Shimla, India using 10 treatment combinations (Control, P_0 , P_0 +PSB, P_0 +AMF, P_0 +AMF+PSB, P_{50} , P_{50} +PSB, P_{50} +AMF, P_{50} +AMF+PSB, P_{100}) in a CRD design replicated thrice. The results of the 3rd year pot-experiment revealed that application of P_{50} +AMF+PSB exhibited significantly higher mycorrhizal root colonization (76%) in potato though it remained at par with P_{50} +AMF. In general, the treatments imbedded with AMF led to higher root colonization ranging from 64-76% alone or in combination with 50% applied soil-P (Fig. 20). Again, sole AMF or its combination with PSB exhibited significantly higher relative leaf water content (RLWC) both at tuber initiation and bulking stages during morning (7.00 am) & evening hours (12.00 noon) in potato crop (Fig. 21). It was noted that sole AMF or in combination with PSB had higher RLWC both at tuber initiation stage during morning (82.7-83.9%) & evening (76.7-78.9%); as well as at bulking stage during morning (85.3-86.7%) & evening (76.1-78.7%). RLWC showed more contrasting results during afternoon over morning time at both stages in potato irrespective of the treatments. It was interesting to note that during evening hours the treatments imbedded with AMF exhibited higher RLWC, hence indicating, the role of AMF in moisture-stress tolerance in AMF-imbedded plants. The P_{50} +AMF+PSB again remained statistically at

Mycorrhizal root colonization (%)

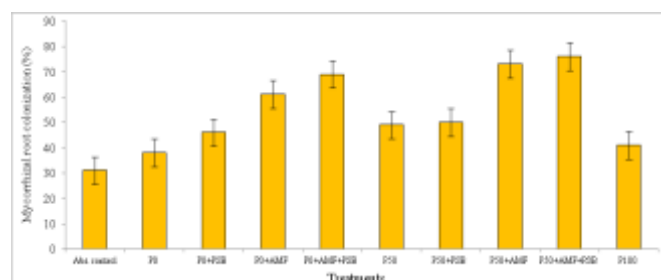


Fig. 20: Effect of AM-fungi, PSB and applied-P on mycorrhizal root colonization (%) in potato in NW Himalayan soil (*Kharif* 2022). (The vertical bars represent $LSD_{0.05}$ values).

par with P_{100} to exhibit higher root dry wt. (Fig. 22). P_{100} proved superiormost w.r.t. no. of tubers (9.9/pot), weight of tubers (59.9 g/pot), but it remained at par with P_{50} +AMF+PSB, hence indicating, an important role of microbial inoculants like AMF alongwith PSB in P bio-availability, growth and tuber yield in potato in acid Alfisol.

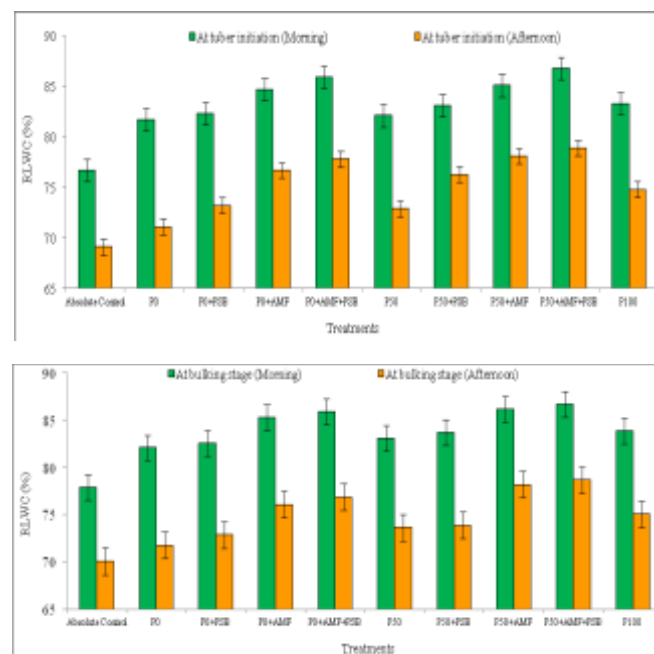


Fig. 21: Effect of AM-fungi, PSB and applied-P on relative leaf water content (%) at (a) tuber initiation and (b) at bulking stage in potato. (The vertical bars represent $LSD_{0.05}$ values).

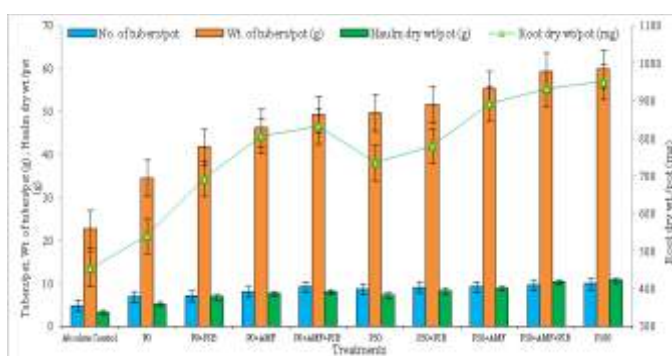


Fig. 22: Effect of AM-fungi, PSB and applied-P on number of tubers/pot, tuber wt./pot, haulm dry wt./pot and root dry wt./pot in potato. (The vertical bars represent $LSD_{0.05}$ values).

Under this project, five hundred (500) bacterial isolates were isolated from tubers, roots of potatoes, rhizosphere of potato and tested for P-solubilization. Out of these 500 rhizobacterial 137 isolates showed solubilization of insoluble P. Solubilization index for P ranged from 1.05–3.60 (Table 4; Fig. 23).

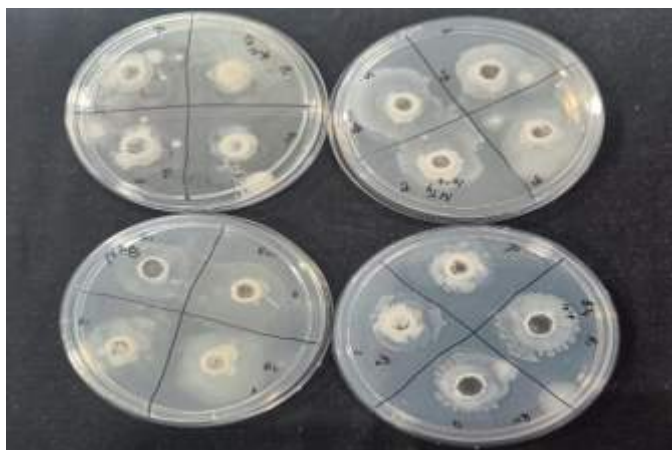


Fig. 23: Bacterial isolates for P-solubilization.

Table 4: P Solubilization index for different bacterial isolates

Isolates	Solubilization index
PSB11	3.05 ± 0.17
PSB33	2.45 ± 0.25
PSB47	2.97 ± 0.91
PSB55	2.19 ± 0.1
PSB71	3.60 ± 0.22
PSB107	2.85 ± 0.67
PSB125	3.21 ± 0.12

Identification of P efficient varieties, hybrids, germplasm: Potato is generally considered to be a crop with a high demand for phosphatic fertilizers due to its low phosphorus use efficiency. Increased pressure on soil fertility for various reasons including human needs and abiotic stresses will require efficient crop varieties which can perform well under degraded and denuded soil conditions. There is an increasing awareness that current type of P use practices are not sustainable because phosphate reserves are finite, and that increasing the efficiency with which these reserves are used to produce crops is vital to maintain current agricultural productivity, or to even increase it. Thus development and identification phosphorus efficient varieties/genotypes could prove as an effective way to improve P use efficiency and field screening of P-efficient genotypes in the natural conditions is trustworthy and efficacious pathway. Thus genotypic variations in phosphorus (P) content were studied in leaf at two plant growth stages and haulms in different genotypes raised on native soil P fertility (Bray's P=42 ppm) on an acidic soil at Shimla. Large

variation was observed in leaf as well as haulm amongst the genotypes. P concentration in leaves varied from 0.32 to 0.58 at Stage I and 0.31 to 0.47 at stage II in leaves. In haulms, P concentration ranged from 0.23-0.49 (mean= 0.36%) in haulms (Fig. 24, 25). This large variability can be exploited for breeding P efficient genotypes after further evaluation.

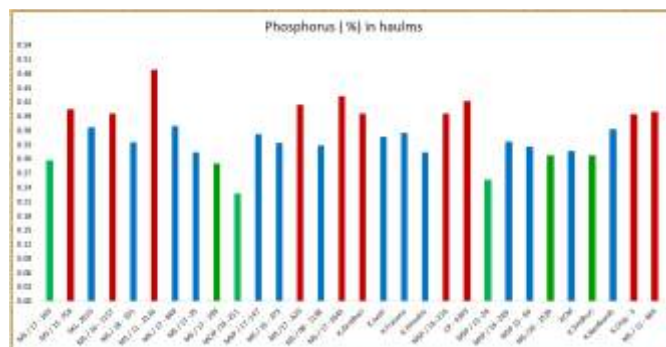


Fig. 24: Variations in haulm P concentration in different genotypes of potato (stage-I)

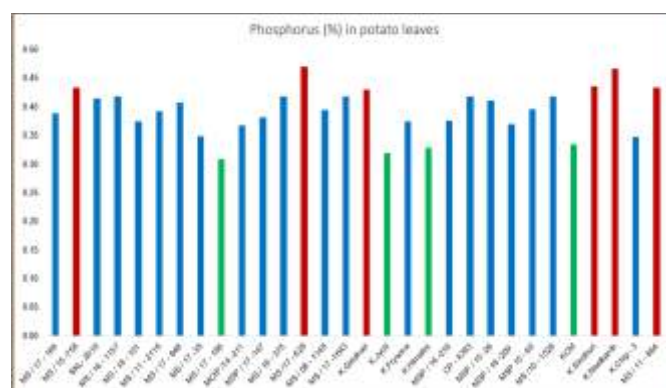


Fig. 25: Variations in leaf P concentration in different genotypes of potato stage-II

Studies on trace and beneficial elements (Drs. Jagdev Sharma, V.K. Dua, Manoj Kumar, Anil K. Choudhary, Anil Sharma, Prince Kumar)

Foliar absorption of zinc (Zn) is limited by several barriers, the first of which is the leaf cuticle. Besides this source of Zn fertilizers is also important. Hence pot experiments on zinc sources including nano-zinc were conducted to study their effect on plant growth and Zn content in tubers. Zinc sulphate as well as nitrate were found superior to nano zinc. Different concentrations were tested for phytotoxicity. A single spray of Zn as zinc nitrate (200 ppm Zn) and zinc sulphate (400 ppm Zn) and nano Zn (50 ppm) increased the plant height, biomass and tuber zinc concentration significantly over control. A single spray of zinc @200 ppm as zinc

nitrate resulted in highest increase of 18.5% (Kufri Chipsona-1) to 27 % (Kufri Jyoti) in tuber zinc concentration. Higher concentrations of nano zinc (single spray 75 and 100 ppm or two sprays of 50 ppm nano zinc) and 300 ppm Zn as zinc nitrate and caused phytotoxicity.

Selenium (Se) is essential to humans and animals due to its antioxidant properties. Although it is not considered an essential nutrient for higher plants. Many studies show that Se in low concentrations provides beneficial effects to non-hyperaccumulating plants by participating in antioxidant defense systems and enhancing tolerance to abiotic stress. Plants sprayed with 75 ppm Se showed higher moisture stress tolerance in an pot experiment (Fig. 26). Relative leaf water content was significantly higher (13.6 to 19.2%) in plants which were sprayed with selenium. In an

experiment conducted under field condition at Jalandhar two sprays of selenium (75 ppm) at 30 and 45 days after planting increased the fresh tuber yield by 15.5%, although the difference was not statistically significant.



Fig. 26: Effect of foliar application of selenium (Se) on moisture tolerance (LHS sprayed with Se and RHS unsprayed.)

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

Several field and laboratory studies/ testing were continuing in this programme under various research project activities during 2022. 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; Development of rapid seed potato production technologies, and Engineering technologies for potato production and utilization. Research activity wise salient findings and conclusions are given as follows:

Indian good agricultural practices (GAP) for production of potato crop (PI: Pooja Mankar; Co-PI: Sanjay Rawal, Sanjeev Sharma, SK Luthra, VK Gupta, Devendra Kumar, Mehi Lal, Subhash S)

Possibility of early potato export from Western Uttar Pradesh: Western Uttar Pradesh has better export potential for the premium early potato segment as leading Indian exporters demand export-grade tubers (>55mm) during January. Field experiments were conducted during 2020-22 for screening promising varieties/ advanced hybrids. The crop was raised for 75 days from September-December and harvested in mid-January. Advanced hybrid WS/07-113 now released as variety Kufri (K) Daksh recorded the highest export-grade tuber yield (4.95 t/ha)

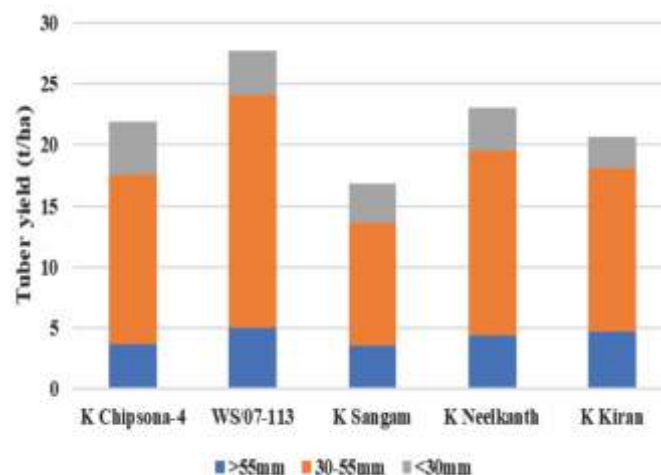


Fig. 26: Mean graded tubers yield at harvest

followed by K Kiran (4.63 t/ha). Exporters also showed keen interest in specialty cv. K Neelkanth which had 4.32 t/ha export-grade tubers yield (Fig. 26).

Strengthening export supply chain in Uttar Pradesh and Gujarat: Eight promising Indian potato varieties for export were screened at Agra and Gujarat during 2020-22. Around 50% export grade yield (>55mm tuber size, oval-oblong shape and >18% dry matter) was recorded in all the varieties at both locations (Fig. 27 and 28). K Frysona, K Ganga, K Sangam and K Chipsona-3 recorded more than 25 t/ha yield at both locations with better storability. In addition, exporters showed keen interest in K Neelkanth as a specialty potato.

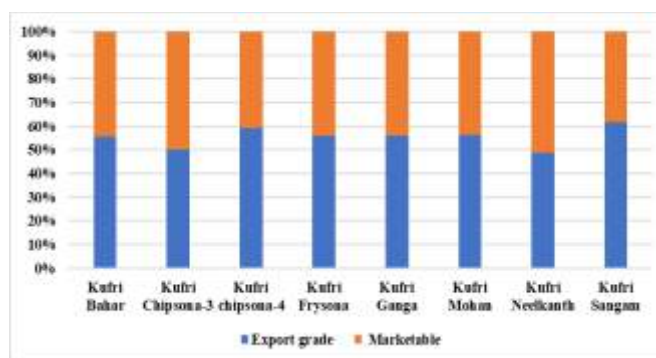


Fig. 27: Percent distribution of graded tubers yield in district Sabarkantha

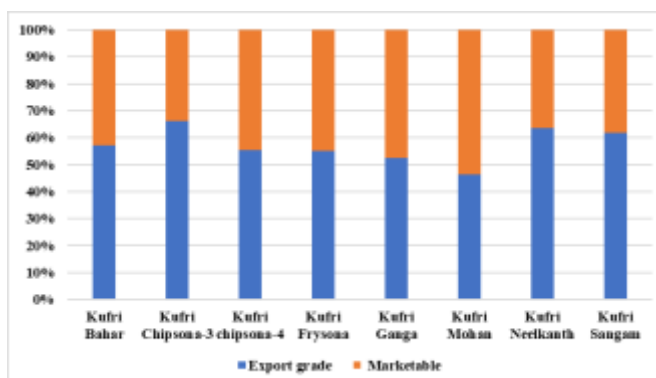


Fig. 28: Percent distribution of graded tubers yield in district Agra

Catalogue of Indian varieties having export potential: The institute has been working to identify and promote potential potato varieties suitable for specific international destinations for past three years. From the field experiments conducted at Modipuram, Agra and Gujarat and feedback received from leading Indian potato

exporters, this catalogue has been designed and developed. The aim is to provide objective information to stakeholders interested in potato export. The first-of-its-kind catalogue will help farmers, exporters, and importers in achieving targeted quality production and trustful business (Fig. 29).



Fig. 29: Catalogue of export potential varieties and its QR code

Germplasm evaluation: Under the activity of screening of germplasm for export potential, 51 advanced clones and check varieties were evaluated for export parameters i.e. shape (oblong, round), size (>55 mm), tuber dry matter (>18%), cosmetic value (skin colour, shine etc.) and texture etc.). Clone MS/15-1001, MS/11-664, MS/9-723, MS/15-1422, MS/14-505, MCIP/11-185, MS/14-1381, MS/16-1156, HT/12-830, CP 4393 and MS/15-758 were promising advanced hybrids in second year of evaluation at Modipuram (Fig. 30).

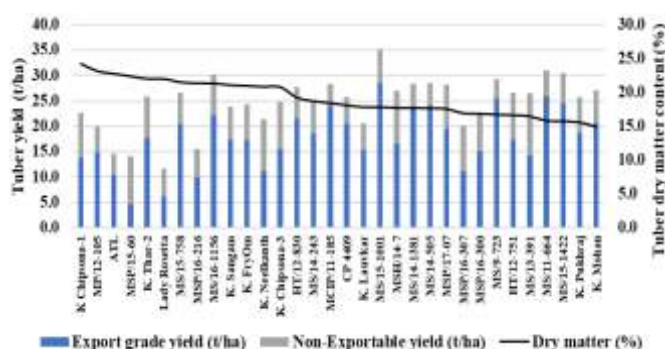


Fig. 30: Yield performance of advanced potato clones at Modipuram

Developing production technology for certified organic seed potatoes (PI: SP Singh, Co-PI: S Katare, M Sadawarti)

Organic seed potato production: Organic seed production includes growing of seed crop by a set of guidelines that prohibit the use of synthetic

products/chemicals. The most compelling reason for using organic seed when growing organic crops is that seed produced organically causes less chemical impact on the environment. During this process soil fertility and pest are managed through crop rotation, organic manure, bio-fertilizers, cultural practices and bio-pesticides. A field experiment was conducted using six nutrient treatments (F0-Control; F1-100% FYM + *Neem* cake@2.5 t/ha + *Vermi-wash*; F2-200% FYM + *Neem* cake@2.5 t/ha + *Vermi-wash*; F3-100% FYM + *Mahua* cake@2.5 t/ha + biofertilizers; F4-200% FYM + *Mahua* cake @ 2.5 t/ha + biofertilizers; F5- RDF NPK) and two varieties (K Chipsona-1 and K Chandramukhi). Highest number of seed size tubers were recorded with K Chipsona-1 (288 thousand/ha) which was significantly higher than K Chandramukhi. Total tuber number was comparable in both the varieties. Higher seed size tuber yield (12.7 t/ha) was recorded with K Chipsona-1 than K Chandramukhi (11.2 t/ha). Total tuber yield was comparable in both the varieties. Highest number of seed size (313 thousand/ha) and total (686 thousand/ ha) tubers were recorded with F1

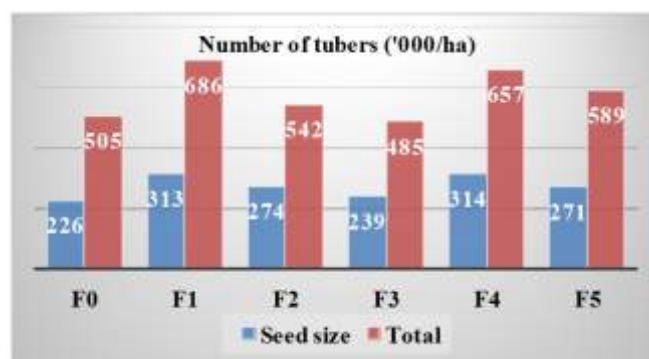


Fig. 31: Graded and total tubers in different nutrient combinations

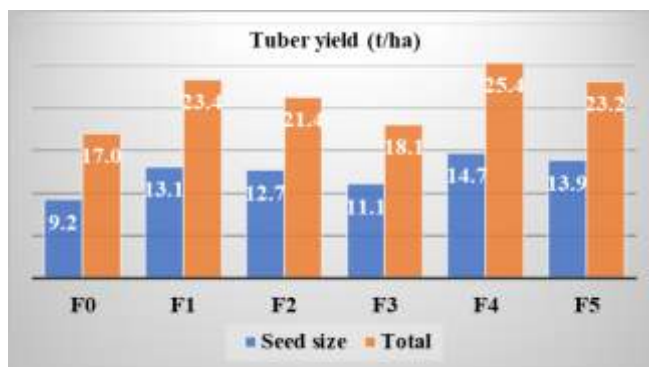


Fig. 32: Graded and total tuber yield in different nutrient combinations

treatment followed by F4. Highest seed (14.7 t/ha) and total (25.4 t/ha) tuber yield was recorded with F4 treatment. Highest benefit-cost ratio was recorded with F5 treatment (Fig. 31-33).

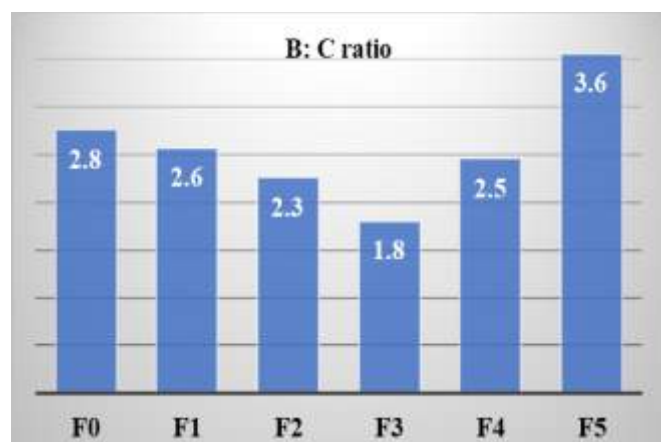


Fig. 33: Benefit- cost ratio among different treatments

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

Germplasm evaluation: Promising 51 advanced clones were evaluated under organic production systems at Modipuram. Selections were made for their earliness, yield performance, resistance to diseases and pest, appearance of tubers and tuber dry matter content etc. Promising advanced clones found during second crop season of the trial were HT/12-751, MS/15-1001, MS/16-1156, MS/14-505, MSP/17-07, MS/15-1422, MCIP/17-89, HT/MK-21, MS/15-758, HT/12-830 and MS/9-723 (Fig. 34).

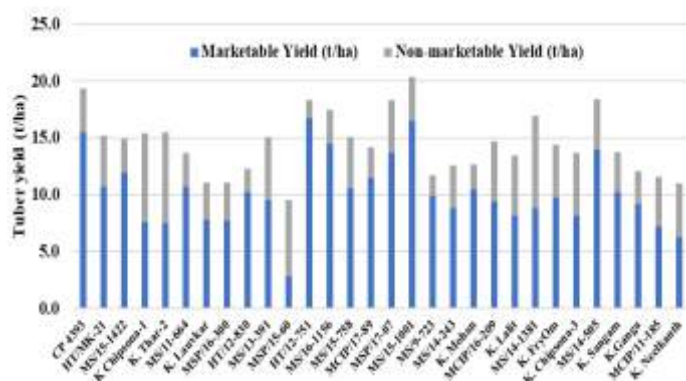


Fig. 34: Yield performance of advanced clones under organic production system at Modipuram

Influence of long-term natural farming vs. conventional farming practices on tuber productivity and soil health in wet-temperate north-western Himalayas

A field experiment has been initiated since *Kharif* 2021 at Shimla to study the influence of organic versus conventional farming practices on tuber productivity in RBD replicated thrice. Second year results revealed that application of 100% RDF @ 150:100:100 kg NPK/ha (T_9) led to significantly highest tuber yield (17.56 t/ha) which though remained at par with integrated nutrient management (INM) treatments T_5 to T_8 comprised of 50% NPK along with varying doses of FYM and vermicompost (VC). Among organic treatments, application of VC @ 10 t/ha (T_2) led to comparatively higher tuber yield (14.71 t/ha) while FYM @ 25 t/ha (T_1) had lower tuber yield (13.39 t/ha), all of which through remained at par with each other (T_1 – T_4). On an average, the conventional farming practices (T_5 – T_9) had ~19.6% higher yield over the natural farming practices (T_1 – T_4) during *Kharif*2022 (Fig. 35).

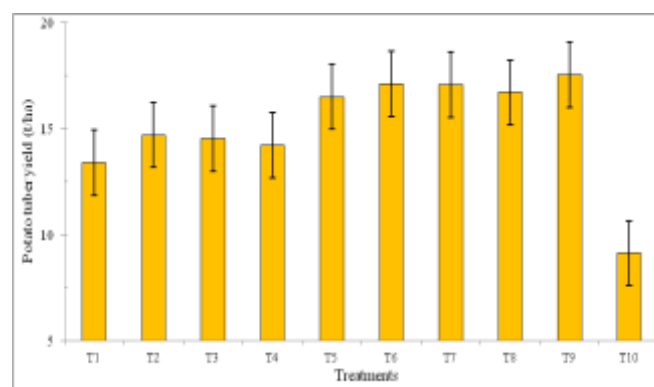


Fig. 35: Effect of source of nutrition on tuber yield in north-western Himalayas [Treatment: T_1 : FYM @ 25 t/ha (100% FYM); T_2 : VC @ 10 t/ha (100% VC); T_3 : FYM @ 12.5 t/ha + VC @ 5 t/ha (50% FYM+50%VC); T_4 : FYM @ 9.375 t/ha + VC @ 3.75 t/ha + MC (37.5% FYM+37.5% VC+MC); T_5 : 50% NPK + FYM @ 12.5 t/ha (50% NPK + 50% FYM); T_6 : 50% NPK + VC @ 5 t/ha (50% NPK + 50% VC); T_7 : 50% NPK + FYM @ 6.25 t/ha + VC @ 2.5 t/ha (50% NPK + 25% FYM + 25%VC); T_8 : 50% NPK + FYM @ 3.125 t/ha + VC @ 1.25 t/ha + MC (50% NPK + 12.5% FYM + 12.5% VC + MC); T_9 : 100% NPK @ 150:100:100 kg NPK/ha (100% NPK); T_{10} : Absolute control (FYM = Farm yard manure; VC= Vermicompost, MC= Microbial consortia (NPK-bf + AMF); Vertical bars represent $LSD_{0.05}$ values)]

Evaluation of Potato cultivars under natural production system in north-eastern hilly region:

A field experiment was conducted during Kharif 2022 to identify suitable potato cultivars with high yield potential under natural farming, where six varieties were evaluated. Tuber yield attributes and yield were significantly influenced by nutrient source (Fig. 36). K Himalini recorded significantly higher marketable (11.62 t/ha) and total tuber yield (15.34 t/ha), while K Kanchan recorded the lowest marketable (4.85 t/ha) and total tuber yield (7.56 t/ha). It was concluded that cv. K Himalini is the most suitable potato cultivar for natural farming for north-eastern hilly region of Meghalaya.

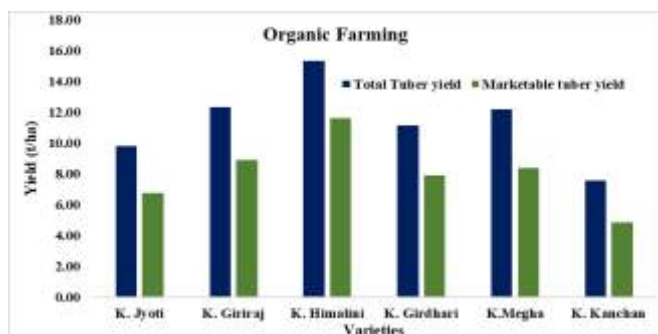


Fig. 36: Yield parameters of potato cultivars under organic cultivation

Weed management in natural potato farming in north-eastern hilly region:

A field trial was conducted at Shillong for potato crop (cv. K Girdhari) in RBD with three replications and seven treatments, viz., weedy check, weed free, one hand weeding with earthing up, rice-straw mulch, chopped grass mulch, silver-black polythene mulch and metribuzin (0.75 kg/ha) as pre-emergence followed by one hand weeding. Silver-black polythene mulch (Fig. 37) was promising as it recorded comparable total (14.39 t/ha) and marketable (9.37 t/ha) tuber yields to weed-free control (16.52 & 10.62 t/ha).

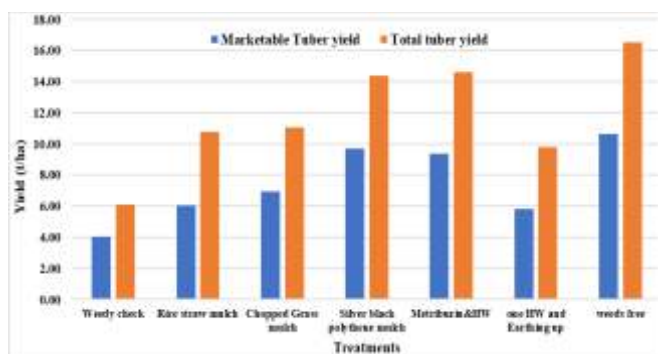


Fig. 37: Effect of mulching materials on potato production (t/ha)

Refining organic potato protection technologies for sustainable yields (PI: Mehi Lal; Co-PI: Anuj Bhatnagar, Sanjeev Sharma, Vinay Sagar, S Katare, Subhash S, P Janani)

Organic management of potato late blight

Management of this disease is a herculean task using organic products due to its fast spreading capability. However some of the restricted chemicals/bio-agents (copper based products, neem oil and *Trichoderma viride* etc.) have been identified for managing the disease up to certain extent. Therefore, eleven treatments consisting different products combination were evaluated against late blight of potato during Rabi season of 2020-21 & 2021-22 on cv. K Bahar and K Mohan. It was observed that all the treatments recorded lower disease severity in comparison to control. Lowest disease severity (36.67%) was recorded in treatment T4 (Neem oil @ 4.0%- Copper hydroxide @ 0.3%- Neem oil @ 4.0%-Copper hydroxide @ 0.3%) followed by T2 (Neem oil @ 4.0%- Copper hydroxide @ 0.25%-Neem oil @ 4.0%- Copper hydroxide @ 0.25%) and T3 (Neem oil @ 4.0%- Copper oxychloride @ 0.25%- Neem oil @ 4.0%- Copper oxychloride @ 0.25%) with disease severity level of 50.00% & 53.33.0%, respectively over the control (85%) in cv K.Mohan (Fig. 38). Similar trend was also observed in cv. K Bahar but with higher level of disease severity. This study shall be repeated in second crop season for confirmation of the results.

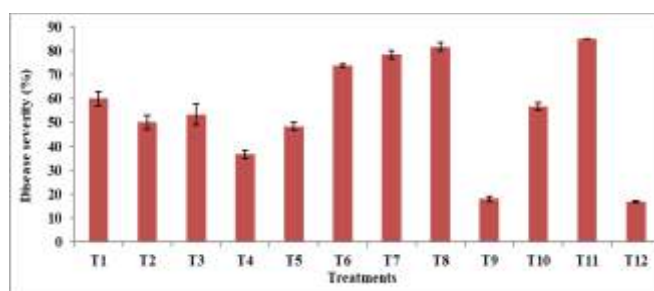


Fig. 38: Effect of various organic based/ restricted used chemicals against late blight (cv. K Mohan)

[Treatments: T1: Neem oil @ 4%- COC 50%WP @ 0.25- FNG @ 2%- Neem oil @ 4%; T2: Neem oil @ 4%- Co hydroxide @ 0.25%- NGF @ 2%- Neem oil @ 4%; T3: Neem oil @ 4% - COC @ 0.25% - Neem oil @ 4.0- COC @ 0.25%; T4: Neem oil @ 4%- Co hydroxide @ 0.3%-Neem oil @ 4%- Co hydroxide @ 0.3%; T5: Neem giri @ 2%- Co hydroxide @ 0.3%- Neem giri @ 2%- Co

hydroxide @ 0.3%; T6: Neem powder @ 2.0%- FNG @ 2.0%- Neem powder @ 2.0%- FNG @ 2.0%; T7: Fresh fermented FYM (1kg/10l)- FYM-FYM; T8: Rotted fermented FYM (1kg/10l)- RFYM- RFYM- RFYM; T9: Fresh fermented FYM- at appearance of blight (1g/1 Dimethomorph +2 g/l mancozeb)- Fresh fermented FYM- Fresh fermented FYM; T10: Cow urine (1:10 part); T11: Control, T12: Chlorothalonil @ 0.2%- cymoxanil+ mancozeb @ 0.3%- dimethomorph @ 0.1%- cymoxanil+ mancozeb @ 0.3% (purely inorganic)]

Evaluation of restricted chemicals against potato late blight disease on susceptible and moderately resistant varieties: Copper hydroxide @ 0.2% and copper oxychloride @ 0.2% were evaluated at six and ten days spray interval against the disease on cvs. K Himalini (moderately resistant) and K Jyoti (susceptible) at Shillong. All copper-based fungicides reduced the disease intensity when compared to the unsprayed control. In K Himalini, lowest disease intensity was recorded in plots sprayed with 0.2% copper hydroxide at 6-day intervals (AUDPC-370.61) followed by 0.2% copper oxychloride at 6-day intervals (AUDPC 453.83), while the highest AUDPC (941.50) was observed in control (Fig. 39). In K Jyoti, both copper hydroxide @ 0.2% sprayed at six-day intervals (AUDPC-736.56) and copper oxychloride @ 0.2% sprayed at six-day intervals (AUDPC- 833.39) had lower disease intensity over the control. Variety K Himalini recorded significantly higher total tuber yield (12.96 t/ha) as compared to cv. K Jyoti (9.84 t/ha) under natural farming system. The results showed that copper hydroxide and copper oxychloride sprays at six-day intervals were effective in controlling the potato late blight under natural farming system.

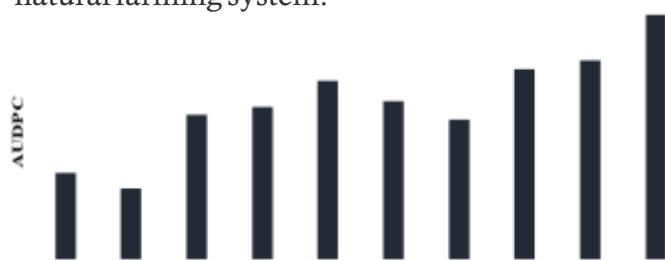


Fig. 39: Effect of copper-based fungicides on late blight of potato

Organic management of black scurf of potato: In a two year study during 2020-22, fifteen treatments were evaluated for management of this disease in potato cv. K Bahar. It was observed that all treatments showed lower disease incidence and severity in comparison to the control. Treatment T2 (TH2: compost multiplied @100g/1.8m²) recorded lowest disease incidence (42.67%) and severity (19.50%) followed by T4 (TH2: talc based formulation) with disease incidence (47.17%) and severity (28.61%), and T3 (*Trichoderma* spp: TH1 in talc based formulation @ 1.0% as seed treatment) having disease incidence (51.52%) and severity (24.30%) in comparison to disease control which recorded highest disease intensity (87.33%) and severity (41.83%) as depicted in Fig. 40.

Evaluation of bio-pesticides against whiteflies in potato crop under field condition: An experiment was conducted in RBD with three replications at Modipuram to evaluate the effect of bio-pesticide spray along with standard insecticide on whiteflies in seed potato crop. There were seven treatments i.e. T1- *Neem* soap (7g/l), T2- *Pongamia* soap (7g/l), T3- *Neemazal* (3 ml/l), T4- *Neemastra* (200 l/acre), T5- *Beauveria bassiana* (@ 10g/l), T6- *Imidacloprid* 17.8 SL (0.4 ml/L), and T7-Control (no spray). The results revealed 94.85% population reduction over control in plots treated with *Pongamia* soap one day after treatment, followed by *Beauveria bassiana* spray (74.92%), *Neemastra* spray (73.09%), *Neem* soap spray (71.69%), and *Imidacloprid* spray (59.64%). There was consistent reduction in the whitefly population three days after spray in *Imidacloprid* (70.79%), followed by *Neem* soap (70.79%) and *Pongamia* soap (53.32%) over control plots. After five days after spray, there was a reduction of about 81.46% and 74.97% in *Neem* soap and *Pongamia* soap sprayed plots over control, respectively. Further, seven days after spray, *Neem* soap sprayed plots (79.74%) recorded the highest reduction in population over control plots, followed by *Beauveria bassiana* (78.80%) sprayed plots (Fig. 41). In case of second spray (Fig. 42), the reduction over control was less than 50% in the first two treatments in all recorded observations, whereas it was 69.4% in the case of *Neemazal*

spray seven days after spray followed by Imidacloprid spray (55.54%). *Neem* soap and *Pongamia* soap performed better than Imidacloprid and these can be used as an alternative to synthetic insecticides in reducing

whitefly populations in organic seed potato production. Additionally, they can be incorporated as an integrated pest management option in seed potato production.

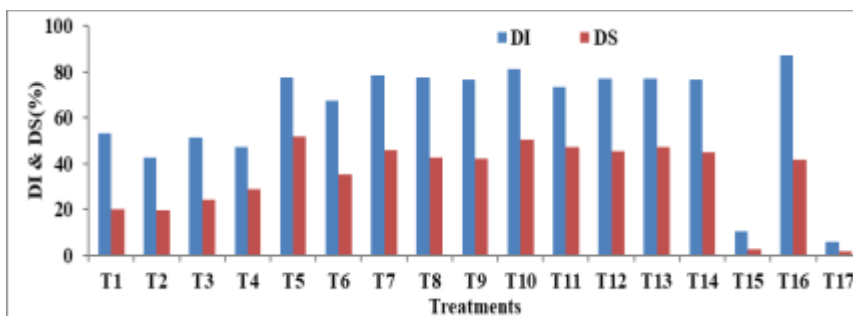


Fig. 40: Effect of organic based products on black scurf incidence and severity. [T1:TH1 (compost multiplied @100g/1.8m²); T2: TH2 (compost multiplied @100g/1.8m²); T3: TH1 (talc based formulation @1.0%); T4: TH2 (talc based formulation @1.0%); T5: TH1 (spore suspension @ 3plates/l); T6: TH2 (spore suspension @ 3plates/l); T7: P1 (spore suspension @ 6 plates/l); T8: P14 (spore suspension @ 6 plates/l); T9: P1 (talc based formulation @ 0.5%); T10: P14 (talc based formulation @ 0.5%); T11: Waste decomposer @ 12ml/l; T12: Rotted butter milk+ copper plate @ 12ml/l; T13: Rotted buttermilk @ 25ml/l; T14: Neem kernel @ 30ml/l; T15: Pencycuron @ 0.25% spray; T16: Diseased control; T17: Healthy control]

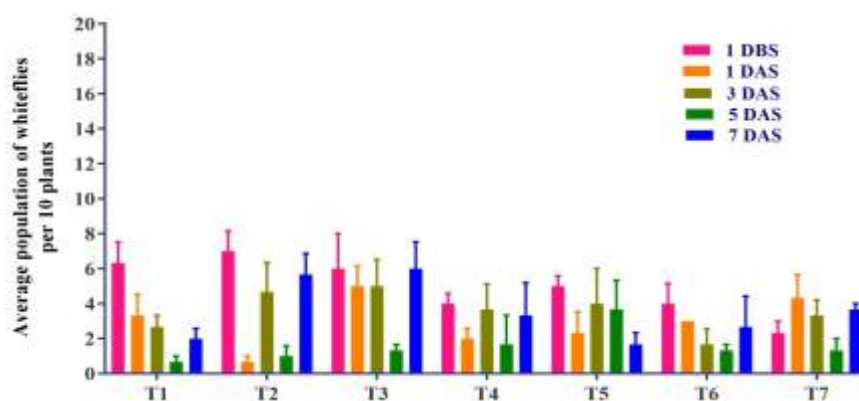


Fig. 41: Mean population of whiteflies per ten plants in different treatments after first spray

[1 DBS: One day before spray; 1, 3, 5 and 7 DAS: days after spray; Treatments: T1- *Neem* soap spray (7g/l); T2- *Pongamia* soap spray (7g/l), T3- *Neemazal* (3 ml/l), T4- *Neemastra* (200 l/Acre), T5- *Beauveria bassiana* (@ 10g/l), T6- *Imidacloprid* 17.8 SL (0.4 ml/l) and T7- Control]

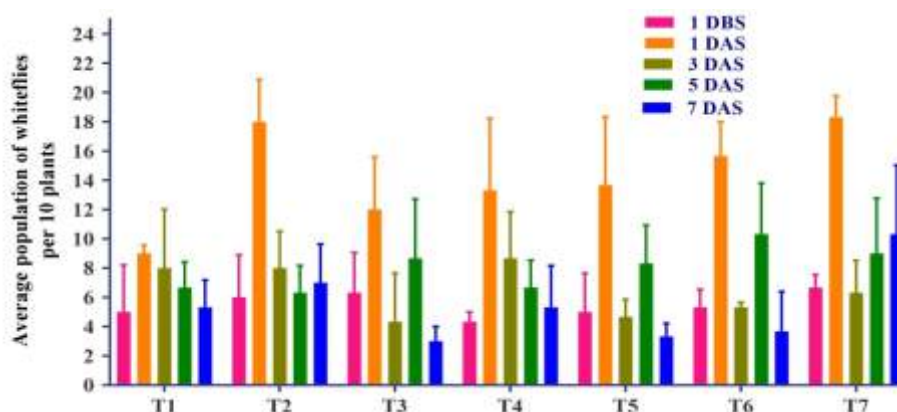


Fig. 42: Mean population of whiteflies per ten plants in different treatments after second spray.

[1 DBS: One day before spray; 1, 3, 5 and 7 DAS: days after spray; Treatments: T1- *Neem* soap spray (7 g/l); T2- *Pongamia* soap spray (7 g/l), T3- *Neemazal* (3 ml/l), T4- *Neemastra* (200 l/Acre), T5- *Beauveria bassiana* (@ 10 g/l), T6- *Imidacloprid* 17.8 SL (0.4 ml/l) and T7- Control]

Evaluation of bio-pesticides for eco-friendly management of sucking pests in potato crop

A field experiment was conducted during Rabi 2020-21 & 2021-22 at Gwalior using bio-pesticides and chemical insecticides for managing whitefly, thrips, and aphid population on cv. K Chandramukhi. The results of two crop seasons showed that all the microbial/ bio-pesticides and chemical insecticides except Azadirachtin @ 1500 ppm and *Verticillium lecanii*, were effective in controlling the whiteflies, thrips and aphids after three and seven days after spraying. Treatment *Metarhizium anisopliae* @ 3g/l was found most effective against whitefly, thrips, and aphids with percent reduction of 60.88 %, 58.12% and 59.80%, respectively over untreated control. Among chemicals, Thiamethoxam 5% WG @ 0.5 g/l, and Imidacloprid 17.8 SL @ 0.5mlg/l was found effective in reducing these pests.

Development of potato based cropping systems for different agro-ecologies (PI: SP Singh, Co-PI: VK Dua, Sanjay Rawal, Anil K Choudhary, Anil Sharma, RK Singh, Pooja Mankar, Janani P, Dharmendra Kumar, Kailash Chandra Naga)

Rice-potato-green manure (*Sesbania spp*) crop sequence under natural farming crop production: Experiment comprised of four fertility levels (F1-100% RDF of NPK; F2- Crop residue @ 25 t/ha + *Azotobacter* @ 1.25 l/ha + PSB @ 1.25 l/ha + Jeevamrut @ 500 l/ha; F3- FYM @ 25 t/ha + Jeevamrut @ 500 l/ha and F4- Control) and two mulches options (No mulch and paddy straw mulch @ 5 t/ha) was carried out. Results revealed that there was significant effect of paddy straw mulching on rice grain yield. Highest rice grain yield (2.69 t/ha) was recorded under mulching situation compared to no-mulching (2.51 t/ha). Application of 100% RDF NPK application recorded highest rice yield (3.86 t/ha) followed by FYM @ 25 t/ha + Jeevamrut (2.68 t/ha). Highest tuber yield (27.1 t/ha) was recorded with 100% RDF NPK which was followed by FYM @ 25 t/ha + Jeevamrut @ 500 l/ha (23.5 t/ha). Significantly higher tuber yield was recorded with paddy straw mulch (23.4 t/ha) compared to no mulch. Highest rice equivalent yield (REY) was recorded with mulching treatment (16.2 t/ha) compared to no mulch (14.2

t/ha). Highest REY (19.1 t/ha) was recorded with 100% RDF NPK. Highest net return (Rs. 2.67 lakh/ha) was recorded with paddy straw mulching compared to no mulch (2.40 lakh/ha). Highest net returns (2.94 lakh/ha) was recorded with FYM @ 25 t/ha + Jeevamrut @ 500 l/ha compared to other fertility treatments. Nutrient management practices significantly influenced the organic content of soil. This varied in different treatments from 0.23% in control, 0.30% in RDF, 0.37% in crop residue and 0.39% in FYM applied treatments after three years of the study.

Evaluation of diversified potato based cropping systems under integrated nutrient management in wet-temperate north-western Himalayas

A field experiment has been conducted during 2020-2022 at Shimla having four potato based cropping systems (Fig. 43). i.e. CS₁: Potato-peas cropping system (PPCS); CS₂: Potato-broccoli cropping system (PBCS); CS₃: Potato-garlic cropping system (PGCS); CS₄: Potato-Matricaria cropping system (PMCS), and four integrated nutrient management (INM) schedules on system basis viz., INM₁: 100% NPK both in Crop-I & II; INM₂: 75% NPK + FYM @ 10 t/ha in Crop-I, and 75% NPK + 25% NPK through FYM in Crop-II; INM₃: 75% NPK + FYM @ 10 t/ha + PSB + AM-fungi (AMF) in Crop-I, and 50% NPK + 50% NPK through FYM in Crop-II; INM₄: 100% NPK + FYM @ 10 t/ha + PSB + AMF, and 75% NPK in Crop-II. Remaining P requirement after adding the required FYM in Crop-II was met through rock phosphate. The experiment was laid-out in split-plot design and replicated thrice. The results of year 2021-22 revealed that total potato tuber yield of K Himalini was significantly higher under PPCS (17.84 t/ha), which was followed by PMCS (17.52 t/ha), PGCS (17.22 t/ha), and PBCS (16.82 t/ha), respectively. Among INM schedules across the four cropping systems, potato tuber yield was found to be significantly higher under the INM₄ (18.63 t/ha), which was followed by INM₃ (17.55 t/ha), INM₂ (16.71 t/ha), and INM₁ (16.52 t/ha), respectively (Table 5). These results indicated that application of 100% RDF + FYM @ 10 t/ha + PSB + AM-fungi in potato crop proved highly beneficial to harness ~12.8 and

6.2% higher potato tuber yield over INM₁ and INM₃, respectively in second year potato crop across all the cropping systems. Among *Rabi* crops, INM₂ was the best INM schedule to exhibit higher crop yields which was followed by INM₃, INM₁ and INM₄, respectively.

On cropping system basis, potato-garlic cropping system (PGCS) exhibited significantly highest system productivity in terms of potato equivalent yield (76.7 t/ha), which was followed by PBCS (50.04 t/ha), PMCS (44.71 t/ha) and PPPC (35.57 t/ha), respectively. Hence, PGCS, PBCS

and PMCS exhibited 115.8, 40.7 and 25.7% higher system productivity, respectively over conventional potato-peas system. On system basis, the INM₂, INM₃ and INM₄ registered ~15.3, 11.4 and 1% higher system productivity over conventional 100% RDF in both crops (INM₁). In nutshell, potato-garlic cropping system and the INM₂ schedule (75% NPK + FYM @ 10 t/ha in Crop-I, and 75% NPK+25% NPK through FYM in Crop-II), exhibited highest system productivity in this region.



Fig. 43: Pictorial view of potato based diversified cropping systems in wet-temperate north-western Himalayas

Table 5: Crop productivity (t/ha) in terms of potato equivalent yield (PEY) as influenced by potato based cropping systems and INM schedules (2021-2022).

Treatments		Potato yield (t/ha)	PEY* of <i>Rabi</i> crops (t/ha)	System- PEY (t/ha)	%increase in System- PEY	
		<i>Kharif</i> 2021	<i>Rabi</i> 2021-22	2021-22		
Cropping systems						
CS ₁	Potato-peas (PPCS)	17.84c	17.73d (10.64)	35.57d	-	
CS ₂	Potato-broccoli (PBCS)	16.82a	33.22b (13.29)	50.04b	40.7	
CS ₃	Potato-garlic (PGCS)	17.22ab	59.54a (11.91)	76.76a	115.8	
CS ₄	Potato- <i>Matricaria</i> (PMCS)	17.52bc	27.19c (1.63)	44.71c	25.7	
Cropping system basis INM schedules						
Crop-I (<i>Kharif</i> crop)		Crop-II (<i>Rabi</i> crop)				
INM ₁	100% NPK @ 150:100:100 kg/ha	100 % NPK	16.52a	31.77c	48.29c	-
INM ₂	75% NPK+ FYM @ 10 t/ha	75% NPK +25% NPK through FYM	16.71a	38.97a	55.68a	15.3
INM ₃	75% NPK + FYM @ 10 t/ha+ PSB+AMF	50% NPK+50% NPK through FYM	17.55b	36.25b	53.80a	11.4
INM ₄	100% NPK + FYM @ 10 t/ha+ PSB+AMF	75% NPK	18.63c	30.70c	49.33bc	1.0

Winter potato-based intercropping system under rainfed conditions in Meghalaya

A field experiment was conducted to study the compatibility of different vegetable crops with potato (*Solanum tuberosum* L.) for maximizing production and income of intercropping system under rain fed conditions. Treatments consisted of French bean, cabbage, cauliflower and radish which were intercropped with potato. Highest tuber production was achieved by the sole potato (16.84 t/ha) which was followed by intercropping with French bean (9.43 t/ha). Highest yields of cabbage (14.88 t/ha) and cauliflower (13.31 t/ha) were recorded in their sole crops, which decreased significantly in potato intercropping. It shows that potato competes with these crops when it is intercropped. Potato+ cauliflower intercropping had the highest potato equivalent yield (21.94 t/ha) followed by potato+ cabbage intercropping (15.16 t/ha) system. Potato+ cabbage recorded the highest land-equivalent ratio (1.37), followed by Potato+ cauliflower (1.13). Potato+ cauliflower and potato+ cabbage were most suitable intercropping systems under rainfed conditions in Meghalaya (Fig. 44).

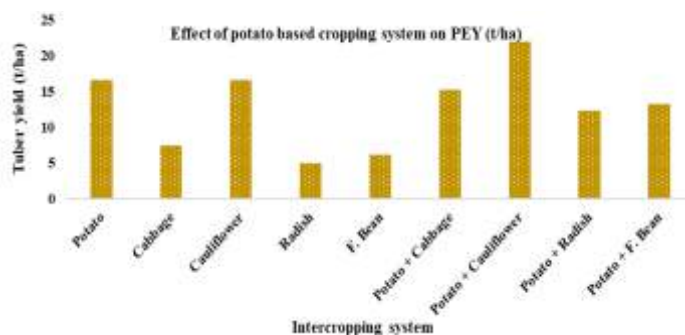


Fig. 44: Potato equivalent yields in various potato-based inter-cropping systems

Suitable potato varieties for various crop sequences of north-eastern hilly region

A field study was conducted at Shillong to evaluate the performance of six potato varieties for tuber yield in RBD consisting four replications during main crop season of 2022. Results indicated significant variations among the varieties for yield and morphological characters. Maximum total tuber yield was recorded in K Himalini (23.96 t/ha) followed by K Megha (18.57 t/ha), K Jyoti (18.47 t/ha) and K Girdhari (17.20 t/ha). Lowest total tuber yield was recorded in K Kanchan (14.57 t/ha) followed by K Giriraj (14.86 t/ha). Highest marketable tuber

yield (19.80 t/ha) was also recorded in K Himalini followed by K Jyoti (14.62 t/ha) and K Megha (13.25 t/ha). In terms of production economics, K Himalini achieved the maximum net return and B:C ratio (1.79) suggesting the suitability of this cultivar for north-eastern hills of Meghalaya (Fig. 45).

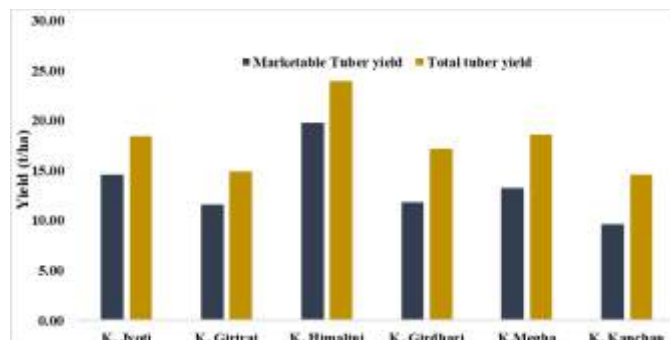


Fig. 45: Total and marketable tuber yield (t/ha) of different potato varieties

Development of rapid seed potato production technologies (PI: Sukhwinder Singh, Co-PI: Sugani Devi, Anil Sharma, Som Dutt, Brajesh Nare, Ratna Preeti Kaur)

Performance of aeroponic minitubers

At Jalandhar, January harvested aeroponic minitubers of four varieties (K Pukhraj, K Himalini, K Khyati and K Chandramukhi) were graded on fresh weight basis (FW) viz., T1 (Under size: 1.0-1.5 g), T2 (Seed size: 2.0-2.5 g) and T3 (Over size: 3.5-4.0 g) and evaluated for their performance. Results revealed that varietal differences were significant and cv. K Pukhraj (773.46) significantly out yielded as compared to K Himalini (589.98) for total tuber number ('000/ha). Among grades, higher tuber number were produced in bigger size minitubers i.e. T3 (698.48) as compared to T2 (630.83) and T1 (608.82) but the differences were statistically non-significant. As per the commercial aspect at G-1 stage, focus is specifically on number of tubers produced per unit area, therefore the results of this experiment indicate that even 1.0-1.5 g minitubers can efficiently be used for producing G-1 seed potatoes.

Tuber number enhancement by CPRI-formulation

CPRI- formulation, which has already been standardized for K Pukhraj and K Jyoti for enhancing total tuber number, was further tested on four varieties namely K Khyati, K

Chandramukhi, K Himalini and K Badshah at Jalandhar. Total tuber number per hectare was enhanced by 17.5%, 19.8%, 18.9% and 28.87% in K Khyati, K Chandramukhi, K Himalini and K Badshah, respectively (Fig. 46-49).

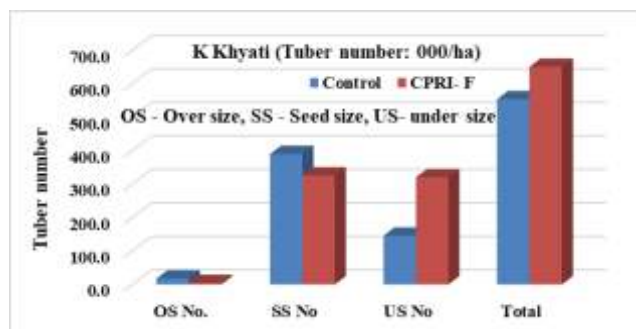


Fig. 46: Graded and total tuber number (000/ha) in cv. K Khyati

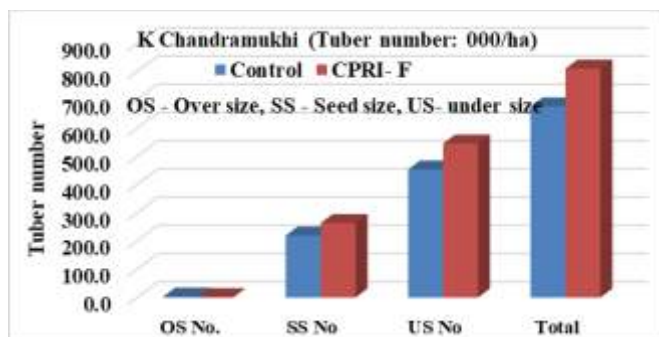


Fig. 47: Graded and total tuber number (000/ha) in cv. K Chandramukhi

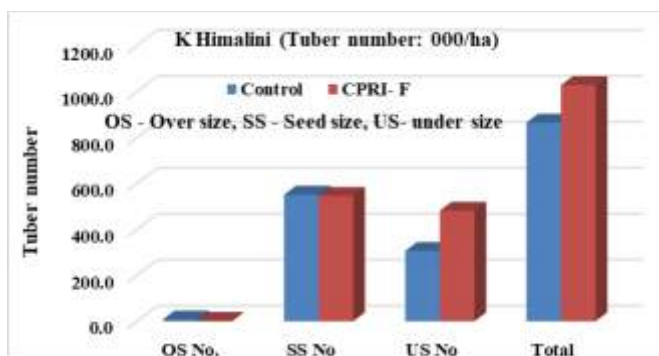


Fig. 48: Graded and total tuber number (000/ha) in cv. K Himalini

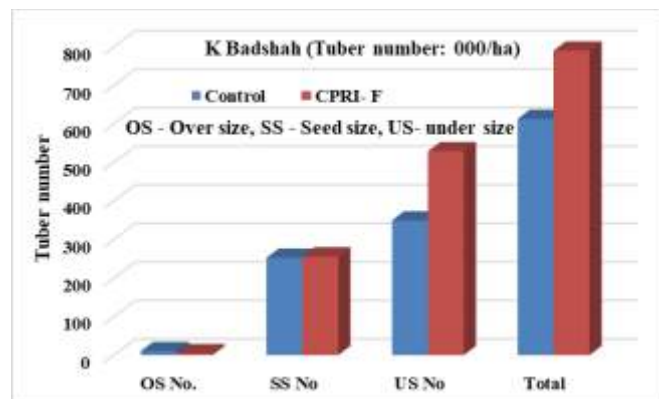


Fig. 49: Graded and total tuber number (000/ha) in cv. K Badshah

Studies on table potato yield enhancement by seed treatment

A preliminary study was conducted at Jalandhar for increasing table potato yield by pre-planting seed treatment. A chemical formulation was tested on three CPRI varieties (K Pukhraj, K Khyati and K Frysona) against non-treated control for crop duration of 100 days. K Khyati (15.0%) and K Frysona (17.4%) exhibited marked improvement in total tuber yield. But improvement in productivity (2.9%) of cv. K Pukhraj was insignificant (Fig. 50). Further work in this direction will be carried out in next crop season.

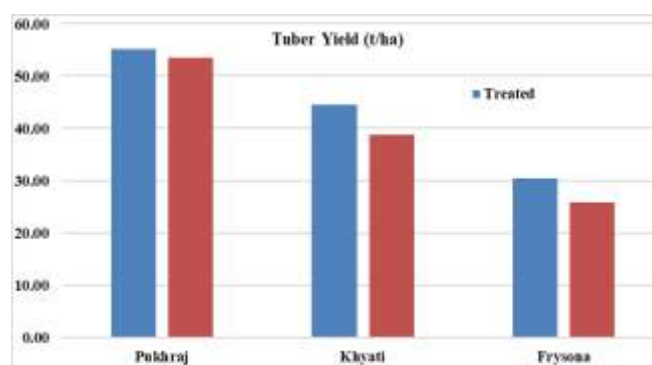


Fig. 50: Tuber yield enhancement by pre-planting seed treatment

Studies on knobbiness in Kufri Bahar tubers

An experiment was carried out at Jalandhar for understanding knobbiness behaviour in K Bahar (Fig. 51). The tubers were produced through aeroponics from indexed tubers. Sprouted eyes were scooped from indexed tubers and seedlings were raised in sterilized polyurethane foam, under artificial light in controlled conditions. Twenty day old plants/seedlings were further shifted to aeroponics to produce tubers. Aeroponically produced tubers were having knobbiness to the extent of 15 per cent. Knobby and normal shaped round tubers were further planted separately in field conditions in next season. In harvest, 7.08% knobby tubers were observed from normal round mother tubers, whereas 7.14% knobby tubers were recorded from knobby mother tubers. Study will continue further for understanding problem of knobbiness in K Bahar produced through hi-tech seed system.



Fig. 51: Tubers produced in aeroponics from indexed tubers and field produce from aeroponically produced tubers of cv. K Bahar

Studies on temperature variation in aeroponic system

Aeroponic systems are installed in fan and pad cooled high-tech green houses. Temperature profile of different greenhouses was studied to further understand and optimize the length of greenhouse structures. Variation of temperature from pad end to fan end in three different greenhouses (L-1, L-2 & L-3) at 13:00 hours was recorded (Fig. 52). This information will be used for designing the length of green house and thereby of grow boxes for optimizing minituber yield per unit area and time.

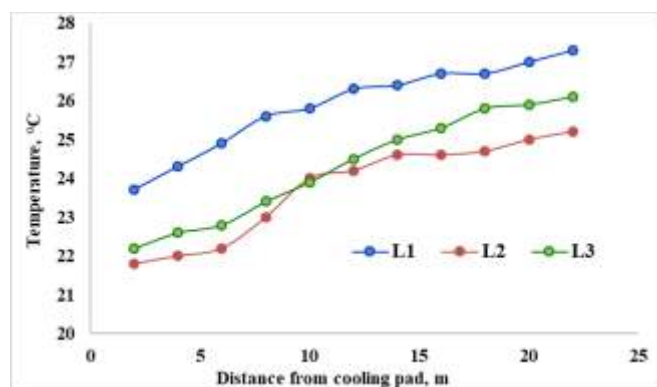


Fig. 52: Temperature profile along with length of grow box of aeroponic unit

Engineering technologies for potato production and utilization (PI: Sukhwinder Singh, Co-PI: Brajesh Nare, Prince Kumar)

Small tools for potato cultivation: Two hand tools were designed for marking on prepared soil ridges during minituber planting process. It includes a frame, handle, thrust plate and four marking pegs. During the planting of minitubers, 66 x 15 cm (base x height) trapezoidal ridge is formed with tractor operated ridger. Impressions of 5-7 cm deep are formed with this tool by simply pressing the handle on the soil ridges. Minitubers are further placed in these impressions/holes manually and covered with 3-5 cm thick layer of soil. This tool is simple in fabrication and useful for precise planting of minitubers.

Pull type safe spraying system

A battery operated pull type spraying system has been developed for spraying of agrochemicals with consideration of human safety. It consists of a light weight main frame, two wheels, handle, spray tank, pump, nozzles and control unit. In this system pump, battery and nozzles are mounted on the frame, where, the nozzle boom of the system is placed 2.5-3.0 m away from the operator. This arrangement protects the operator from exposure of harmful chemicals.

Patents: 3

Title	Patent type	Status	Reg. No.
Trough for production of plants (S type VEGFAST Trough)	Design	Granted	340333-001
Trough for production of plants (Rectangular VEGFAST Trough)	Design	Granted	340330-001
Vertical hydroponic system for production of plants	Design	Granted	347610-001

DIVISION OF PLANT PROTECTION

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, Vinay Sagar & Priyank H Mhatre)

In most of the locations in the sub-tropical plains, late blight appeared during second-third week of January, 2022; however, in West Bengal it appeared during 2nd week of February. Hence, losses were insignificant. However, in the hills it appeared early i.e. within 20 days of planting at Ooty and intensity of blight was up to 100%; whereas in Shimla hills, it appeared on 11th July, 2022 and intensity of the disease was up to 80%. Besides, the occurrence of early blight was also reported from most of the potato growing areas and its intensity ranged between 2-29.5%. Incidence of common scab is increasing across agro-ecologies. At Ooty, the incidence of common scab was recorded up to 80% in certain cultivars (Fig. 1).



Fig. 1: Severity of scab disease in Kufri Girdhari

Comparative Genomics of Potato Pathogens Characterization of *Phytophthora infestans* (Sanjeev Sharma & Sundaresha S)

Understanding pathogen variability is essential for devising suitable management strategies. The population of *P. infestans* was monitored for mating types, sensitivity to fungicides and SSR genotypes. A total of 124 isolates of *P. infestans* collected during the crop season of 2021-22 from different potato agro-ecologies were mated individually with the reference isolates Jal 21-1(A1) and HP 21-86 (A2). Isolates that produced oospores with the A2 tester were designated as A1 mating type. Similarly, isolates forming oospores with A1 tester were designated as A2 mating type. Isolates forming oospores with both tester

isolates and on their own were designated as self-fertile i.e. homothallic. The results revealed that 29 (59.18%) out of 49 isolates collected from West Bengal were homothallic belonging to A1 mating type. Similarly, in Punjab, 7 (46.67%) out of 15, in Pune (Maharashtra), 2 out of 2 were homothallic belonging to A1 mating type while 7 (12.73%) out of 55 in Himachal Pradesh were homothallic belonging to A2 mating type. On the other hand, the isolates collected from Jharkhand, Bihar and Haryana (one from each location) were A1 mating type (heterothallic). None of the isolates from these locations was self-fertile. In general, 45 (36.29%) isolates were homothallic belonging to both A1 and A2 mating types. This information is important for planning strategies for the effective management of late blight in India.

Phytophthora infestans isolates (130) were also phenotyped for fungicide / oomycide (metalaxyl / mefenoxam, cymoxanil, dimethomorph, phenomidon and amisulbrom) sensitivity. All tested isolates were observed to be intermediate resistant/resistant to metalaxyl / mefenoxam (Fig. 2) while sensitive to cymoxanil, dimethomorph, fenamidone and amisulbrom fungicides.

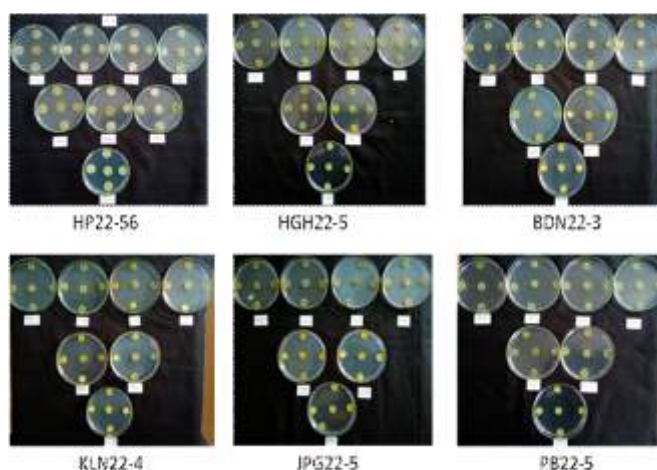


Fig. 2: Evaluation of metalaxyl/mefenoxam against *Phytophthora infestans*

Genotyping of *P. infestans* by SSR markers has proven valuable tools for tracing pathogen population change as these markers are robust

and provide comparable results between laboratories. Ninety five isolates of *P. infestans* collected from different agro-ecologies of the country (Himachal Pradesh, Punjab, Haryana,

Pune, Jharkhand, Bihar and West Bengal) were characterized using 12-plex PCR assay. Results revealed that all the isolates belong to EU_13_A2 clonal lineage (**Fig. 3**) only.

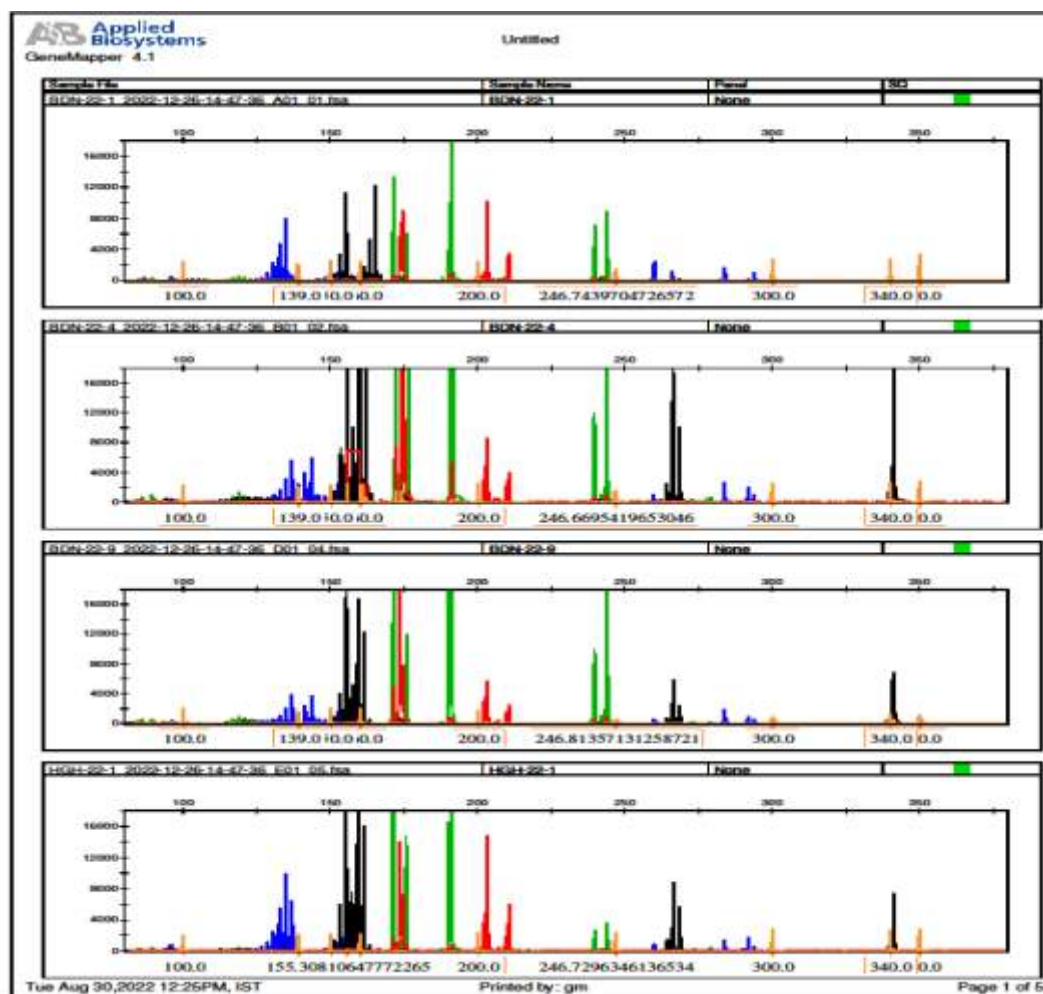


Fig. 3: Genotyping of *Phytophthora infestans* isolates using SSR markers reveals EU_13_A2 clonal lineage

The incidence of Sclerotium rot is being observed sporadically in western UP. Therefore, it was planned to evaluate a subset of *Sclerotium rolsfii* isolates collected from potato, lady finger, ginger and taro against carbendazim 25 + mancozeb 50% WS under *in vitro* conditions. Result revealed that cent-percent isolates were resistant to the tested fungicide at 10 and 20 ppm. However, at 40 ppm 30% isolates were resistant, 30% intermediate resistant and 40% were sensitive. At 60 ppm, 30% isolates were intermediate resistant and 70% were sensitive. None of the isolate was resistant at this concentration.

Characterization of *Streptomyces* species

The infected potato tubers showing characteristic scab symptoms were collected from various potato growing regions of Punjab, Haryana, Rajasthan, Gujarat, Uttar Pradesh, Bihar, West

Bengal, Odisha, Jharkhand, Telangana, and Arunachal Pradesh during 2021-22. The scab lesions on tubers appeared as rough, corky lesions, which ranged from a mere brownish roughening or abrasion of tuber skin (russet scab), to raised dotted or circular lesions or deep or shallow star shaped corky lesions measuring 3-4 mm pits surrounded by corky depositions (**Fig. 4**). The isolations on starch casein agar medium yielded 78 *Streptomyces* spp. isolates. DNA extraction of all the isolates was done by using a versatile quick-prep method for genomic DNA of Gram-positive bacteria. The phylogenetic analysis based on 16s rRNA gene sequences indicated that Indian *Streptomyces* isolates belonged to previously described different pathogenic *Streptomyces* species (*Streptomyces scabiei* is predominant one). The molecular identification of these isolates is under progress.



Fig. 4: Scab infected tubers

All the *Streptomyces* spp. isolates were also analysed by PCR for the presence of genes associated with pathogenicity i.e. pathogenicity islands (PAI) using primers specific to *txtAB* operon, the *tomA* gene and the *nec1* gene. Among the tested isolates, only eighteen isolates were positive for all the three marker genes i.e. *txtAB*, *tomA* and *nec1* genes; six isolates for *txtAB* and *tomA* genes; two for *txtAB* and *nec1* gene; five for *tomA* and *nec1*; and one for *txtAB* only (Fig. 5).

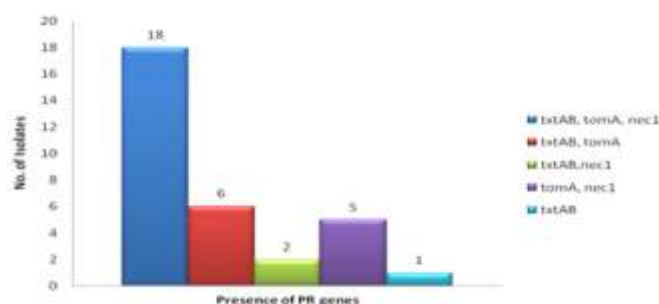


Fig. 5: Presence of pathogenicity genes in different isolates of *Streptomyces*

Molecular Identification of *Fusarium solani* associated with potato dry rot disease

Recently, some members of the *Fusarium solani* species complex (FSSC) have been moved to the genus *Neocosmospora* which comprises a separate clade in phylogenetic analyses and contains both plant and human pathogens. However, still more work is required in the genus as not all of the species of FSSC have been identified as *Neocosmospora* and the exact species number in this genus remains vague. In a previous study, we identified 13 *Fusarium solani* isolates based on ITS, TEF1 α . Further, those 13 isolates which were belonging to *Fusarium solani* group were characterized using RPB2 gene to delineate them in the new group. The PCR amplification gave bands of 900 bp each. The gel extraction followed by sequencing of partial genomic DNA demonstrated that all these isolates belonged to *Fusarium solani* with maximum identity in the range of 99-100 %. None of the isolates matched with recently identified *Neocosmospora* species. The obtained 13 sequences were deposited to the Genbank and accession numbers were obtained (Table 1).

Table 1: RPB2 gene-based molecular identification of *Fusarium solani*

Isolate	RPB2 gene	GenBank Accession
GF4	<i>Fusarium solani</i>	OM319400
GF14	<i>Fusarium solani</i>	OM319401
FJ1	<i>Fusarium solani</i>	MZ227124
FJ2	<i>Fusarium solani</i>	OM319374
PF3	<i>Fusarium solani</i>	OM319353
MOD1	<i>Fusarium solani</i>	OM319354
NE5	<i>Fusarium solani</i>	OM319355
NE6	<i>Fusarium solani</i>	OM319356
NE7	<i>Fusarium solani</i>	OM319357
OTY4	<i>Fusarium solani</i>	OM319358
OTY5	<i>Fusarium solani</i>	OM319375
OTY9	<i>Fusarium solani</i>	OM319400
OR4	<i>Fusarium solani</i>	OM319401

Epidemiology and Forecasting of Potato Pathogens

Forecasting of late blight (Sanjeev Sharma & Mehi Lal)

Indo-Blightcast model was used to predict appearance of late blight across the agro-ecologies during *kharif* 2022 and *rabi* 2022-23 and the model predicted late blight accurately at each location (Table 2). Accordingly, the agro-advisories were issued to respective regions through print and electronic media to protect the crop from the onslaught of late blight.

Table 2: Performance of Indo-Blightcast model during *kharif* 2022 and *rabi* 2022-23

Location	Prediction date of late blight	Actual date of late blight appearance
Bhubaneswar (Odisha)	Did not predict	Did not appear
Deesa (Gujarat)	Did not predict	Did not appear
Dholi (Bihar)	26.12.2022	03.01.2023
Faizabad (UP)	Did not predict	Did not appear
Hisar (Haryana)	Did not predict	Did not appear
Jorhat (Assam)	24.12.2022	26.12.2022
Kanpur (UP)	Did not predict	Did not appear
Kota (Rajasthan)	Did not predict	Did not appear
Pantnagar (Uttarakhand)	Did not predict	Did not appear
Pune (Maharashtra)	Did not predict	Did not appear
Modipuram (UP)	Did not predict	Did not appear
Jalandhar (Punjab)	Did not predict	Did not appear
Bankura (WB)	09.01.2023	21.01.2023
Burdwan (WB)	27.12.2022	08.01.2023
Hooghly (WB)	10.01.2023	16.01.2023
Jalpaiguri (WB)	03.01.2023	14.01.2023
West Mednapur	Did not predict	Did not appear
Shimla (HP)	07.07.2022	11.07.2022

Pathogenicity test of *Streptomyces* isolates

Tuber slice assay

Pathogenicity of 44 *Streptomyces* isolates was tested by tuber slice method and the severity was determined based on the lesion and pit formation on tuber slices. Based on the symptoms developed, the isolates were grouped into four different categories *viz.*, severe, medium, mild and non-pathogenic. Out of forty four, fourteen isolates were severely pathogenic and produced deep pits along with the dark lesions. Eleven isolates were medium in pathogenicity and formed dark lesions with slight pits. Eighteen isolates produced light lesion with no or slight pits and were kept under the mild pathogenic category (Fig. 6).

Tuber Slice Assay

■ Severe ■ Medium ■ Mild ■ Non Pathogenic

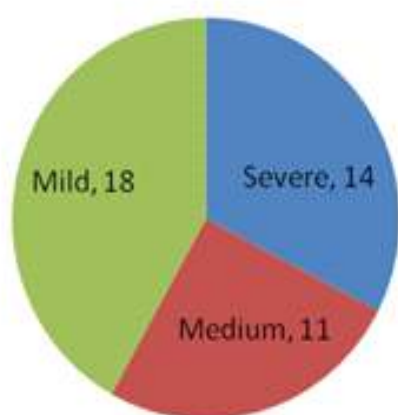


Fig. 6: Characterization of *Streptomyces* species isolates for aggressiveness

Radish seedling test

The germinating radish seeds (*cv Chetaki*) were used for this assay. Ten germinating seeds per isolate were transferred and incubated at room temperature (25°C) on each culture plate. Root browning/ necrosis indicate pathogenic nature of each individual *Streptomyces* isolates. Among 44 isolates, 23 were found to be highly pathogenic, 12 were moderately pathogenic and remaining 7 were mild pathogenic and 2 isolates were found to be non-pathogenic showing no necrosis on radish seedling (Fig. 7).



Fig. 7: Radish seedling test for pathogenicity

Pot study in glass house

To confirm pathogenicity of the all the 44 isolates, tissue culture raised plants (*cv. Kufri Jyoti*) were planted in pots (two plants per pot) with sterile soil mixed with coco-peat and perlite (1:1:1) under greenhouse conditions (18 to 28°C). Each pot was inoculated one week after planting with 200 ml spore suspension (1×10^6 CFU/ml) of respective strains of *Streptomyces* isolates. The inoculation was again repeated at tuber initiation stage. After two months of last inoculation, tubers were harvested and observed for visible symptoms. All the 44 isolates showed visible symptoms ranging from severe corky deep pitted scab to mild russet with no symptoms on above plant parts (Fig. 8). The un-inoculated plants produced healthy tubers with no scab symptoms.



Fig. 8: Pot study in glasshouse showing inoculated plant, infected and healthy tubers

Dynamics of mycelial growth and sporulation behaviour of *Fusarium* species at different temperature regimes

Potato dry rot caused by several *Fusarium* species is a major concern in potato production. The growth and sporulation behaviour of *Fusarium* isolates can be influenced by a range of environmental factors, including temperature. At different temperature regimes, the mycelial growth and sporulation behaviour of *Fusarium* isolates may vary. In general, *Fusarium* species are known to grow optimally at temperatures between 20-30°C. However, some species can tolerate a wide range of temperatures, from as low as 4°C to as high as 40°C. When exposed to temperatures outside their optimal range, *Fusarium* isolates may exhibit changes in their growth rate and morphology which affects the disease development in susceptible hosts. With this information and background, a study was proposed to assess the spore production, mycelial growth and pathogenicity of diverse *Fusarium* species at 4°C, 10°C, 18°C, and 24°C. The isolates were morphologically and molecularly identified in a previous study and pathogenicity was established. These well characterized isolates of six *Fusarium* species were observed for the aforementioned parameters. The results of mycelial growth revealed that significant differences exist among *Fusarium* species at different temperatures. Among six species, the mycelial diameter was significantly higher ($p < 0.005$) for *Fusarium sambucinum* followed by *Fusarium oxysporum* and *Fusarium solani* at all the storage temperatures (Fig. 9). Interestingly among all these species, *Fusarium sambucinum* and *Fusarium verticillioides* could grow well at 4°C. The sporulation pattern revealed significant differences among species at different storage temperatures. The highest sporulation was observed in *Fusarium sambucinum* at all storage

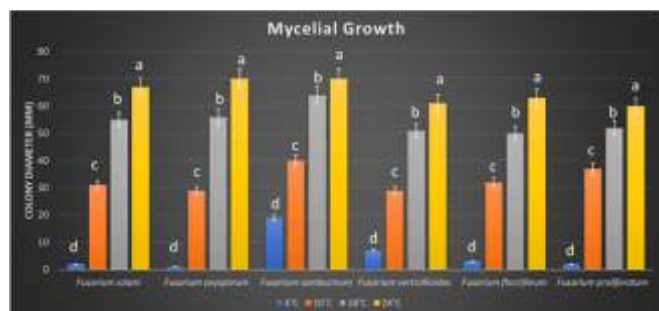


Fig. 9: The mycelial growth pattern of different *Fusarium* species at temperatures ranging from 4-24°C

temperatures (Fig. 10). Two of the fungi, viz., *Fusarium sambucinum* and *Fusarium verticillioides* sporulated well even at 4°C. The disease assessment in terms of lesion diameter revealed the higher aggressiveness of *Fusarium sambucinum* at 4 to 24°C. The heat map depicts the progressive increase in lesion diameter over all the storage temperatures, and significant differences were observed among the six species in causing the rot development in inoculated tubers (Fig. 11).

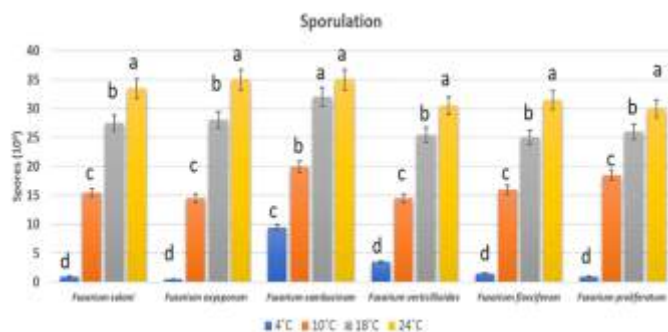


Fig. 10: The sporulation behaviour of different *Fusarium* species at temperatures ranging from 4-24°C.

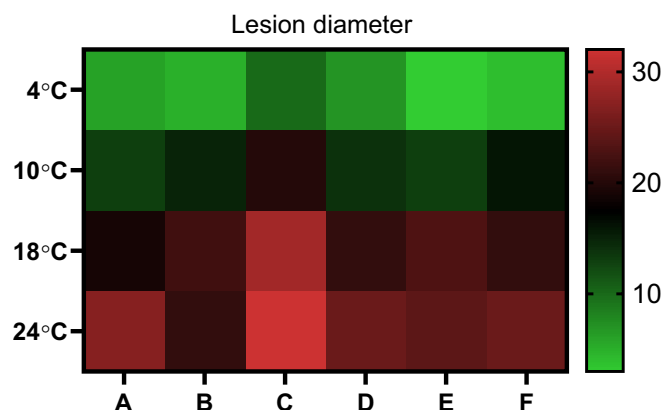


Fig. 11: Heat map depicting the lesion diameter on artificially inoculated tubers at temperatures ranging from 4-24°C (A: *Fusarium solani*, B: *Fusarium oxysporum*, C: *Fusarium sambucinum*, D: *Fusarium verticillioides*, E: *Fusarium flocciferum*, F: *Fusarium proliferatum*)

Host-pathogen Interaction

Kinetic metabolite profiling of potato leaves infected with *Phytophthora infestans* (Sanjeev Sharma, Portia Singh, Shyam K Masakapalli)

This work was done in collaboration with IIT, Mandi. Potato varieties namely Kufri Chandramukhi, Kufri Jyoti (susceptible), Kufri Himalini (moderately resistant) and Kufri Girdhari (resistant) were challenge inoculated with *Phytophthora infestans* in the screening chamber and samples were collected at regular intervals (0 hpi up to 120 hpi). The harvested samples were crushed in liquid nitrogen, vacuum freeze dried and subjected to aqueous methanolic

extraction. Derivatized samples (1 μ l) were injected, using an automatic liquid sampler (7683B ALS, Agilent, USA) by splitless mode into GC-MS system (7890A GC, 5975, USA). Molecules were separated by an DB-5MS column (5% diphenyl, 95% dimethylpolysiloxane; 30 m $\times$ 0.25 mm $\times$ 0.25 μ m; Restek USA) and helium was used as a carrier gas at a constant flow rate of 1 mL/min. Front injection temperature was set constant at 250 $^{\circ}$ C. A temperature gradient of 1 min at 50 $^{\circ}$ C isothermal, followed by a 10 $^{\circ}$ C/min oven temperature gradient to a final 200 $^{\circ}$ C, and then hold for 4 min at 200 $^{\circ}$ C, followed by a 10 $^{\circ}$ C/min to a final 300 $^{\circ}$ C temperature for 10 min was used. Ions were generated by a 70-eV electron beam in electron ionization mode. The spectra were recorded with a scanning range of 50-600 m/z. The lower limit of detection of the adopted method was calculated to 0.01 μ g/ μ l of ribitol.

A total of 96 GC-MS peaks of MeOX-TMS derivatised extracts were annotated as metabolic features (**Fig. 12**). The metabolic features with a probability score of >70% against the NIST17 and/or those that matched the elution times and m/z fragmentation patterns of the metabolic standards were considered. The identified metabolites (n=66) from healthy and infected samples (**Table 3**) of all the varieties were grouped into amino acids (valine, leucine, proline, serine, asparagine, iso-leucine, and aspartic acid), organic acids (malic, fumaric, lactic, 4-aminobutanoic acid, and 2,3,4 trihydroxy butyric acid), sugars and their derivatives (glucose, xylose, fructose and mannitol), lipids (Palmitic acid, stearic acid) and secondary metabolites and their pathway intermediates (shikimic acid, quinic acid, putrescine and myoinositol).

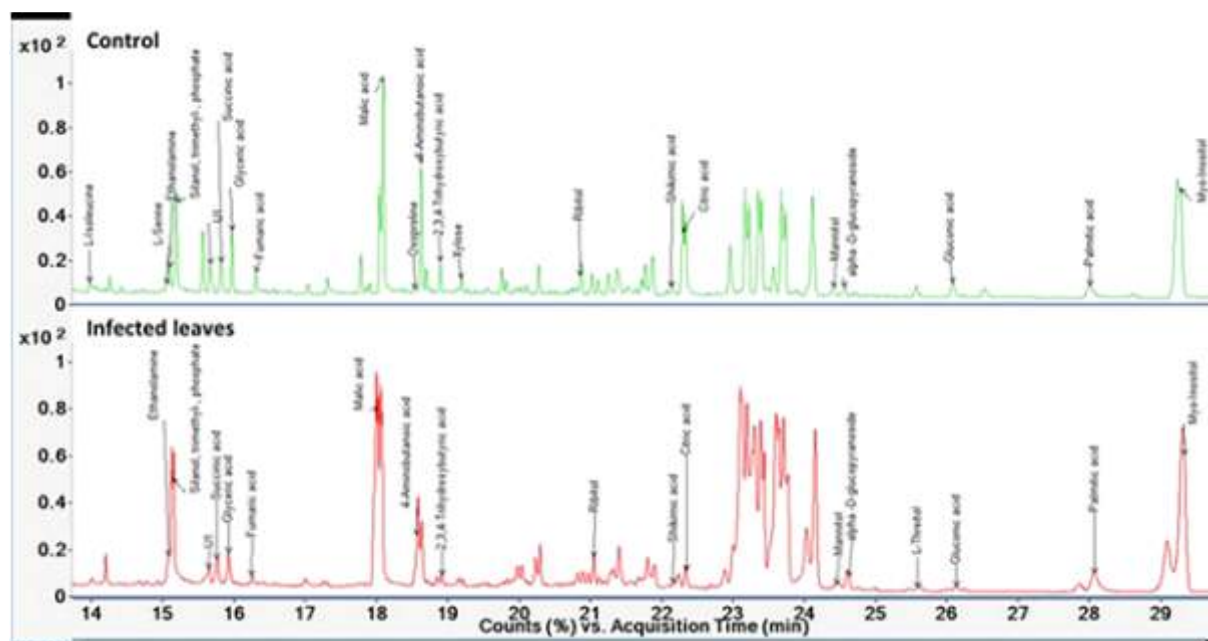


Fig. 12: Representative GC-MS spectra annotated metabolic profile of control and infected leaves

Table 3: Metabolites identified from NIST17 and Fiehn13 library

Amino acid	Organic acid	Sugars
L-Valine	Succinic acid	Xylose
L-Leucine	Glyceric acid	D-Fructose
L-Proline	Fumaric acid	D-Glucopyranoside
L-Isoleucine	Boric acid	D-Gluconic acid
L-Serine	Lactic acid	Mannobiose
Phenylalanine	Malic acid	Sucrose
Asparagine	5-Oxoproline	
L-Aspartic acid	4-Aminobutanoic acid	Phenolics
	Trihydroxy butyric acid	Shikimic acid
Sugar Alcohol	Ethanolamine	Quinic acid
D-Mannitol	Phosphoric acid	Lipid
Erythritol	Tartaric acid	Palmitic acid
Myo-Inositol	Citric acid	Stearic acid

Unsupervised multivariate data analysis of all the metabolic features resulted in different clusters of healthy and infected samples with PC1 and PC2 scores of 35.9% and 16.7%, respectively (**Fig. 13a**). The metabolites of the susceptible cultivars (Kufri Chandramukhi & Kufri Jyoti) had close relatedness in both healthy and infected samples (**Fig. 13b & 13c**). The pathway impact analysis depicted the impact of identified metabolites involved in different metabolic pathways i.e., sugar metabolism, amino acid metabolism, citrate cycle etc (**Fig. 13b**). The heatmap (**Fig. 13c**) showed the response of metabolites in all the four

varieties in both the categories i.e. infected and healthy. The metabolite which showed drastic elevation in the varieties was Putrescine. Apart from that the change in sucrose and gluconic acid

has also been observed in infected leaves. The data is further being explored to identify potential disease markers.

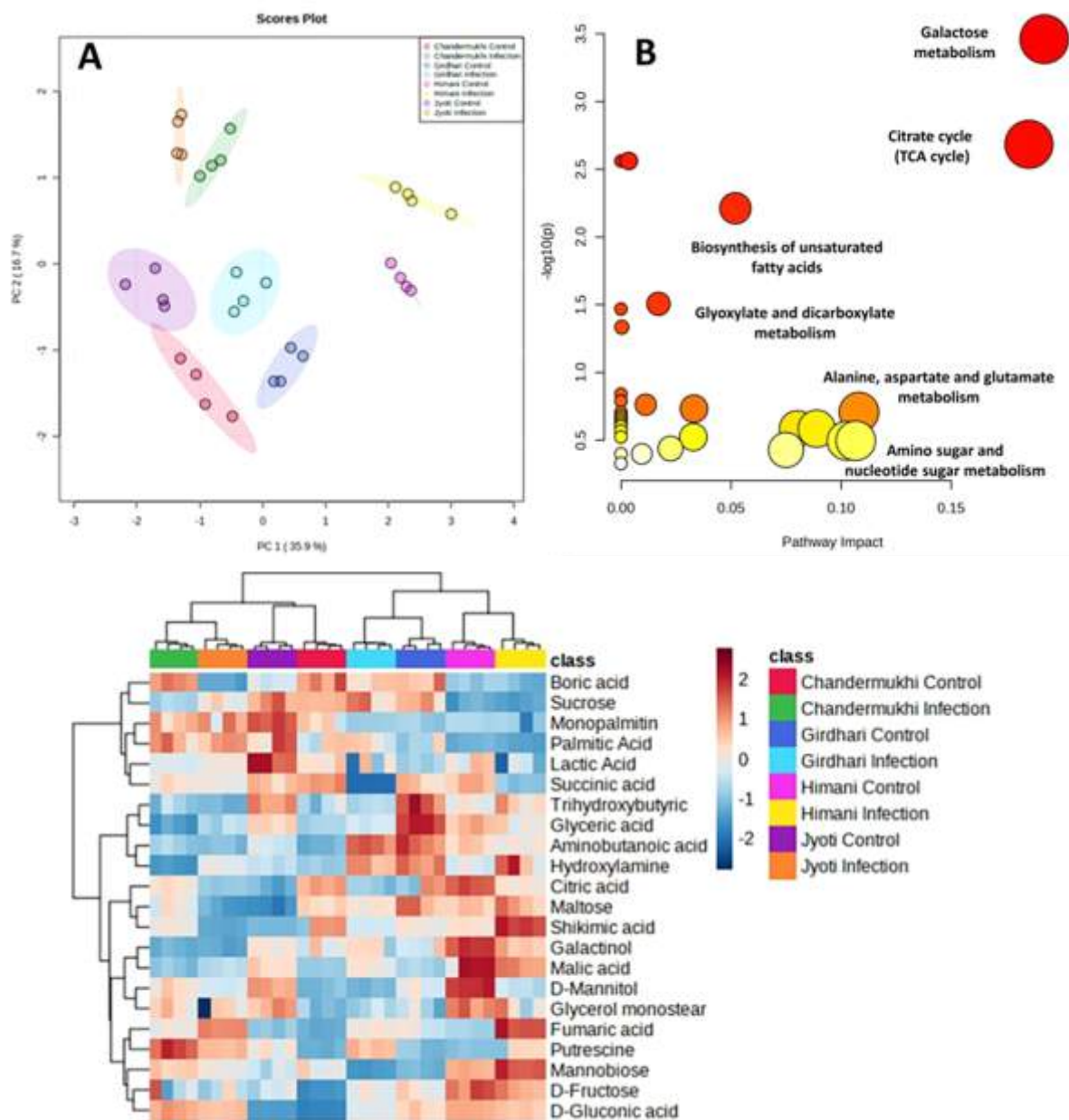


Fig. 13: a) PCA plots showing variation among metabolome under control and infection under varieties b) the metabolic pathways influenced under *P. infestans* infection c) heatmap showed the response scale of metabolites

Management of Potato Pathogens

Chemical management (Mehi Lal, Sanjeev Sharma, Priyank H Mhatre)

It is essential to test new fungicides on regular basis for their efficacy and subsequently for their inclusion in spray schedules for management of late blight. Ten treatments consisting of existing and new fungicides (Dimethomorph 12% + Pyraclostrobin 67% WG, Cyazofamid 34.5% SC, Benalaxyl 4 M + mancozeb 65% WP and Carbendazim 12 + mancozeb 63% WP) were

evaluated against late blight of potato for two crop seasons. Amongst the tested fungicides, Cymoxanil 8 + mancozeb 64% WP @ 0.3% (23.67% DS), Dimethomorph 50% WP @ 0.1% (26.00% DS), Fenamidon 10 + mancozeb 50% WG @ 0.3% (26.00% DS) and Dimethomorph 12% + Pyraclostrobin 67% WG @ 0.25% (24.00% DS) showed less disease severity as against control (98.67%) (Fig. 14). These results indicate that these fungicides could be used effectively for the management of late blight.

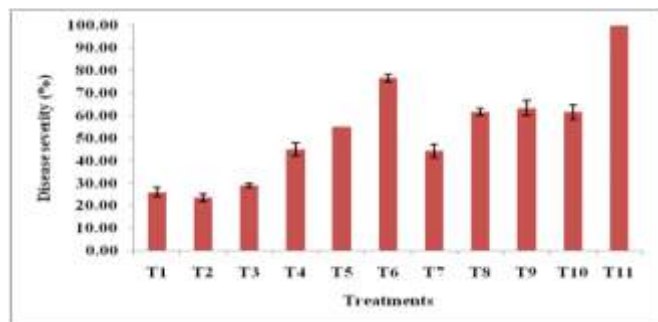


Fig. 14: Efficacy of new chemicals against late blight of potato

[T1: Dimethomorph 50%WP @ 0.1%, T2: Cymoxanil 8% + mancozeb 64% WP @ 0.3%, T3: Fenamidon 10% + mancozeb 50% WG @ 0.3%, T4: Cyazofamid 34.5% SC @ 0.04% + mancozeb 75% WP @ 0.2%, T5: Cyazofamid 34.5% SC @ 0.02% + mancozeb 75% WP @ 0.1%, T6: Cyazofamid 34.5% SC @ 0.04% + mancozeb 75% WP @ 0.1%, T7: Dimethomorph 12% + pyraclostrobin 67% WG @ 0.25%, T8: Benalaxyl M 4% + mancozeb 65% WP @ 0.5%, T9: Carbendazim 12% + mancozeb 63% WP @ 0.35%, T10: Azoxystrobin 12.5 + Tebuconazole 12.5 SC @ 0.1%, T11: Control]

Use of phosphorus acid for late blight management

Spray schedule consisting of Phosphorus acid (0.2%) and *Bacillus subtilis* (0.25%) + *Trichoderma viride* (2.0%) were evaluated during Rabi season 2020-21 & 2021-22. Results revealed that application of Phosphorus acid (before disease appearance) - *B. subtilis* + *T. viride* at disease appearance - Phosphorus acid - *B. subtilis* + *T. viride* recorded lowest average disease severity (48.75%) followed by four sprays of Phosphorus acid (58.75%) as against of 90.75% in control. The application of four sprays of *B. subtilis* + *T. viride* resulted in 65% disease severity.

At Ooty, seven spray schedules were evaluated for the management of late blight. Results revealed that treatment (T2) consisted of chlorothalonil @0.25% (before appearance of disease) followed by Flupicolide 5.56% + Propamocarb hydrochloride 55.6% SC @ 0.3% (at 6-12 days intervals) recorded maximum tuber yield (21.49 t/ha). The next best treatment was T1 i.e. Prophylactic spray (just at the time of canopy closure) with mancozeb @0.25% followed by Flupicolide 5.56% + Propamocarb hydrochloride 55.6% SC @ 0.3% at 6-12 days intervals (16.76 t/ha). This was followed by other fungicide treatments T6, T5, T4 and T3. All the fungicide treatments significantly reduced the intensity of late blight (AUDPC) compared to untreated control. The lowest yield (1.68 t/ha) and highest AUDPC value (219) was recorded in untreated control (T7) (Fig. 15).

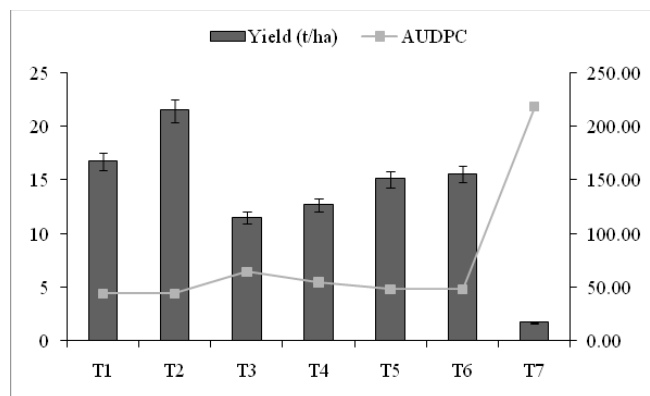


Fig. 15: Effect of different fungicides spray schedule on late blight development

[T1: Prophylactic spray (just at the time of canopy closure) with mancozeb @0.25% followed by Flupicolide 5.56% + Propamocarb hydrochloride 55.6% SC @ 0.3% at 6-12 days intervals, T2: Prophylactic spray (just at the time of canopy closure) with chlorothalonil @0.25% followed by Flupicolide 5.56% + Propamocarb hydrochloride 55.6% SC @ 0.3% at 6-12 days intervals, T3: Prophylactic spray (just at the time of canopy closure) with mancozeb @0.2% followed by Cymoxanil 8% + Mancozeb 64% WP @ 0.25% at 6-12 days intervals, T4: Prophylactic spray (just at the time of canopy closure) with chlorothalonil @0.25% followed by Ametoctradin + Dimethomorph @ 0.3% at 6-12 days intervals, T5: Prophylactic spray (just at the time of canopy closure) with mancozeb @0.25% followed by Metiram 44% + Dimethomorph 9% WP @ 0.1% followed by alternate sprays at 6-12 days intervals, T6: Farmers practice [Prophylactic spray (just at the time of canopy closure) with mancozeb @0.25% followed by Cymoxanil 8% + Mancozeb 64% WP @ 0.25% followed by mancozeb @0.25% followed by Metiram 44% + Dimethomorph 9% WP @ 0.1% followed by mancozeb @0.25% followed by Ametoctradin + Dimethomorph @ 0.3% followed by mancozeb @0.25% followed by Cymoxanil 8% + Mancozeb 64% WP @ 0.25%, T7: Control]

Management of tuber borne diseases (Mehi Lal, Vinay Sagar & Sanjeev Sharma)

Under the category of soil and tuber borne fungal pathogens, *Rhizoctonia solani* causing black scurf and stem canker of potato is a major pathogen. About eight different fungicides are available in the market to manage this disease. However, their efficacy varies with the dose and methods of application. Different concentrations of fungicides (Penflufen 22.43% FS, Pencycuron 22.9% SC, Thifluzamide 24% SC, Carbendazim 25% + Mancozeb 50% WP, Carbendazim 12% + Mancozeb 63% WP, Carboxin 37.5% + Thiram 37.5% WS, Carboxin 17.5% + Thiram 17.5%, Thiophanate-methyl 450g/l + Pyraclostrobin 50g/l w/v, Validamycin, Azoxystrobin 23% SC, Boric Acid & Huwa San TR 25) were evaluated for management of black scurf of potato using

seed treatments by both dip and spray methods at the time of planting for two crop seasons (2020-21 & 2021-22). It was observed that all the treatments were effective in reducing the disease incidence and disease severity in comparison to control. However, lowest disease incidence (2.67%) and disease severity (0.67%) was recorded with Thifluzamide 24%SC @ 0.35% (T10) followed by Penflufen @0.1% (7.33% DI, 2.00% DS, **Fig. 16**). These treatments differed significantly from each other. Pencycuron @ 0.25% (T1) as dip method & Pencycuron @ 0.35% (T2) as spraying method and Azoxystrobin

@ 0.15% (T4) as spray method, Penflufen @ 0.083% (T7) as dip method and Thiophanate-methyl 450g/l + Pyraclostrobin 50g/l @ 0.5% as dip method (T17), also recorded less disease incidence and severity. Highest disease incidence (84.34%) and severity (40.26%) were recorded in disinfectant @ 10ml/L by dipping method (T21) followed by Carboxin 17.5 + Thiram 17.5% FF @ 0.3 using spray (T13) (DI: 81.17% & DS: 31.67%) against control (T23) 84.50% DI and 42.00% DS. These fungicides could be applied for managing black scurf of potato.

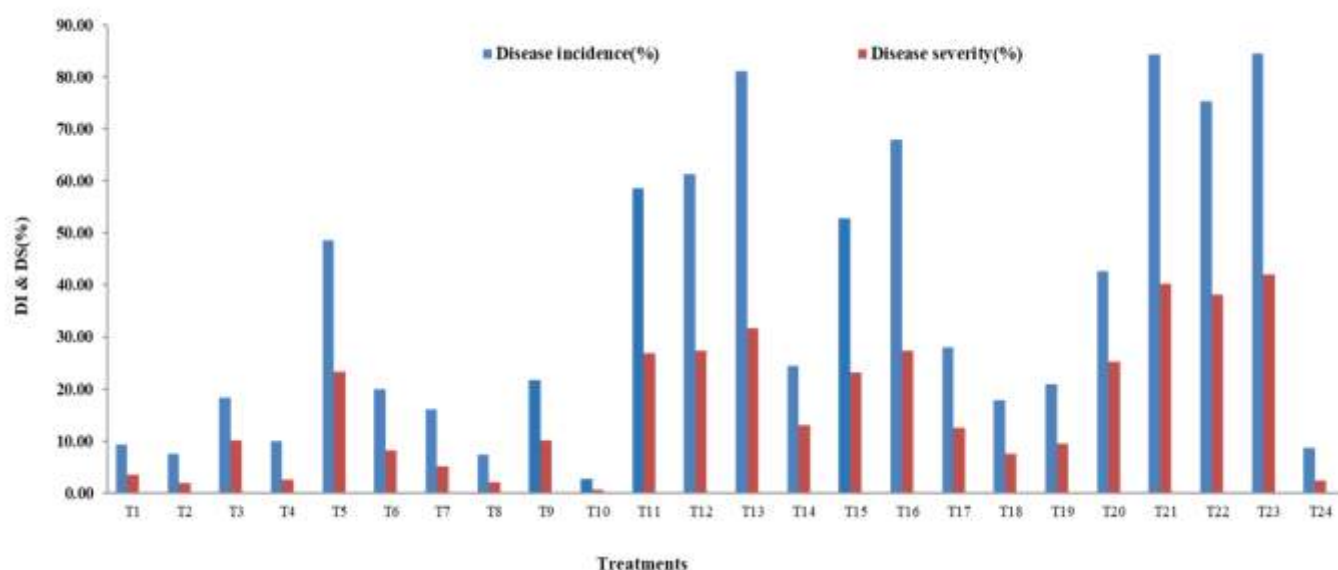


Fig. 16: Efficacy of different chemicals against Black scurf of potato

Field screening of potato varieties for resistance to *Ralstonia solanacearum*

Eight potato lines/ collections namely, Assomia Alu, SM/11-93, Badami, Champaran Lal,



Fig. 17: Screening of potato lines for resistance to *R. solanacearum* under field conditions in a bacterial wilt sick field

Rangpuria, K. Lauvkar, SM/ 03-23, and SM/ 92-338 having shown resistance to *Ralstonia solanacearum* in earlier *in-vitro* screening tests and in a pot experiment under controlled conditions were further tested under replicated field experiment in a bacterial wilt sick field at lower lab farm of ICAR-CPRI, Shimla. Variety “Kufri Jyoti” was planted in every alternate row as susceptible check. Two lines/ collections namely SM/92-338 and Badami did not show any wilt symptoms till harvesting, one line SM/11-93 showed good resistance (8.5% wilt) and rest all lines including susceptible check “Kufri Jyoti” wilted completely (**Fig. 17**). The brown rot incidence in Badami, SM/92-338 and SM/ 03-23 was 0, 4.0 and 10.0%, respectively, compared to 100.0% in Kufri Jyoti.

Screening of potato varieties for tolerance to thaxtomin A toxin through tuber slice assay

Pathogenic *Streptomyces* species synthesize the phytotoxin thaxtomin, which elicits scab symptoms and is the primary pathogenicity determinant in common scab-causing species. Due to its central importance in disease expression, selection for tolerance to thaxtomin A may be an effective way of preliminary screening of potato lines for resistance to *Streptomyces* sp. A total of 243 core collection

genotypes and varieties received from Crop Improvement Division were screened for their tolerance to Thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay. Only four lines 'CP 1012', 'CP 2171', 'CP 2110' and 'J/A-197' showed resistance (tested twice, **Fig. 18**) and rest were found highly sensitive to the toxin resulting in brown to black necrosis of tissues along with medium to deep pit formation on tuber slices.

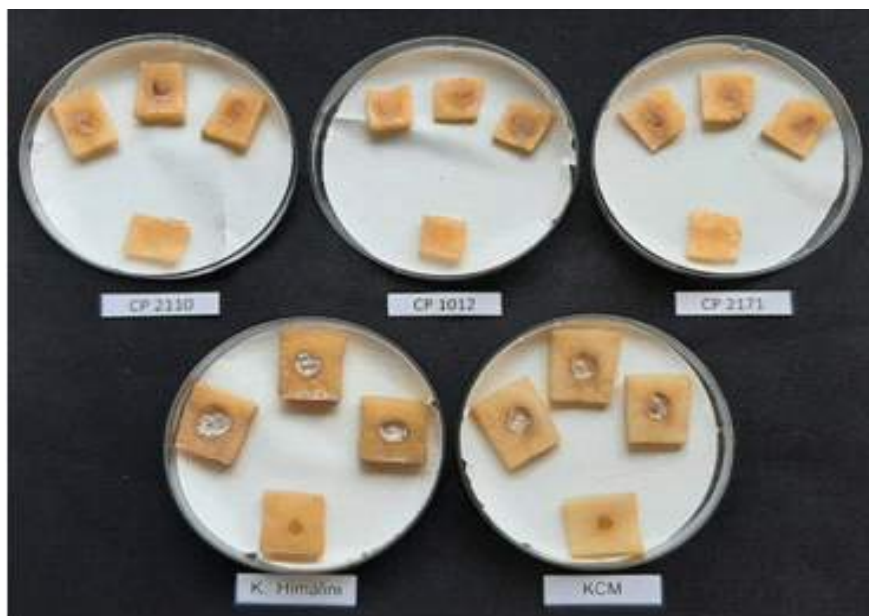


Fig. 18: Screening potato lines for tolerance to thaxtomin A toxin produced by *Streptomyces scabies* through tuber slice assay

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

A total of 137 *in-vitro* cultures and 05 TPS lines imported by Head, CI&ST (137 *In-vitro* lines from Peru CIP), M/s Sungrow Seeds Pvt Ltd (01 TPS line), M/s Syngenta India P Ltd (02 TPS lines) and Mahindra HZPC (02 TPS) lines were tested for post entry quarantined pathogens.

Project 2: Diagnostic and Management of Viral Diseases of Potato

Development of reverse transcription recombinase polymerase amplification (RT-RPA): A methodology for quick diagnosis of potato leafroll viral disease in potato (Ravinder Kumar, Rahul Kumar Tiwari, Milan Kumar Lal, Kailash Chandra Naga, Awadhesh Kumar, Brajesh Singh, Vinay Sagar, Sanjeev Sharma)

During the course of the study, we developed a reliable one-step RT-RPA assay that was found to be suitable for testing PLRV on a large scale in

seed potato production. Seed tubers are a primary means of disseminating viruses, and the fact that the established RT-RPA method could be employed for testing of tubers adds further value to this work. Compared to PCR, RT-PCR, and ELISA tests, RPA has several advantages, the most notable being its rapid detection time and the requirement for isothermal conditions (25-40°C). In contrast to RT-PCR, existing methods for detecting PLRV are labor-intensive, require highly specialized laboratory equipment, and take a significant amount of time. RT-PCR typically requires about 120 minutes (usually 35 cycles) before gel visualization can produce the desired result. Additionally, the DAS-ELISA assay for virus testing requires a minimum of two days to complete. The RT-RPA assay designed for PLRV can be carried out in a laboratory using basic equipment, and it can detect amplification in less than 30 minutes without the need for a thermal cycler (**Fig. 19**).

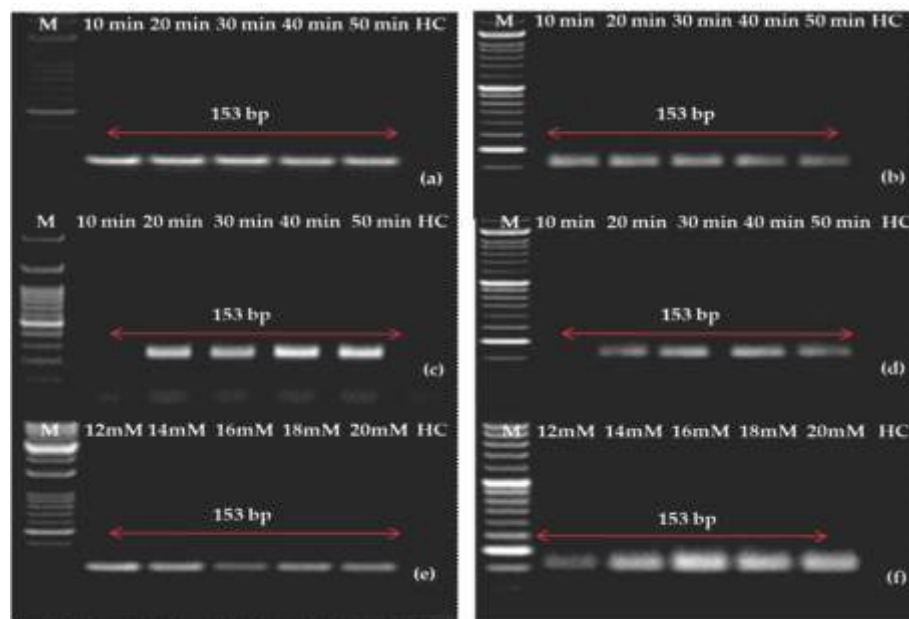


Fig. 19: Reverse transcription-recombinase polymerase amplification (RT-RPA) optimization for potato leafroll virus (PLRV) detection using forward and reverse primer LRRPAF3/R3-Set C. The RT-RPA amplified products on (a) a PCR machine and (b) a water bath using a cDNA template at a temperature of 40 °C and a duration range of 10, 20, 30, 40 and 50 min. Likewise, the RT-RPA amplified amplicons using total RNA (1 µL) in (c) a PCR machine and (d) a water bath under the same conditions of temperature and duration. Optimization of magnesium acetate concentrations ranging from 12 mM to 20 mM under a similar setup of (e) thermal cycler and (f) water bath. Lane M: 50 bp ladder; HC: healthy control.

Additionally, the proposed test benefits from the use of cellulose disc paper-mediated RNA extraction, which is relatively inexpensive. The study found that a one-step RT-RPA using a simple RNA extract is just as effective as the more traditional RT-PCR technique (**Fig. 20**). The sensitivity of the

RNA preparation method based on cellulose disc paper was not affected in any way when compared to RT-PCR from leaves. This was achieved by using 1.0% sodium sulfite in the extraction solution, which in the past has been shown to increase RNA production two to three times.

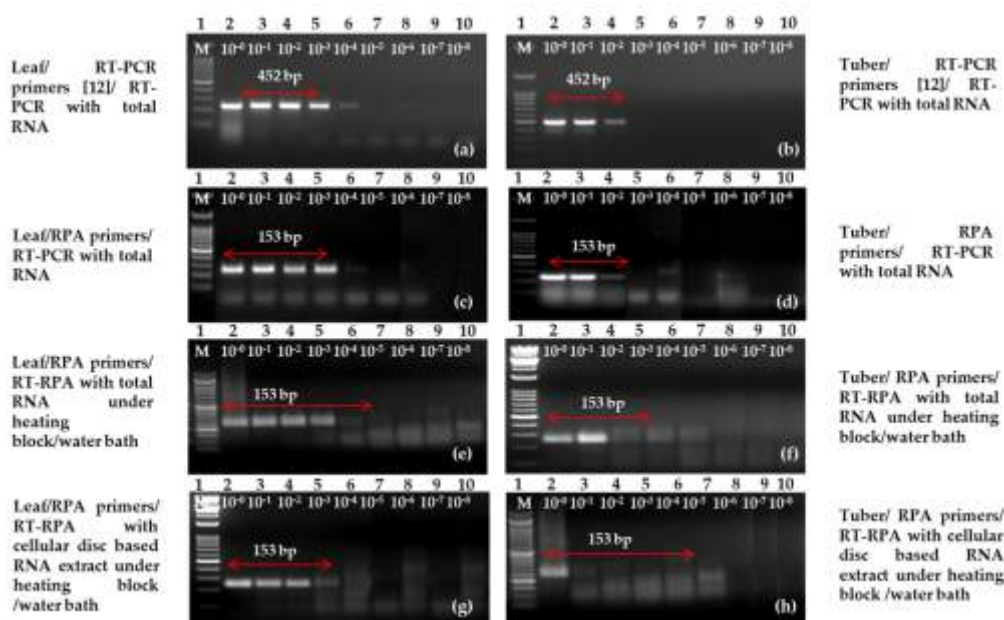


Fig. 20: Reverse transcription-polymerase chain reaction (RT-PCR) and reverse transcription recombinase polymerase amplification (RT-RPA) amplified amplicons at dilutions levels ranging from 10⁰ to 10⁻⁸ detect potato leafroll virus (PLRV). One-step RT-PCR with previously reported primers on purified RNA performed with (a) infected leaves and (b) infected tubers. One-step RT-PCR with optimized primer LRRPAF3/R3 on purified RNA in (c) infected leaves and (d) infected tubers. One-step RT-RPA with newly optimized primer LRRPAF3/R3 on purified total RNA in (e) infected leaves and (f) infected tubers. One-step RT-RPA with optimized primer LRRPAF3/R3 on cellular disc-mediated RNA extract in (g) infected leaves and (h) infected tubers. Lane M (a–h): 50 bp DNA ladder

The development of optimal primer specificity is crucial for RPA-based assays and requires the analysis of multiple sets of primers. In this study, the coat protein (CP) gene of PLRV was targeted due to its prevalence in diseased potatoes and its location at the 3'-end. The primer parameters, including annealing temperature, primer length, and GC composition, were carefully considered during the primer design process. While 30-35 bp primers are commonly used for RPA, the 27-31 bp primers used in this study gave satisfactory results, consistent with previous reports (Fig. 21).

The genetic diversity data of PLRV available in the NCBI database contributed significantly to the development of specialized primers, which were designed from highly conserved portions of the CP gene. Overall, the designed RT-RPA assay was able to detect PLRV rapidly and efficiently, making it a valuable tool for seed potato production. Compared to traditional detection methods such as PCR, RT-PCR, and ELISA, RT-RPA has the advantages of faster detection time, isothermal conditions, and the ability to be carried out in a laboratory using basic equipment.

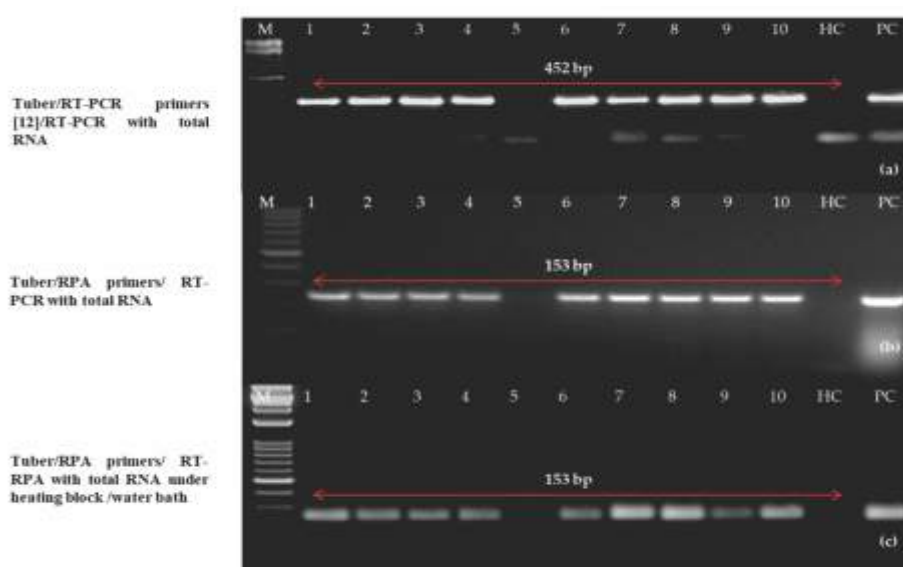


Fig. 21: Optimization of reverse-transcription recombinase polymerase amplification/reverse transcription-polymerase chain reaction (RT-RPA/RT-PCR) for successful detection in potato leafroll virus (PLRV) infected tubers. (a) One-step RT-PCR performed with previously reported primers on purified RNA; (b) one-step RT-RPA with newly optimized primer LRRPAF3/R3 on purified total RNA; (c) one-step RT-RPA with optimized primer LRRPAF3/R3 on cellular disc-mediated RNA extract. Lane M (a-c): 50 bp DNA ladder, lanes 1–15: potato leaf samples, PC: known positive, HC: healthy, NC: negative (water). In all three gel images, a 50 bp DNA marker (Lane M) has been used. The amplicons of infected tuber samples represent lane 1–10 along with a positive control (PC) and a healthy control (HC)

The developed one-step RT-RPA assay was tested on 129 field samples, including one leaf and one tuber sample each, and the results were compared to those obtained by standard DAS-ELISA and RT-PCR methods. The comparison showed that the RT-RPA assay was highly effective in detecting PLRV, and the results were consistent with those obtained by the traditional methods. The RT-RPA assay demonstrated a high level of sensitivity, specificity, and accuracy in detecting PLRV in the samples tested, making it a reliable and efficient method for large-scale testing of seed potato production. Overall, the one-step RT-RPA assay offers a cost-effective and time-efficient alternative to the current labor-intensive and time-consuming methods of detecting viruses in plants.

Nutritional profiling of ToLCNDV infected tubers in resistant and susceptible potato cultivars (Rahul Kumar Tiwari, Ravinder Kumar, Milan Kumar Lal)

ToLCNDV-potato outbreak has caused significant damage to potato crops resulting in decreased yield. However, there has been no research conducted to understand how virus infection affects the dry matter content and nutritional composition of potato tubers. Therefore, this study aims to investigate the impact of ToLCNDV-potato infection on the growth parameters and nutritional profiles of potato plants, using both resistant and susceptible cultivars. The infection caused by the virus has been reported to have negative effects on the physical characteristics of plants and their tubers.

The height of ToLCNDV-potato infected Kufri Pukhraj plants was significantly reduced ($P < 0.05$) compared to healthy controls, while the reduction in Kufri Bahar plants was nonsignificant ($P > 0.05$). The infection caused a significant reduction of 15% in plant height in susceptible cultivar Kufri Pukhraj (**Fig. 22A, B**). Additionally, ToLCNDV-potato infection had a significant effect on the weight of fresh potato tubers, causing a 14% reduction in Kufri Pukhraj and a 11% reduction in Kufri Bahar (**Fig. 22B** $P < 0.05$). Furthermore, the dry matter (DM) content of both cultivars was significantly reduced (**Fig.**

22C, $P < 0.01$) as a result of ToLCNDV-potato infection, with the susceptible cultivar (Kufri Pukhraj) experiencing a greater reduction of 12.5% compared to the resistant cultivar (Kufri Bahar), which experienced a reduction of only 11%. The estimation of total chlorophyll content revealed the deterioration of chlorophyll A, Chlorophyll B, and total Chlorophyll in infected cultivars as compared to the control (**Fig. 22C, D, E**). The percent reduction in total chlorophyll content was significantly higher in Kufri Pukhraj as compared to Kufri Bahar.

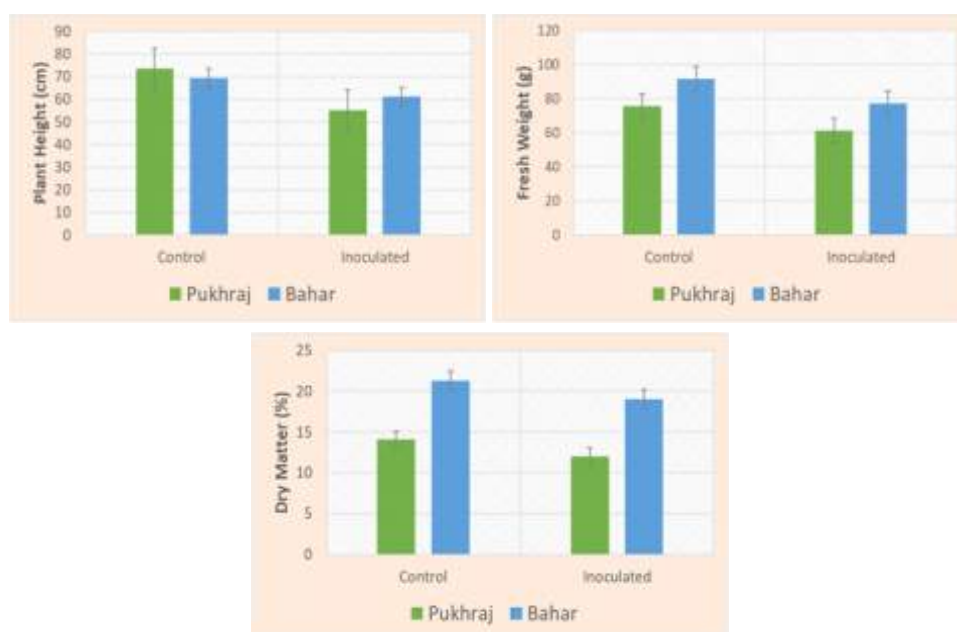


Fig. 22: A-C: The effect of ToLCNDV infection on plant height, tuber fresh weight and dry matter content on plants.

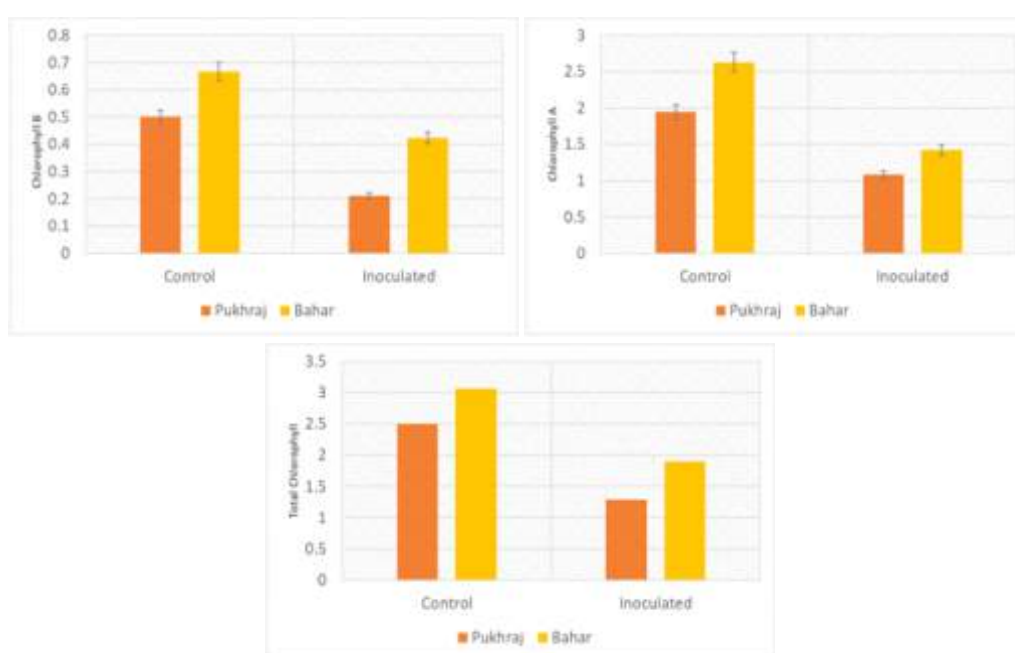


Fig. 22: D, F: The effect of ToLCNDV infection on total chlorophyll content of infected and control tubers

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

In this study, 50 tubers of each transgenic line (GTLC2-127 and KPLC2-53) were planted in a containment facility to observe their phenotypic characteristics. The harvested tubers from these plants were further multiplied, and their tuber traits were studied. In addition, six other transgenic lines (GTLC2-90, GTLC2-127,

KPLC2-13, KPLC2-37, KPLC2-53, and KPLC2-54) were also maintained and multiplied under tissue culture conditions. To evaluate the resistance of the transgenic lines against ToLCNDV, two promising lines (GTLC2-127 and KPLC2-53) were screened using the agro inoculation technique. The results of the screening showed that these two transgenic lines did not exhibit any symptoms of ToLCNDV infection, in contrast to the control plants.



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

Project 1: Biology, epidemiology and management of insect pests of potato

Survey, monitoring and collection of various potato pests (Anuj Bhatnagar, Kailash C. N, Subhash S and Priyank HM)

1) Aphids

The population of aphid species was monitored at weekly interval in unsprayed potato fields from the 3rd week of October 2022 till the first week of January 2023 at Modipuram. Alate morphs of aphids first appeared on the potato plants in the 3rd week of October and crossed the threshold limit in the 4th week of October (Fig. 1). Afterwards the alate morphs population decreased exponentially whereas the non alate morphs remained above the threshold during initial two weeks and started fluctuating till the last week of January. The population of the winged morphs of aphids started out at 12 aphids per 100 compound leaves in the first week after emergence of the crop and crossed threshold in the second week after emergence of the crop (Fig. 1). The population declined after that and fluctuated between 1 and 13 aphids per 100 compound leaves. The population of non alate morphs started out at 50 aphids per 100 compound leaves in the second week after emergence of the crop (Fig. 1). The population showed increasing trend after third week of December and fluctuated between 2 and 38 non alate morphs per 100 compound leaves. The flight activity of the aphids, monitored with yellow pan water traps indicated that the flight was highest during the second week of November to first week of December, and after the fourth

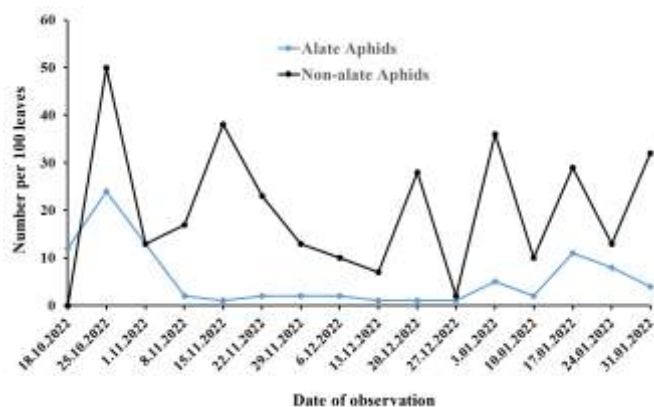


Fig. 1: Population dynamics of the alate and non alate morphs of aphids on potato at Modipuram

week of November population started to decline (Fig. 2). Incidence of *Myzus persicae* was recorded on potato crop in 4th week of November at Gwalior. After that it was increasing in trends and reached its peak population (38 aphids/100 compound leaves) in fourth week of December.

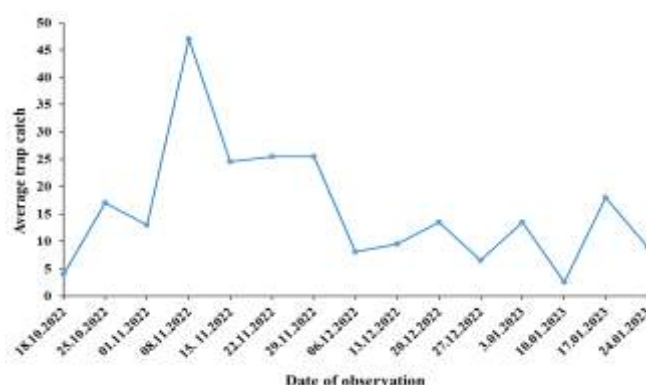


Fig. 2: Flight activity of aphids on potato at Modipuram

2) Whitefly

The population of whitefly, *Bemisia tabaci* was monitored at weekly interval in unsprayed potato fields from the 3rd week of October 2022 till the first week of January 2023 by leaf count method. In general, the population of whitefly adults showed a general decline in population over time which begun high initially (Fig. 3). The population remained above economic threshold till the 1st week of November and after that less than one whitefly per plant was recorded. Incidence of whitefly in unsprayed crop was recorded in 4th week of November at Gwalior. Thereafter it was increasing in trends and reached its peak population (37 whiteflies/10plants) in third week of December.

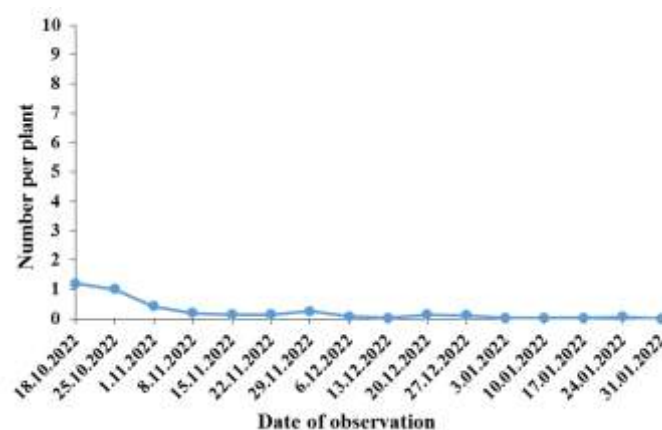


Fig. 3: Population dynamics of adults of *Bemisia tabaci* at Modipuram

2) Leafhoppers

The population of leafhoppers was monitored at weekly interval in unsprayed potato fields from the 3rd week of October 2022 till the first week of January 2023 by leaf count method. In general, the population of leafhoppers showed a general increase in population over time which begun high in first week of December and remains high till 2nd week of January (Fig. 4). Later, less than one leafhopper per plant was recorded.

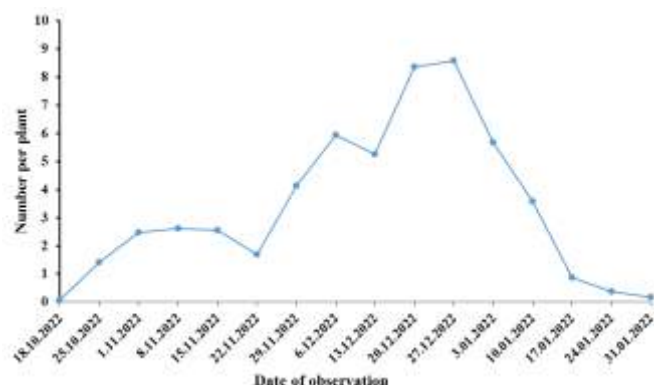


Fig. 4: Population dynamics of leafhoppers at Modipuram

Diversity and seasonal occurrence of vectors in new potential area-Murena-MP for potato seed production

The population of aphids and whiteflies remained below ETL since the beginning of crop

season till first week of January and again population crossed the threshold in the second week of January on unsprayed potato crop. The highest population of 24 aphids/100 compound leaves and 2 whiteflies/10 plants were recorded in the second week of January. The temperature of this location varied from a minimum of 6.2 °C to maximum of 29.5 °C and maximum relative humidity at morning 72.2 % and evening 37.8 % with 4.5 mm rains in fourth week of January.

Succession and incidence of major sucking insect pests on different potato varieties

Among the eight potato varieties namely, K. Sangam, K. Kiran, K. Neelkanth, K. Surya, K. Mohan, K. Anand, K. Chipsona-1 and K. Bahar, K. Sangam (3.38 ± 1.13) and K. Kiran (3.50 ± 1.16) found to be less preferred by whiteflies, whereas K. Mohan (5.00 ± 1.41), K. Anand (4.75 ± 1.47) and K. Bahar (4.75 ± 1.41) found to be highly preferred by whiteflies, remaining varieties comes under moderately preferred. K. Bahar (6.50 ± 1.44) found to be highly susceptible to aphid infestation compared to rest of the selected varieties. K. Bahar (4.67 ± 1.21) and K. Sangam (3.21 ± 0.69) highly preferred by leaf hoppers whereas K. Surya (1.92 ± 0.67) and K. Mohan (1.88 ± 0.67) least preferred by leaf hoppers (Table 1).

Table 1: Seasonal mean numbers (and coexistence %) of major sucking insect pests on different potato cultivars at Modipuram

Cultivar	Whiteflies	Aphids	Leafhoppers	General mean
K. Sangam	3.38 ± 1.13^b (32.53)	3.79 ± 0.80^b (36.55)	3.21 ± 0.69^{ab} (30.92)	10.38 ± 0.17 (100 %)
K. Kiran	3.50 ± 1.16^b (33.87)	4.67 ± 1.06^b (45.16)	2.17 ± 0.48^{bc} (20.97)	10.33 ± 0.72 (100 %)
K. Neelkanth	3.92 ± 1.39^{ab} (36.58)	4.42 ± 0.79^b (41.25)	2.38 ± 0.73^{bc} (22.18)	10.71 ± 0.61 (100 %)
K. Surya	4.17 ± 1.67^{ab} (41.15)	4.04 ± 1.17^b (39.92)	1.92 ± 0.67^c (18.93)	10.13 ± 0.73 (100 %)
K. Mohan	5.00 ± 1.41^a (47.81)	3.58 ± 1.07^b (34.26)	1.88 ± 0.67^c (17.93)	10.46 ± 0.90 (100 %)
K. Anand	4.75 ± 1.47^a (42.38)	3.58 ± 0.51^b (31.97)	2.88 ± 0.79^{bc} (25.65)	11.21 ± 0.55 (100 %)
K. Chipsona-1	4.33 ± 1.32^{ab} (42.28)	3.25 ± 0.34^b (31.71)	2.67 ± 0.57^{bc} (26.02)	10.25 ± 0.49 (100 %)
K. Bahar	4.75 ± 1.41^a (29.84)	6.50 ± 1.44^a (40.84)	4.67 ± 1.21^a (29.32)	15.92 ± 0.60 (100 %)
F _{0.05}	2.254	3.314	4.184	-
LSD	0.277	0.340	0.329	-

Studies on phyto-semiochemicals involved in insect-plant interactions of major potato pests (Subhash S and Anuj Bhatnagar)

Prospecting Estragole as an attractant of aphid, *Aphis gossypii*

Results of last year experiment showed that basil oil with sticky trap catches more number of aphids in the potato fields. Therefore, electrophysiology and olfactometry studies were carried out to identify the compound from basil oil. In electrophysiological studies, winged *A. gossypii*'s antennae responded consistently to estragole in basil oil (Fig. 5). In olfactometer assays with estragole, winged *A. gossypii* spent significantly more time in the treatment arm of the olfactometer than in the control arm, validating estragole's attractiveness. Further, yellow sticky traps baited with pure estragole, in potato fields, attracted similar number of winged *A. gossypii* as yellow sticky traps baited with basil oil.

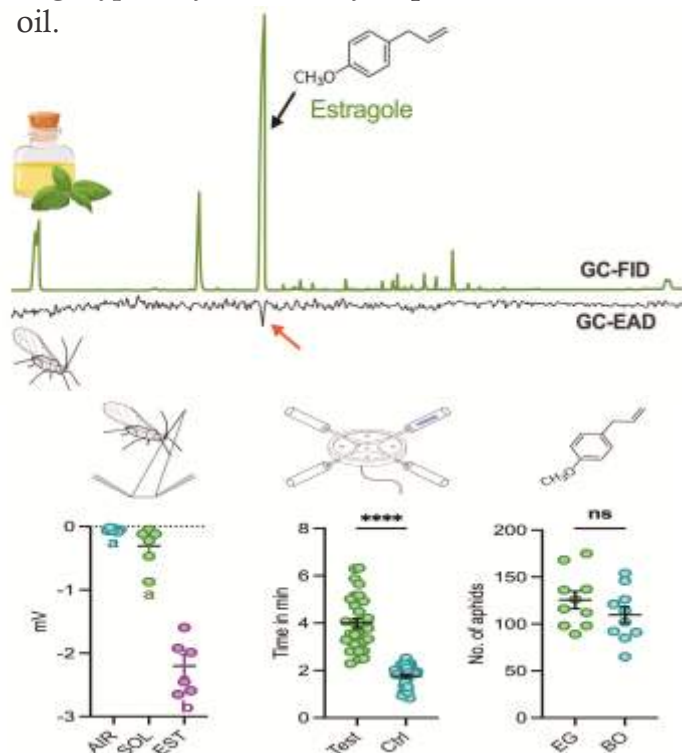


Fig. 5: Estragole in basil oil mediated attraction of winged *A. gossypii*. a. GC-EAD and b. EAG analysis with antenna of winged *A. gossypii* and basil oil proved estragole to be electrophysiologically active. c. In olfactometer assay, winged *A. gossypii* spent significantly more time in the olfactometer arm containing estragole (Test) than control (Ctrl). d. In field choice assay, winged *A. gossypii* were attracted to yellow sticky traps with estragole (EG) and basil oil (BO) similarly. Each coloured circular point represents a single data point and the whiskers represent s.e.m (standard error of mean). **** $P < 0.0001$; *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; ns: not significant.

Conventional and novel strategies for the management of insect pests of potato (Subhash S and Anuj Bhatnagar)

Evaluation of seed potato crop spray schedule through UAV spray

An experiment was conducted to study the efficacy of drone spraying and to compare it with tractor and battery operated knapsack spray along with untreated control. Seed potato crop spray schedule was followed in the experiment. As such, there was no phytotoxicity observed in any of the four insecticides sprayed. In general, the population of aphids and leafhoppers was very low in the experimental plot throughout the season whereas whitefly population was very high throughout the crop growth except 5th and 6th spray. In the first spray (Movento energy), only 10.5 % reduction over control was observed with drone spraying whereas 21.04 % and 53.30 % reduction over control observed in tractor mounted spray and knapsack spray respectively against whiteflies. In the second spray (Thiamethoxam), only 25.22 % reduction over control was observed with drone spraying whereas 40.57 % and 41.44 % reduction over control observed in tractor mounted spray and knapsack spray respectively against whiteflies. In the third spray (Flonicamid), only 38.74 % reduction over control was observed with drone spraying whereas 58.91 % and 69.77 % reduction over control observed in Tractor mounted spray and knapsack spray respectively against whiteflies. In the fourth spray (Imidacloprid), 62.45 % reduction over control was observed with drone spraying whereas 70.53 % and 69.38 % reduction over control observed in Tractor mounted spray and knapsack spray respectively against whiteflies.

Evaluation of insecticides against white grub at Fagu, Shimla (Kailash C. Naga, Ashwani K. Sharma, Subhash S., Aarti Bairwa, Rahul K Tiwari, Chandan Maharana, Ravinder Kumar, Anuj Bhatnagar, Sanjeev Sharma and Brajesh Singh)

To search alternate synthetic chemicals for the management of white grubs in potato, five insecticides and a combination product of Fipronil+Imidacloprid 40WG were evaluated against white grubs attacking potato. The least percent tuber losses and percent weight loss were observed in the treatment T5 Clothianidin 50DWG @ 250 g / ha, which was however on par with the treatment T8 Chlpyrifos 20EC @ 2.5 liter /ha (Fig. 6). Whereas, the highest percent tuber loss and percent weight loss was recorded in control plots.

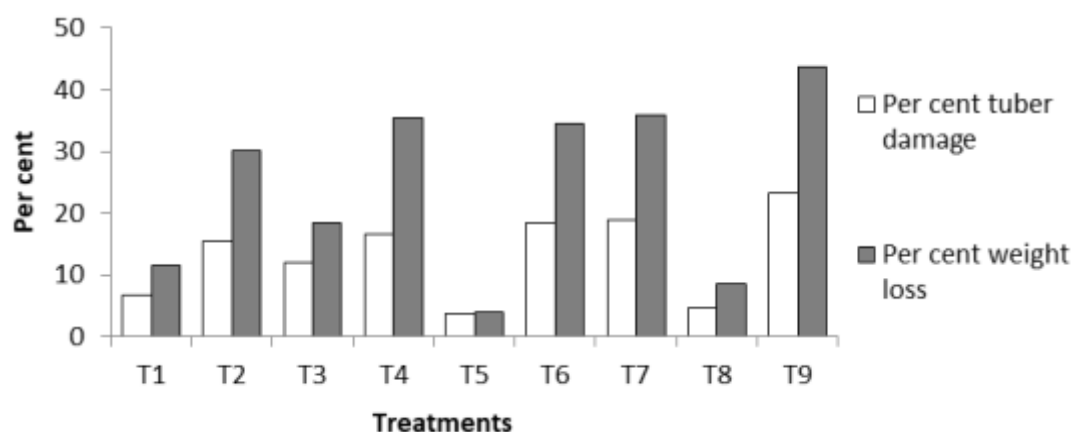


Fig. 6: Evaluation of insecticides against white grub

Bioassay of neonicotinoids against *Myzus persicae* field populations (Kailash C. Naga, Subhash S., Aarti Bairwa, Rahul K Tiwari, Chandan Maharana, Ravinder Kumar, Anuj Bhatnagar, Sanjeev Sharma and Brajesh Singh)

To monitor the status of resistance against neonicotinoids a total of 17 *Myzus persicae* populations were collected from major potato growing areas of India. The least LC_{50} against imidacloprid recorded in Nerwa population (2.315 mg/L) whereas highest LC_{50} observed in Karnal population (70.826 mg/L) (Fig. 7). The

thiamethoxam bioassay against the *M. persicae* populations revealed a LC_{50} range of 2.887 (Jalandhar) to 171.368 mg/L (Karnal) (Fig. 8). Similar to imidacloprid bioassay Karnal population showed highest resistance ratio of 33.1 which suggested a moderate level of resistance in the population. The *M. persicae* populations showed a higher LC_{50} against clothianidin which ranged from 10.336 mg/L (Jagraon) to 1492.3 mg/L (Karnal). The resistance ratio of Karnal population suggests a very high level of resistance (RR 129.7).

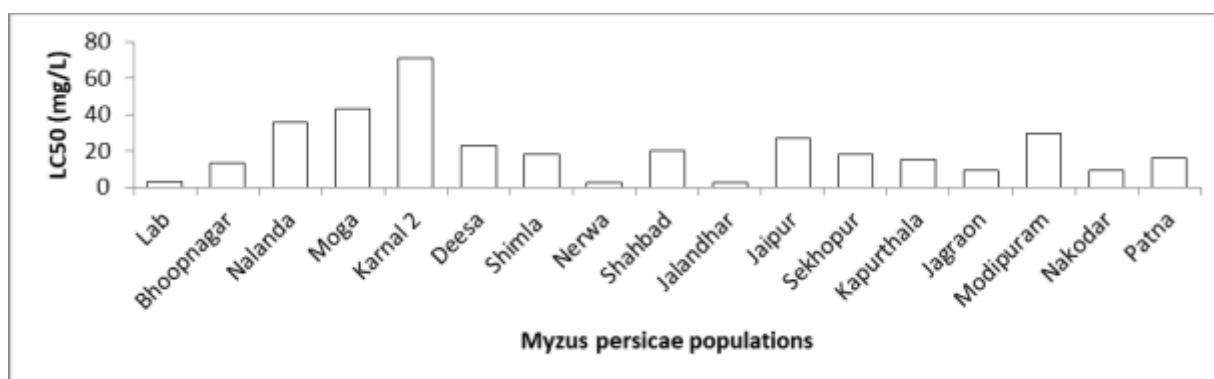


Fig. 7: LC_{50} (mg/L) of *Myzus persicae* populations against imidacloprid

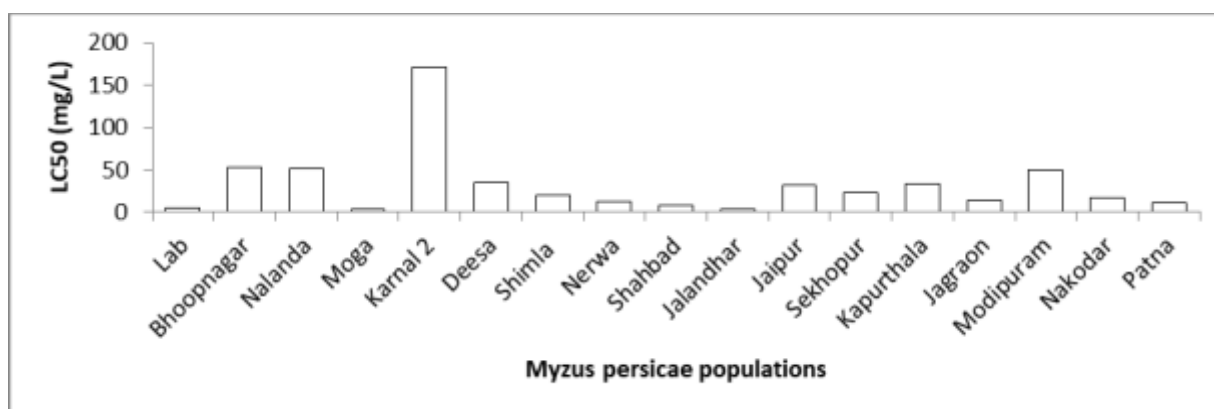


Fig. 8: LC_{50} (mg/L) of *Myzus persicae* populations against thiamethoxam

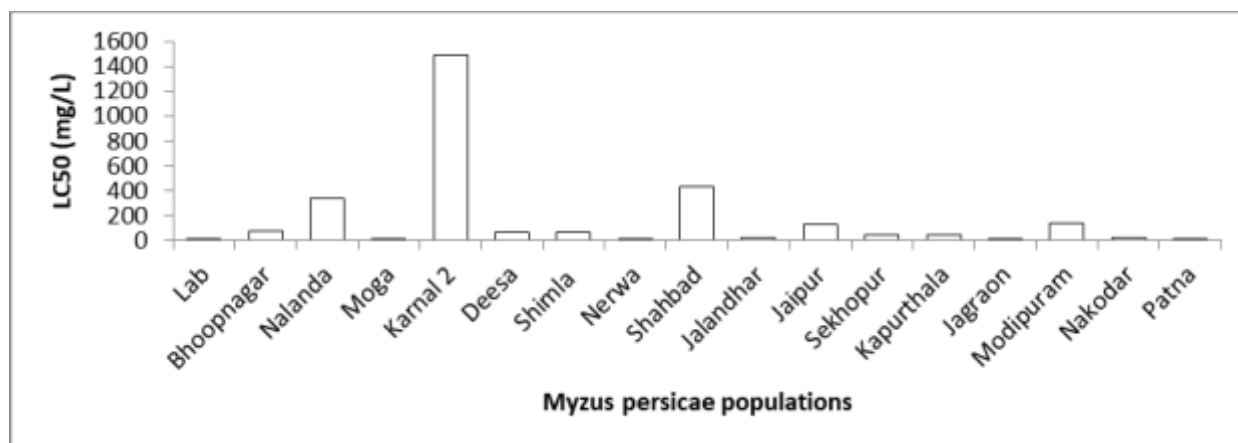


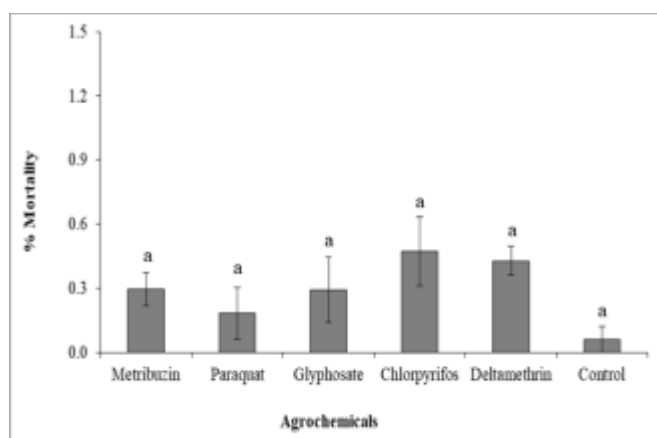
Fig. 9: LC50 (mg/L) of *Myzus persicae* populations against clothianidin

Compatibility of entomopathogenic nematode, *Steinernema cholashanense* with agrochemicals

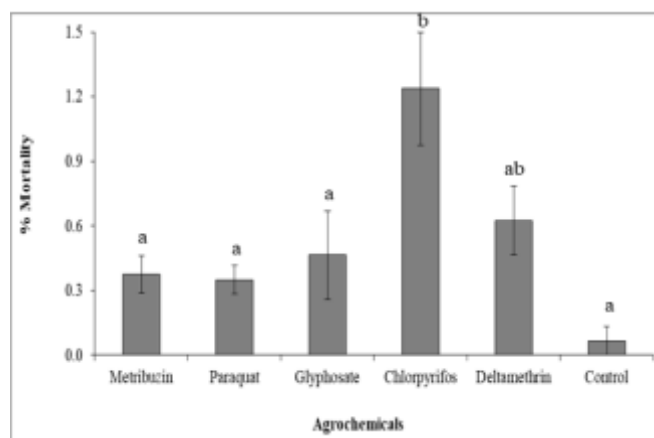
(Priyank H M, Subhash S., Aarti Bairwa, Anuj Bhatnagar)

The result of the present study demonstrated that all the tested agrochemicals at their recommended doses showed negligible effect (< 1.5% mortality)

on IJs survival (Fig. 10a). Moreover, IJs were able to infect and reproduce in *P. operculella* larvae after exposure to all tested agrochemicals (Fig. 10b). The study revealed that *S. cholashanense* is compatible with the tested agrochemicals and can be readily combined and used under the field conditions against *P. operculella*.



10 a. Mortality (%) of EPNs after 24 hrs of exposure to respective treatment



10 b. Mortality (%) of EPNs after 48 hrs of exposure to respective treatment

Fig. 10: Effect of agrochemicals on EPN survival

Ecological characterization of *Steinernema cholashanense*

(Priyank H M, Subhash S., Aarti Bairwa, Anuj Bhatnagar)

The assay to study the nematode migration in sand: soil column revealed that the nematode is able to search and kill the host, *Galleria mellonella* vertically up to 40 cm within 5 day of inoculation. In host attachment assay it was noted that up to 28 number of IJs were able to attach to the body of mobile host, *G. mellonella* within ten minutes of exposure when 1000 IJs were exposed per larvae. In effect of soil moisture on the infectivity of EPN assay, it was noted that the moisture level of 13-

20% is good for nematode infection and penetration in the host insect. In heat tolerance assay, it was observed that the identified EPN is able to survive at lower temperature but all the juveniles died at $\geq 35^{\circ}\text{C}$. The effect of temperature on mortality of *G. mellonella* and reproduction in *G. mellonella* showed that the EPN is able to kill and reproduce in the host up to the temperature from 10 to 25°C ; however the temperature $\geq 28^{\circ}\text{C}$ is not suitable for infection and reproduction in to the host. These studies clearly showed that *S. cholashanense* is a cold tolerant species of EPN, suitable for the temperate regions.

Management of *Liriomyza huidobrensis* in potato crop at Ooty (Priyank H M, Subhash S., Aarti Bairwa, Anuj Bhatnagar)

Experiment results showed that the application of Cyantraniliprole 10.26% (T2) significantly reduced the new leaf mines after each spray and yielded (29.67 t/ha) highest compared to other treatments. This was followed by T3: Abamectin 1.9% (29.05 t/ha). The lowest yield (25.56 t/ha) and highest mines were recorded in control treatment (Fig. 12).

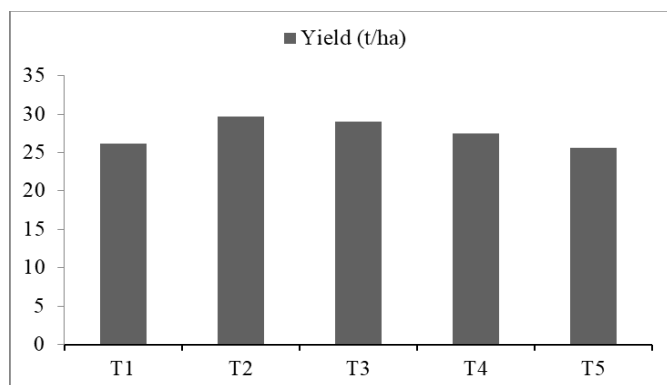


Fig. 12: Effect of different treatments on yield improvement in potato crop

Use of barrier crop, and trap crop in IPM module of potato at Modipuram (Anuj Bhatnagar, Subhash S, Priyank H M, Aarti Bairwa, Kailash N)

Field experiments were conducted to evaluate the role of barrier crop (maize) and trap crop (mustard) along with plant products and yellow sticky traps against sucking pests (whiteflies & aphids). The IPM module was effectively working against insect vectors with low incidence of viral diseases in plots using barrier crop (maize) and trap crop (mustard) along with plant products and yellow sticky traps (Fig. 13 & 14).



Fig. 13: Effect of barrier & trap crops on insect vectors



Fig. 14: Effect of trap and inter crops on insect vectors

Management of Thrips at Gwalior (Subhash Katare)

Most effective treatment were found seed treatment with *Beaveria bassiana* (ST@10 g/kg)+Thiomethoxam 5% WG (Sp.@ 0.5 ml/l) against thrips with percent reduction 82.75%, followed by imidacloprid 17.8 SL (ST@0.4ml/kg) +thiomethoxam 5% WG (Sp.@ 0.5gm/l), 75.08% and *Beaveria bassiana* (ST@10 g/kg)+ *Beaveria bassiana* (Sp@.1200g/ha), 63.25% and *Beaveria bassiana* (ST @10 g/kg), 57.82% over untreated control. Treatments T-6 and T-7 found effective for reducing % leaf curl disease.

Project II: Biology, ecology and management of nematodes pests of potato

Study on potato cyst nematode (*Globodera* spp.) management strategy (Aarti Bairwa, Sanjeev Sharma, Ashwani K. Sharma, Dalamu)

Different potato cyst nematode management strategies as detailed in Table 2, 3 and 4 were followed at PCN sick fields of Kufri Farm to see their effect on PCN population dynamics.

Table 2: Effect of soil treatments in combination with trap crop on PCN population

T1 :	Trap crop (35DAP) followed by non host crop (Mustard) followed by fallow
T2 :	Trap crop (35DAP) followed by antagonistic crop (Marigold) followed by fallow
T3 :	Trap crop (35DAP) followed by application of Dazomet (Basamid 95G) @ 5q/ha (50 gm/m ²) for 10 days followed by non host crop (Mustard) followed by fallow
T4 :	Application of ARL @ 5 lit/m ² followed by non host crop (Mustard) followed by fallow
T5 :	Application of Nimitiz @ 50kg/ha (100% dose) with trap crop (35DAP) at the time of planting followed by non host crop (Mustard) followed by fallow

T6 :	Application of Nimitiz @ 50kg/ha, 50% at the time of planting of trap crop and 50% Nimitiz at the time of planting of non host crop (Mustard) followed by fallow
T7 :	Application of <i>Bacillus cereus</i> @ 30 kg/ha with Trap crop (35DAP) followed by non host crop (Mustard) followed by fallow
T8 :	Fallow

Among the treatments, significantly less nematode reproduction factor ($R_f = F_p / I_p$) was recorded in the treatment T₇: Application of *Bacillus cereus* @ 30 kg/ha with Trap crop (35DAP) followed by non host crop (Mustard) followed by Fallow (**Rf:0.33**). The next best treatments were T₅: Application of Nimitiz @

50kg/ha (100% dose) at the time of planting with trap crop (35DAP) followed by non host crop (Mustard) followed by Fallow (**Rf:0.40**), T₁: Trap crop (35DAP) followed by non host crop (Mustard) followed by fallow (**Rf:0.38**) and T₂: Trap crop (35DAP) followed by antagonistic crop (Marigold) followed by fallow (**Rf: 0.42**) (Fig. 15).

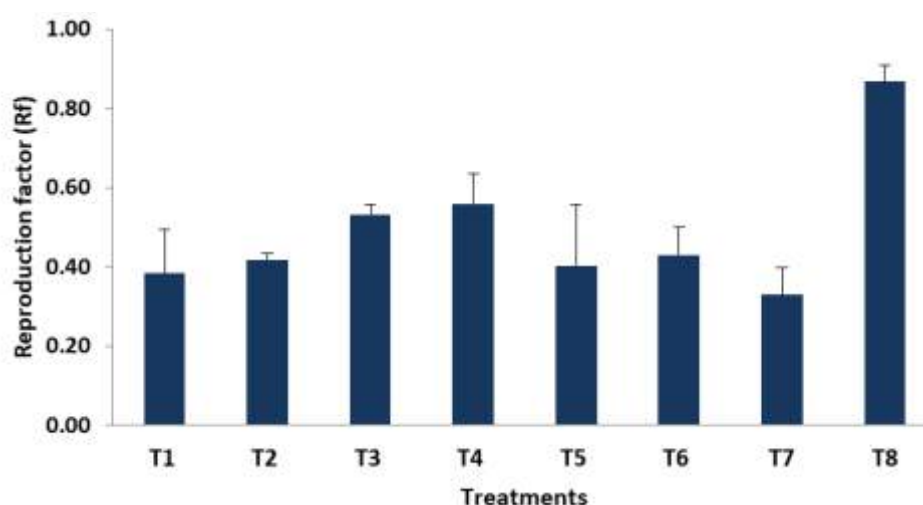


Fig. 15: Effect of soil treatments in combination with trap crop on PCN population.

Table 3: Evaluation of genotypes along with nematicides and bioagent against PCN

T1 :	Alone planting of moderately resistant variety (Kufri Karan) followed by fallow
T2 :	Alone planting of susceptible variety (K. Jyoti) followed by fallow
T3 :	Alone planting of resistant advance hybrid (SM/11-120) followed by fallow
T4 :	Application of Nimitiz @ 50kg/ha, 100% at the time of planting of moderately resistant variety (K. Karan) followed by fallow
T5 :	Application of Nimitiz @ 50kg/ha, 50% at the time of planting of moderately resistant variety (K. Karan) and 50% during earthing up followed by fallow
T6 :	Application of Nimitiz @ 50kg/ha, 100% at the time of planting of susceptible variety (K. Jyoti) followed by fallow
T7 :	Application of Nimitiz @ 50kg/ha, 50% at the time of planting of susceptible variety (K. Jyoti) and 50% during earthing up followed by fallow
T8 :	Application of <i>Bacillus cereus</i> @ 30 kg/ha with susceptible variety (K. Jyoti) at the time planting followed by fallow
T9 :	Application of <i>Bacillus cereus</i> @ 30 kg/ha with moderately resistant variety (K. Karan) at the time planting followed by fallow
T10 :	Fallow

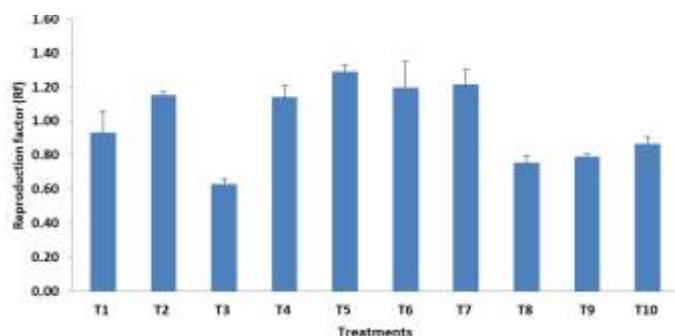


Fig. 16: Evaluation of genotypes along with nematicides and bioagent on PCN.

Out of ten treatments evaluated, treatment **T3**: Alone planting of resistant hybrid (SM/11-120) followed by fallow, recorded significantly less PCN reproduction factor (**Rf: 0.63**) followed by **T8**: Application of *Bacillus cereus* @ 30 kg/ha with susceptible variety (K. Jyoti) at the time planting followed by fallow (**Rf=0.76**) and **T9**: Application of *Bacillus cereus* @ 30 kg/ha with moderately resistant variety (K. Karan) at the time planting followed by fallow (**Rf=0.79**) (Fig. 16).

Table 4: Evaluation of bleaching powder along with host and non-host crops on PCN population

T1 :	Application of bleaching powder @ 40kg/ha with moderately resistant variety (K. Karan) at the time planting followed by fallow
T2 :	Application of bleaching powder @ 40kg/ha with susceptible variety (K. Jyoti) at the time planting followed by fallow
T3 :	Trap crop (35 DAP) followed by application of bleaching powder @ 40kg/ha by fallow
T4 :	Application of bleaching powder @ 40kg/ha with trap crop (35DAP) followed by fallow
T5 :	Application of bleaching powder @ 40kg/ha followed by fallow
T6 :	Application of bleaching powder @ 40kg/ha followed by non host crop (Rajmash) followed by fallow
T7 :	Application of bleaching powder @ 40kg/ha followed by non host crop (Oat) followed by fallow
T8 :	Fallow

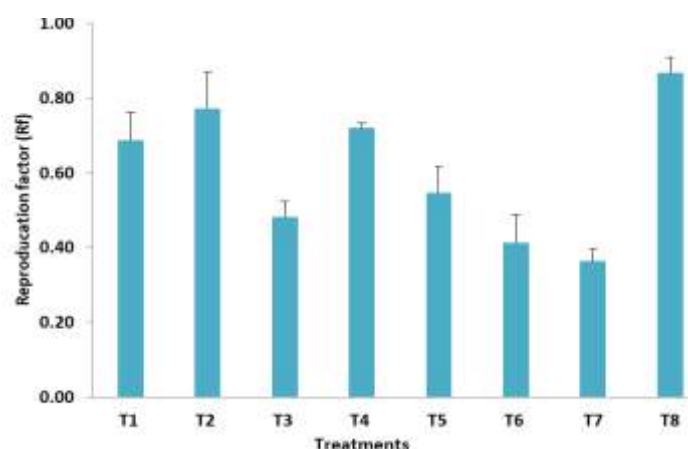


Fig. 17: Evaluation of bleaching powder along with host and non-host crop on PCN population

Out of eight treatments evaluated, significantly less nematode reproduction factor (Rf) was recorded in the treatment **T7**: Application of bleaching powder @40kg/ha followed by non host crop (Oat) followed by fallow (**Rf:0.36**) followed by **T6**: Application of bleaching powder @40kg/ha followed by non host crop (Rajmash) followed by fallow (**Rf=0.41**), **T3**: Trap crop (35DAP) followed by application of bleaching powder @40kg/ha by fallow (**Rf=0.48**) and **T5**: Application of bleaching powder @40kg/ha followed by fallow (**Rf=0.55**) (Fig. 17).

Effect of different cropping systems on PCN population dynamics (Aarti Bairwa, Sanjeev Sharma, Ashwani K. Sharma, Dalamu)

After following four years of management strategies at Kufri Farm, growing Oat-Oat-Mustard-Trap cropping system resulted in maximum reduction (61.4%) of PCN population followed by Potato-Rajmash-Trap-Rajmash (48.7%). In Fagu farm, Oat-Mustard-Rajmash-Trap cropping system resulted in maximum reduction (63.3%) followed by Oat-Rajmash-Trap-Rajmash (62.9%) and Potato-Oat-Mustard-Mustard (54.6%) cropping systems (Table 5).

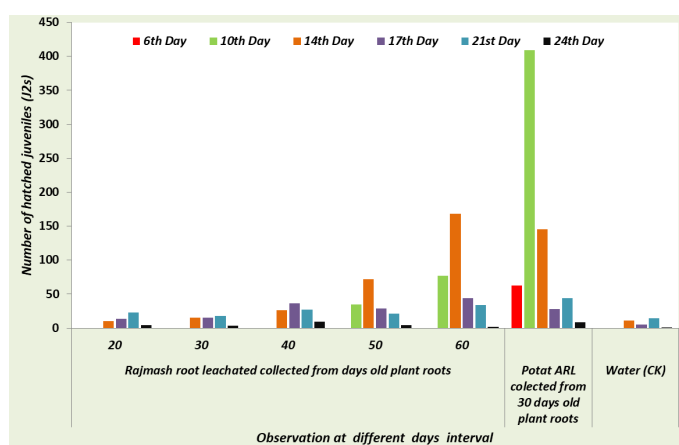
Table 5: Effect of different cropping systems on PCN population dynamics.

Kufri Farm					
Block	Year / Crop				% Increase or decrease of PCN population
	2018	2019	2020	2021	
1	Fallow	Trap	Potato	Oat	-6.8
2	Fallow	Trap	Trap	Potato	-6.2
3	Potato	Rajmash	Trap	Rajmash	-48.7
4	Potato	Mustard	Rajmash	Trap	-27.9
5	Oat	Oat	Mustard	Trap	-61.4
6	Oat	Potato	Oat	Trap	-25.6
Fagu farm					
1	Oat	Potato	Oat	Trap	-27.3
2	Oat	Trap	Potato	Oat	-47.7
3	Potato	Trap	Trap	Potato	-44.3
4	Oat	Rajmash	Trap	Rajmash	-62.9
5	Oat	Mustard	Rajmash	Trap	-63.3
6	Potato	Oat	Mustard	Mustard	-54.6

Effect of Rajmash root leachates on PCN hatching

(Aarti Bairwa, Sanjeev Sharma, Tanuja Buckseth, Ashwani K. Sharma, Dalamu)

An *in vitro* study was conducted to examine the effect of rajmash root leachates (collected from the 20, 30, 40, 50 and 60 days old plant roots) on PCN hatching along with potato aeroponic root leachate (ARL) (30 days old) and water. Each treatment was incubated with ten cysts and replicated four times. The experiment was kept at 20°C temperature. Initiation of PCN hatching was observed after six days in the ARL while in 50 and 60 days old rajmash root leachates, hatching was initiated after 10 days of cyst incubation.


Fig. 18: Effect of rajmash root leachates on PCN hatching

Maximum number of hatched juveniles were recorded in 50 (72 nos) and 60 (168 nos) days old rajmash root leachates after 14 days of cyst incubation while in potato ARL, maximum number of hatched J2s recorded after 10 days of

cyst incubation (409 nos) (Fig. 18). In water, less number hatched J2s (5-14 nos) was recorded. This study demonstrates that, in the absence of the primary host crop, the potato, rajmash roots leachates also sustain PCN hatching (Fig. 19).


Fig. 19: Hatched juveniles (J2s) in the root leachates of Rajmash

Survey of potato growing areas of Gujarat for root-knot nematode infestation in potato tubers

(Priyank H M, Subhash S., Aarti Bairwa, Anuj Bhatnagar)

Survey of potato growing areas for root-knot nematode (RKN) infestation on potato tubers was conducted during the month of March 2022 in 9 tehsils of Sabarkantha and Aravalli districts of Gujarat. A total of 36 potato growing fields were sampled for RKN infestation on tubers (Fig. 20). The result of the survey showed that, the RKN was prevalent in both the districts and found responsible for qualitative (bumps on the tubers making them unmarketable) as well as quantitative (reduced healthy tubers) reductions in potato yields. The RKN infestation (on tubers

or on roots) was observed in almost all the potato cultivars commonly grown in this area such as Lady Rosetta, FC11, FC5, Santana, Kufri Lauvkar etc. (Fig. 21 and 22). Among cultivars, maximum area was under Lady Rosetta, which was found as one of the most susceptible variety for RKN infestation (Fig. 22). In tehsil Himatnagar (Sabarkantha), RKN infestation in potato tubers was observed in all the surveyed locations. The RKN infestation was not observed from any of the surveyed locations of tehsil Dhansura (Aravalli). Among locations, maximum infestation of RKN was noticed in a field of tehsil Talod followed by tehsil Modasa. The collected RKN female samples were subjected to identification using perennial pattern morphology as well as molecular confirmation.

Based on this survey, it is concluded that, RKN is becoming an emerging threat to potato cultivation in the state of Gujarat, which has potential for growing cultivars suitable for processing and export. Infestation of RKN on tubers leads to rejection of consignments meant for processing or export. Therefore, integrated nematode management (INM) approach has to be developed for sustaining the supply chains of processing and export.



Fig. 20: Survey for RKN infestation in potato crop in Gujarat. Left- field observations; Right- pack house observations



Fig. 21: Infestation of potato tubers (cultivar Lady Rosetta) by RKN

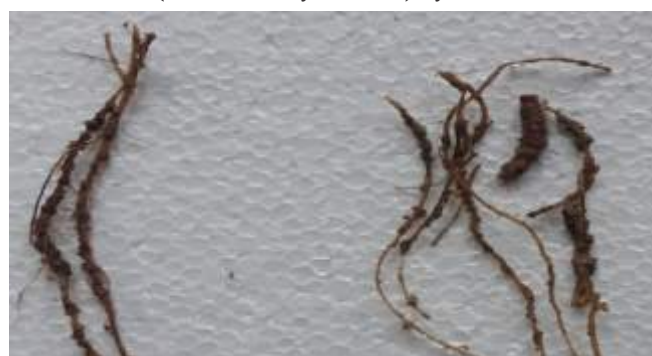


Fig. 22: Potato roots infected with RKN. Left (cv. Lady Rosetta) & right (cv. Kufri Lauvkar)

Effect of PCN in yield reductions in susceptible cv. Kufri Girdhari

The results of the experiments showed that PCN is responsible for about 31-69% decrease in tuber yield. The highest yield of 17.21 t/ha was observed in the plots treated with Dazomet however the lowest yield of 10.18 t/ha was noted in untreated control (Fig. 23).

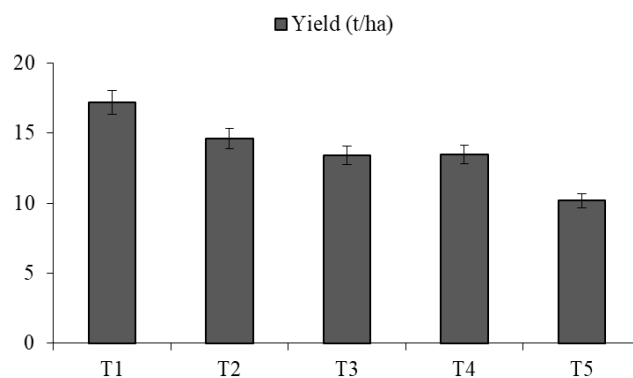


Fig. 23: Effect of potato cyst nematode on yield of potato susceptible cv. Kufri Girdhari

DIVISION OF CROP PHYSIOLOGY, BIOCHEMISTRY & POST-HARVEST TECHNOLOGY

PROGRAMME: POST HARVEST MANAGEMENT AND NUTRITIONAL ENHANCEMENT OF POTATOES

1. Sprout suppression in potatoes with naturally occurring volatile compounds

During previous years studies, a total of seven naturally occurring oils were chosen for additional sprout suppression efficacy investigations in potatoes. Selected oils were tested in various combinations and as singles in a 5 kg container stored at 10-12°C and 95% relative humidity. One extremely effective cocktail "A" of seven oils (from the 2021 study) was tested in bulk storage at 10-12°C and 95% relative humidity during April to July 2022. A total of 17 container storage combinations were examined on the potato variety Kufri Chandramukhi for the container storage study. Similarly, nineteen potato varieties namely Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Surya, Kufri Himsona, Kufri Pukhraj, Kufri Arun, Kufri Sutlej, Kufri Himalini, Kufri Jyoti, Kufri Badshah, Kufri Khyati and Kufri Bahar, Kufri Mohan, Kufri Thar-3, LR, Diamont, Kufri Lalit, 20 kg of each were evaluated for bulk storage using one highly effective cocktail "A". Each treatment combination was spray applied after appropriate dilution in alcohol. For container storage, Kufri Chandramukhi and for bulk storage, Kufri Chipsona-1, 2, Kufri Thar-3 and Kufri Chandramukhi were kept untreated as control. Each treatment was monitored for a period of 120 day. CIPC treated control potatoes were kept in separate chambers. Periodic observations on sprouting (%), sprouting index, percent rotting tubers, change in skin colour, and stiffness were made throughout storage. Combinations A, B, C, D, and E were found to be highly effective for container-stored potatoes throughout the storage period. Combinations F, H, I, and J, on the other hand, were effective for up to 60 days of storage. Except for orange oil, all oils were highly effective in single oil treatments for up to 120 days of storage. Except for Kufri Chipsona-2 (12.8%), Kufri Badshah (11%), and Kufri Sutlej (26%), total weight loss in all types was between 3 and 10% during bulk storage. Maximum rotting was found in Kufri Badshah (4.4%) followed by K

Mohan (3.5%). Rotting in other varieties varied from 0% to 0.5% throughout storage. After 30 days of storage, 100% sprouting was seen in untreated tubers. CIPC-treated tubers, on the other hand, remained unsprouted throughout storage. The skin colour of treated tubers remained unaltered throughout storage.

In another experiment, the efficacy of a crude aqueous-alcoholic extract of turmeric, fresh garlic, and basil leaves in suppressing potato sprouts was tested. Each extract was applied individually and in combination to 2 kg Kufri



Fig. 1: Effect of oil mixture treatment (bulk) after 120 days of storage (1) K Chipsona-1(control), (2) K Surya, (3) K Jyoti (4) K Chipsona-3 (5) K Badshah (6) K Chipsona-2 (7) K Chipsona-4 (8) K Himalini (9) K Bahar and (10) K Arun



Fig. 2: Sprout suppression effect of new oils cocktail on K Chandramukhi after 150 days of storage (in PET can)

Chandramukhi potatoes inside PET containers at 10-12°C and 95% relative humidity. One and two millilitres of Aqueous-alcoholic extract were applied as sprays and kept for observation. Results revealed that after 30 days of storage, all

treatments had 100% chitting. The crude aqueous-alcoholic extracts of turmeric, fresh garlic, and basil leaves were found to be ineffective in controlling sprouting in potato tubers.

Another experiment was carried out this year, this time with a crude aqueous-alcoholic extract of turmeric powder, fresh garlic, and fresh basil leaves. On 2 kg of Kufri Chandramukhi potatoes, each extract was tested for sprout suppression efficiency alone and in combination inside PET cans at 10-12°C and 95% RH. In the form of a spray, one to two millilitres of aqueous-alcoholic (20:80) extract of was administered. After 30 days of storage, all treatments had 100% chitting. The crude aqueous-alcoholic extracts of turmeric, fresh garlic, and basil leaves were found to be ineffective in preventing sprouting in potato tubers.

2. Novel value-added products from potatoes

Potato-Bengal Gram-based boondi for sweet and raita

Boondi is a deep-fat fried spherical traditional product made out of droplets of chickpea/ Bengal gram/ *besan* (*Cicer arietinum*) flour batter. In India, after sugar syrup impregnation boondi is served as a prasad on religious events moreover, after compressing in the form of small balls these sweetened boondi are being used to prepare Ladoo which is commonly offered as festive treats. On the other hand, spiced boondi is also commonly used to serve large meal after the addition into the crud and is known as boondi raita. We have developed similar kind of boondi by replacing more than 50% of Bengal gram flour

with the potato flour. From the texture analysis (Figure 3) we have found that the crispiness and crunchiness of the developed boondi was better than traditional boondi (Table 1). Developed boondi was suitable for both sweet and raita preparation (Figure 4 & 5).

Table 1: Texture analysis of developed boondi using Ottawa cell

Test ID	Work done (N.mm)	Toughness (N.mm)	Crispiness
Besan lab Boondi	1863.621	925.607	61
Market Besan Boondi	1795.121	897.878	83
Potato Besan Boondi	643.108	563.904	100



Fig. 4: Sweetened Potato-Bengal Gram boondi



Fig. 5: Potato-Bengal Gram boondi based raita

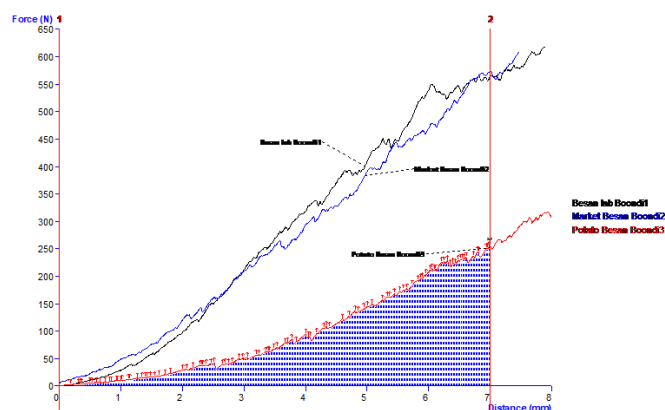


Fig. 3: Texture analysis of (1) Besan boondi prepared in lab; (2) Besan based Boondi available in market; (3) CPRI Developed potato based boondi

Potato-based boondi snack

This year, we created another boondi variation by combining potato flour, black gram flour, corn flour and chickpea flour to be eaten as a salty snack (figure 6). The developed boondi snack comprises more than 35% potato flour. Unlike other fried processed potato dishes, boondi can be made from any type of potato. These boondi can be stored for up to 3 months in cold, dark, dry, and inert environments.



Fig. 6: Potato based boondi snack

3. Effect of rain on quality of potato

Excess rains on the time of ready to harvest or fully mature potato is very challenging and deteriorate the quality of crop. Reduction in quality of potato tubers is likely to be affected, which will have negative impact on growth and development particularly due to terminal heat stress and decreased water availability. To address this problem for common man and farmer, an experiment was conducted at ICAR-CPRIC, Modipuram. Artificial simulation on excess water or stress studies in two Indigenous potato varieties Kufri Chipsona-3 and Kufri Frysona were carried out. Seven treatments were T1-control, T2-water dipping-1hr, T3-water dipping + soil (1hr), T4-water dipping (2hr), T5-water dipping + soil (2hr), T6-water dipping (24hr), T7-Water dipping (24hr) +soil. Potato samples after different treatments were wiped with paper towel and stored for 14 days to observe the quality during storage (Fig. 7).

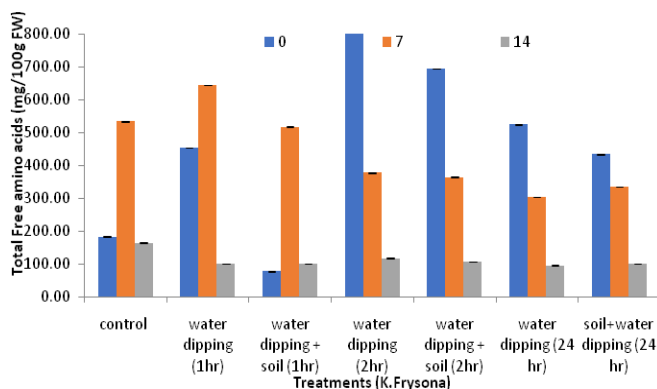


Fig. 7: Effect of different treatments on total free amino acids in variety Kufri Frysona

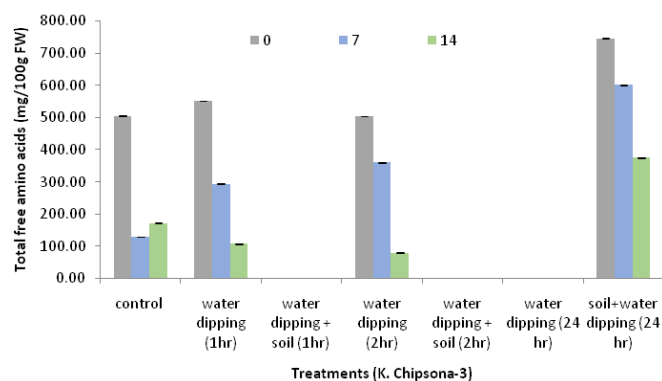


Fig. 8: Effect of different treatments on total free amino acids in variety Kufri Chipsona-3

Results revealed that treatments of water dipping 2 hours gave maximum total free amino acids at 0 day of sampling (Kufri Frysona) followed by water dipping + soil (2hr). Total free amino acids seems to be stabilised at 14 days of storage as compared to sampling at initiation and 7th day of experiment. Minimum total free amino acids was indicated by water+soil (1hr dipping). K. Chipsona-3, T3, T4 and T5 treatments dipping reported rotting of potato tubers and studies couldn't be pertained (Fig. 7 and 8).

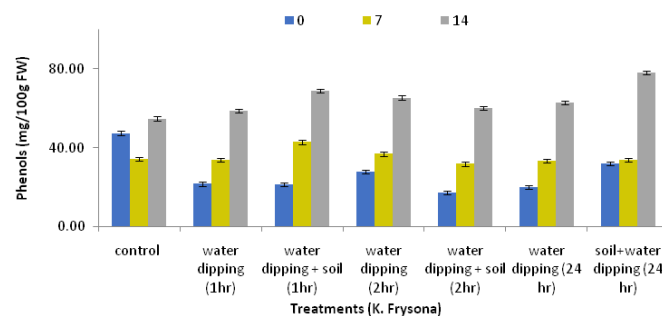


Fig. 9: Effect of different treatments on phenols in variety Kufri Frysona

Maximum phenols were observed in treatment T7 (soil+water dipping for 2hrs) at 14 days of storage after dipping followed by water dipping for 2 hours only. Another variety i.e. K. Chipsona-3, T3, T4 and T5 treatments dipping reported rotting of potato tubers (Fig. 9).

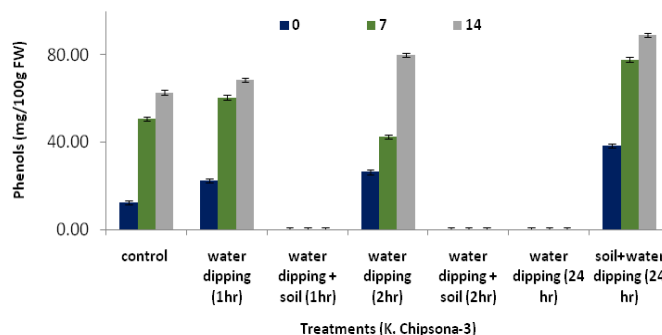


Fig. 10: Effect of different treatments on phenols in variety Kufri Chipsona-3

Soil+water dipping treatments for 24 hours indicated highest phenols at 14 days of storage as compared to water dipping only. It may be concluded that excess period combined with soil/mud may have positive and negative impacts on total free amino acids and phenols during storage that may ultimately affect the quality of potato tubers. Mature tubers combined with prolonged dipping in water may have detrimental effects on crop (Fig. 10).

4. Effect of potato-cooking oil combination and retrogradation on available carbohydrate (ACHO)

Potato is usually fried in different cooking oils and then consumed in the form of chips and French fries. Results in the present study suggested that the addition of cooking oil to the potato tubers of both the cultivars (KJ and KC3) resulted in a significant lowering ($P < 0.05$) of ACHO in the potato-cooking oil combination (Table 2). The ACHO of KJ was 13.78 g/100 g DW and on the addition of mustard, sunflower, soybean, ghee, olive, rice bran and coconut oil the ACHO was reduced to 10.87, 11.26, 10.81, 8.84,

7.90, 9.85 and 9.06 g/100 g DW, respectively (Table 3). The maximum (42.7%) and minimum (18.3%) reduction in ACHO were noted in potato (KJ)-olive oil and potato (KJ)-soybean oil, respectively. Similarly, the addition of olive oil, ghee and coconut oil to potato of KC3 resulted in a significant reduction ($P < 0.05$) in ACHO by 47.7, 39.4 and 39.3%, respectively.

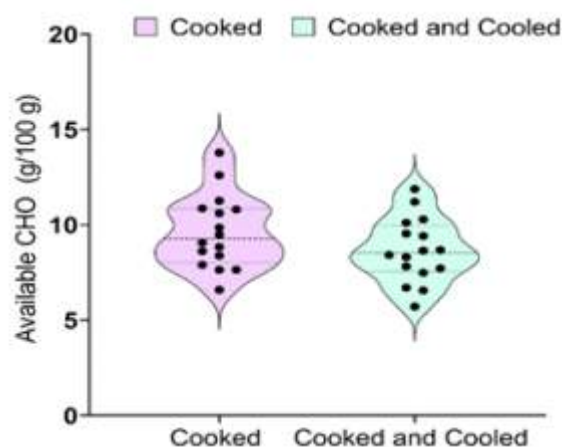


Fig. 11: Effect of retrogradation on available carbohydrate (ACHO) content in potato-cooking oil combination represented as a violin plot.

Table 2: ANOVA table for interaction between treatment (cooked and cooled potato tubers) of Kufri Jyoti and Kufri Chipsona 3 with various cooking oil combination viz., mustard oil, sunflower oil, soybean oil, ghee, olive oil, rice bran oil, coconut oil

Potato cultivar	Parameters	Cooking oil	Treatment	C x T
Kufri Jyoti	Glycemic index	***	***	***
	Starch hydrolysis index	***	***	***
	Resistant starch	***	***	**
	Available carbohydrate content	***	***	NS
	Glycemic load	***	***	***
Kufri Chipsona 3	Glycemic index	***	***	***
	Starch hydrolysis index	***	***	***
	Resistant starch	***	***	***
	Available carbohydrate content	***	***	***
	Glycemic load	***	***	***

Abbreviations: C: Combination of potato + pulses, T: cooking treatment, NS: Not significant at $P \leq 0.05$,

*: Significant at $P \leq 0.05$, **: Significant at $P \leq 0.01$ and ***: Significant at $P \leq 0.001$

The ACHO was significantly reduced due to the addition of all the seven cooking oils followed by cooling in both the cultivars. The cooked and cooled potato (KJ)-olive oil, potato (KJ)-ghee and potato (KJ)-coconut oil combinations showed significant increase of 51.3, 45.6 and 43.2%, respectively in ACHO (Table 2, Table 3). The least effect of cooling was observed in potato (KJ)-sunflower oil as this was only 25.3 % as compared to Potato (KJ)-control (Fig. 1). In KC3, addition of cooking oil followed by cooling in

potato (KC3)-olive oil, and potato (KC3)-rice bran oil showed maximum (54.7 %) and minimum (24.3 %) lowering of ACHO, respectively (Table 3). Addition of ghee and coconut oil suggested lowering ACHO by 48 and 31.4 % respectively in potato (KC3)-ghee, and potato (KC3)-coconut oil. From this experiment, it can be suggested that olive oil, ghee and coconut oil are better in lowering the ACHO in both cultivars.

Table 3: Effect of cooking and cooking followed by cooling for potato alone and potato-cooking oil combinations on available carbohydrate (ACHO) and starch hydrolysis index (SHI) when potato belongs to cultivars Kufri Jyoti (KJ) and Kufri Chipsona 3 (KC3).

Varieties	Potato alone or potato-cooking oil combinations	ACHO (g/ 100g DW)		SHI	
		Cooked	Cooked and Cooled	Cooked	Cooked and Cooled
Kufri Jyoti	Potato (KJ)	13.78 ± 0.15 ^a	11.88 ± 0.13 ^b	45.99 ± 0.15 ^a	31.16 ± 0.22 ^b
	Potato (KJ) + Mustard Oil	10.87 ± 0.40 ^a	10.11 ± 0.08 ^a	43.52 ± 0.74 ^a	35.02 ± 0.08 ^b
	Potato (KJ) + Sunflower Oil	11.26 ± 0.18 ^a	10.29 ± 0.04 ^b	36.91 ± 0.23 ^a	31.74 ± 0.15 ^b
	Potato (KJ) + Soybean Oil	10.81 ± 0.27 ^a	9.41 ± 0.08 ^b	39.76 ± 2.29 ^a	35.62 ± 0.42 ^b
	Potato (KJ) + Ghee	8.84 ± 0.39 ^a	7.49 ± 0.09 ^b	32.18 ± 0.34 ^a	28.26 ± 0.68 ^b
	Potato (KJ) + Olive Oil	7.90 ± 0.17 ^a	6.70 ± 0.14 ^b	33.10 ± 0.24 ^a	26.38 ± 0.33 ^b
	Potato (KJ) + Rice Bran Oil	9.85 ± 0.29 ^a	8.68 ± 0.15 ^b	42.09 ± 0.23 ^a	33.35 ± 0.13 ^b
	Potato (KJ) + Coconut Oil	9.06 ± 0.31 ^a	7.82 ± 0.09 ^b	31.82 ± 0.31 ^a	27.69 ± 0.11 ^b
Kufri Chipsona 3	Potato (KC3)	12.6 ± 0.13 ^a	11.21 ± 0.13 ^b	54.6 ± 0.23 ^a	42.10 ± 0.14 ^b
	Potato (KC3) + Mustard Oil	9.47 ± 0.28 ^a	8.42 ± 0.15 ^b	40.86 ± 0.42 ^a	33.45 ± 0.17 ^b
	Potato (KC3) + Sunflower Oil	8.39 ± 0.15 ^a	8.30 ± 0.02 ^a	36.91 ± 0.23 ^a	30.09 ± 0.16 ^b
	Potato (KC3) + Soybean Oil	8.61 ± 0.18 ^a	7.72 ± 0.35 ^b	48.21 ± 0.04 ^a	37.08 ± 0.82 ^b
	Potato (KC3) + Ghee	7.64 ± 0.29 ^a	6.56 ± 0.15 ^b	34.93 ± 0.69 ^a	29.42 ± 0.29 ^b
	Potato (KC3) + Olive Oil	6.59 ± 0.16 ^a	5.71 ± 0.14 ^b	34.20 ± 0.07 ^a	27.02 ± 0.13 ^b
	Potato (KC3) + Rice Bran Oil	10.61 ± 0.13 ^a	9.54 ± 0.20 ^b	50.70 ± 0.09 ^a	36.20 ± 1.77 ^b
	Potato (KC3) + Coconut Oil	7.64 ± 0.045 ^a	8.65 ± 0.18 ^b	41.19 ± 0.23 ^a	32.95 ± 0.72 ^b

Values followed by a different superscripted alphabetic letter for each row and each parameter are significantly different at $P \leq 0.05$ between those of cooked and cooked and cooled as per Sidak's multiple comparison test.

5. Effect of potato-cooking oil combination and retrogradation on starch hydrolysis index (SHI)

As per our results, SHI of combinations i.e., potato (KJ)-ghee, potato (KJ)-coconut oil and potato (KJ)-olive oil increase by 30.8, 30.1 and 28.1 %, respectively when compared with control (**Table 3**). Similar results were also obtained by the addition of different cooking oils to potatoes of KC3 as this resulted in a significant reduction of SHI (**Table 2**). The SHI of potato (KC3)-olive oil and potato (KC3)-ghee showed an increase of 37.4 and 34.9%, respectively. For the potato of cultivar KC3, SHI was least affected by the addition of rice bran oil, only 7.1% as compared to KC3-control.

Cooking of potato tuber with different oils followed by cooling also resulted in a significant lowering of SHI in both the cultivar. Cooking followed by cooling of potato (KJ)-olive oil and potato (KJ)-coconut oil resulted in significant lowering by 42.6 and 39.8 %, respectively in SHI as compared to potato (KJ)-control (**Table 3**). The least lowering of SHI by 27.5% was noted in cooking and cooling of potato (KJ)-rice bran oil. For the potato of cultivar KC3, cooking and cooling of potato (KC3)-olive oil and potato (KC3)-ghee showed a significant reduction of 50.5 and 46.1%, respectively in SHI when compared with control (**Fig. 12**). Here, the addition of soybean oil resulted in the least lowering of SHI (by 32.1 %).

6. Effect of potato-cooking oil combination and retrogradation on in vitro glycemic index (GI)

The addition of different cooking oils has a significant GI lowering effect on both the potato cultivars (**Fig. 13a and b**). The combination of potato (KJ)-olive oil (GI of 65.05) and potato (KJ)-ghee (GI of 65.79) reported maximum lowering of GI in comparison to potato tuber (KJ) alone (GI of 76.14) which reduced GI by 14.5 and 13.6%, respectively (**Fig. 13a**). Similarly, the addition of olive oil and ghee to potato of KC3 showed a significant lowering of GI by 19.7 and 19.0%, respectively. In both of the potato cultivars, the addition of rice bran oil was least effective as the reduction in GI only by 2.6 and 3.8 % were seen in potato (KJ)-rice bran oil and potato (KC3)-rice bran oil combinations, respectively.

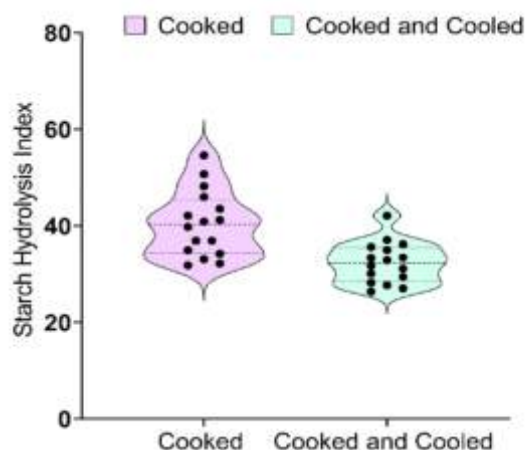


Fig. 12: Effect of retrogradation on starch hydrolysis index (SHI) content in potato-cooking oil combination represented as a violin plot.

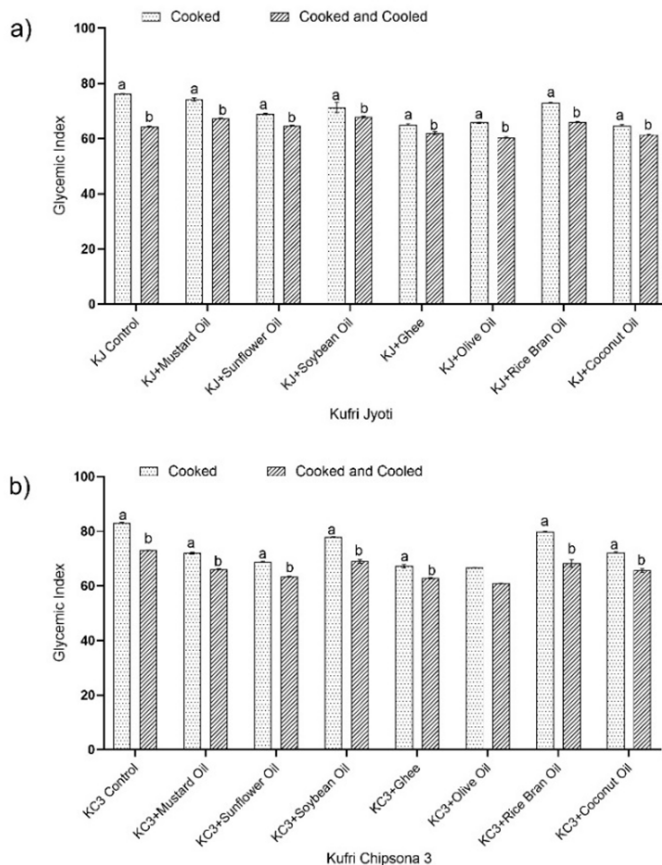


Fig. 13: Effect of cooking and cooking followed by cooling for potato alone and potato-pulse combinations on glycemic index of when potato belongs to cultivars Kufri Jyoti, KJ (a) and Kufri Chipsona 3, KC3 (b). Statistical significance of difference between the means across the cultivars. Bar are represented as mean values $\pm$ SEM of three replicates. For each of the food (potato alone) or food combinations (potato with pulse), two columns with different alphabet (a, b) represent statistically different values for glycemic index at $P \leq 0.05$ for cooked and cooked and cooled as per Sidak's multiple comparison test.

There are meagre or no direct reports on how the GI is affected in combination with potato-cooking oil followed by retrogradation (cooling). Our results on two potato cultivars showed that cooling of cooked potato-oil combinations results in a significant reduction in GI (Fig. 13a and b). The maximum and minimum lowering of GI were observed in cooked and cooled products i.e., potato (KJ)-olive oil (60.93) and potato (KJ)-mustard oil (67.33) in comparison to control (potato (KJ) alone (76.14) (Fig. 13a). Similarly, for potato tuber of KC3, GI decreased significantly in all the potato-oil combinations on cooking followed by cooling (Fig. 14). Here, the reduction was maximum (26.6%) and minimum (17.8 %) for potato (KC3)-olive oil and potato (KC3)-rice bran oil combinations (Fig. 13b).

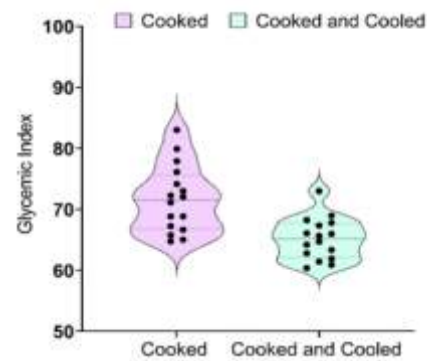


Fig. 14: Effect of retrogradation on glycemic index (GI) content in potato-cooking oil combination represented as a violin plot.

7. Effect of potato-cooking oil combination and retrogradation on in vitro glycemic load (GL)

Our finding suggests that the addition of cooking oil has a significant effect on lowering GL in both the cultivars (Fig. 15a and b, Table 2). The addition of olive oil brings about the maximum reduction of GL by 50.4 and 58.0% in potato

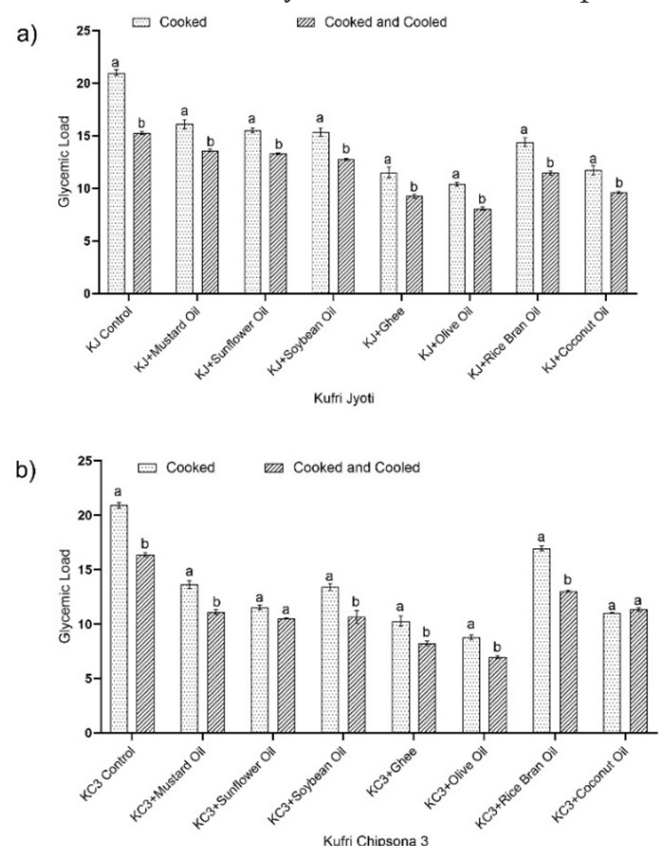


Fig. 15: Effect of cooking and cooking followed by cooling for potato alone and potato-pulse combinations on glycemic load of when potato belongs to cultivars Kufri Jyoti, KJ (a) and Kufri Chipsona 3, KC3 (b). Statistical significance of difference between the means across the cultivars. Bar are represented as mean values $\pm$ SEM of three replicates. For each of the food (potato alone) or food combinations (potato with pulse), two columns with different alphabet (a, b) represent statistically different values for glycemic load at $P \leq 0.05$ for cooked and cooked and cooled as per Sidak's multiple comparison test.

(KJ)-olive oil (with GL value of 10.39) and potato (KC3)-olive oil (with GL value of 8.79), respectively as compared to their respective controls (KJ: 20.99 and KC3: 20.94). However, the least reduction of GL by 23.3 and 18.9% was observed in potato-oil combinations of KJ-mustard oil (with GL value of 16.11) and KC3-olive oil (with GL value of 10.96), respectively. Cooking followed by cooling resulted in a significant lowering of GL in all seven potato-oil combinations for both the cultivars (Fig 15a and b). Among seven different potato (KJ)-oil combinations, potato (KJ)-olive oil showed a higher (61.4%) and potato (KJ)-mustard oil showed a lower (35.1%) reduction in GL as compared to the control (Fig. 15a). Similar results were observed with cooked and cooled potato (KC3)-olive oil (6.96), where the reduction of GL was maximum (66.8 %) out of all the different oil combinations (Fig. 16). However, potato (KC3)-rice bran oil reported the least reduction of 37.8% whose GL was 13.02 as compared to the control value of 20.94 (Fig. 15b).

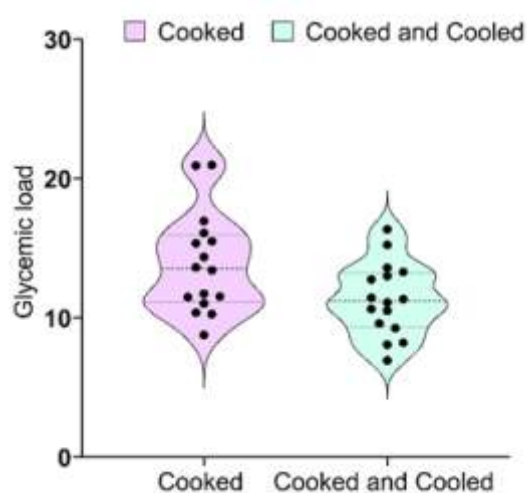


Fig. 16: Effect of retrogradation on glycemic load (GL) content in potato-cooking oil combination represented as a violin plot.

8. Effect of potato-cooking oil combination and retrogradation on resistant starch content (RSC)

Amylose has a compact structure so its digestion is difficult by starch hydrolysing enzymes and its interaction with cooking oil results in the formation of RS. The addition of each of the cooking oil (seven different types) increased the RSC significantly for potato tubers of both cultivars (Table 2). Out of seven cooking oils,

addition of olive oil and ghee enhanced the RSC in potato of KJ by 2.7 and 2.7 folds, respectively (Fig. 17a). Whereas, the least increase of only 1.79 folds in RSC was observed with rice bran oil with the potato of KJ. Similarly, RSC in potato tubers of KC3 in combination with olive oil and ghee was enhanced by 1.8 and 1.7 folds, respectively (Fig. 17b).

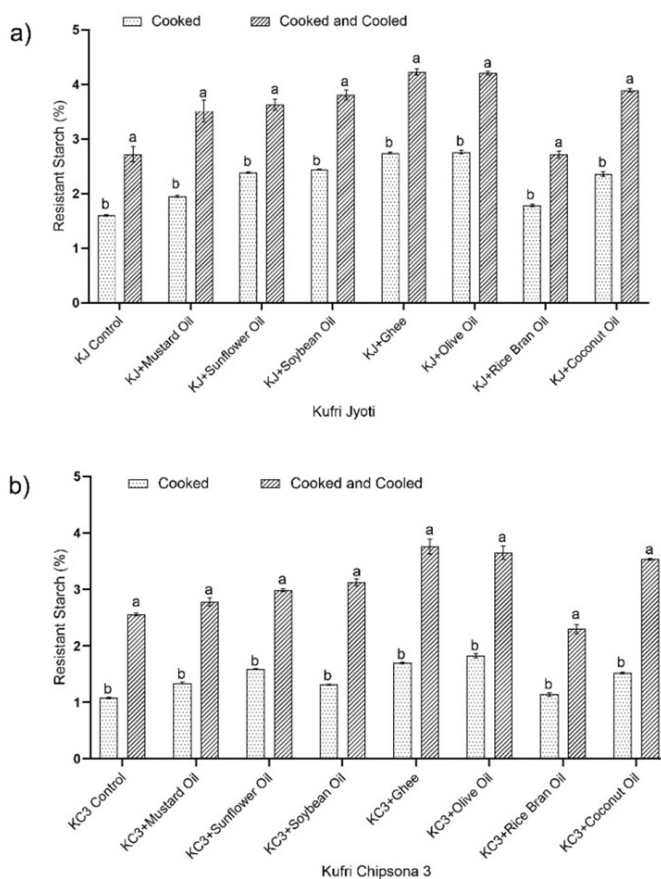


Fig. 17: Effect of cooking and cooking followed by cooling for potato alone and potato-pulse combinations on resistant starch (%) of when potato belongs to cultivars Kufri Jyoti, KJ (a) and Kufri Chipsona 3, KC3 (b). Statistical significance of difference between the means across the cultivars. Bar are represented as mean values $\pm$ SEM of three replicates. For each of the food (potato alone) or food combinations (potato with pulse), two columns with different alphabet (a, b) represent statistically different values for resistant starch (%) at $P \leq 0.05$ for cooked and cooked and cooled as per Sidak's multiple comparison test.

A combination of cooking oil with potato followed by cooling (leading to the process of retrogradation) ultimately increases the RSC significantly in both the potato cultivars. It was seen that cooling of cooked potato (KJ)-ghee and potato (KJ)-olive oil combinations showed increase in RSC by 1.63 and 1.62 folds, respectively. Such an increase in RSC was 1.4

folds in potato (KJ)-coconut oil combination after cooling. The least increase, only 0.7 folds was observed in potato (KJ)-rice bran oil combination followed by cooling (Fig. 17a). Similar, results were obtained in cooked and cooled potato (KC3)-ghee and potato (KC3)-olive oil combinations, where a significant enhancement of RSC by 2.4 and 2.5 folds, respectively were recorded in comparison to control (Fig. 17b). In our experiment, the formation of RS might be accelerated due to the addition of cooking oil followed by cooling (Fig. 18).

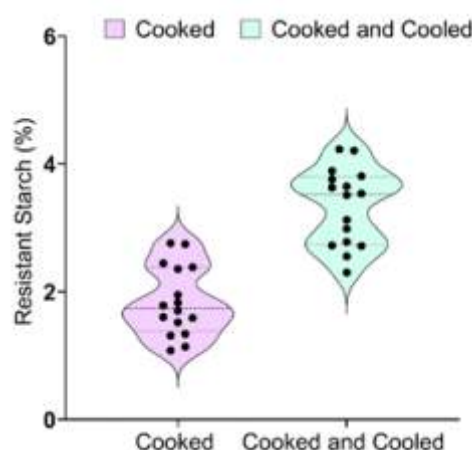


Fig. 18: Effect of retrogradation on resistant starch (RS) content in potato-cooking oil combination represented as a violin plot.

9. Development of functional fermented probiotics beverages from potato juices

Probiotics are live microorganisms that confer a beneficial effect on the host when administered in proper amounts. Multiple reports have described their health benefits on gastrointestinal infections, antimicrobial activity, improved lactose metabolism, reduction in serum cholesterol, anticarcinogenic properties, antidiarrheal properties, and improvement in inflammatory bowel disease. Dairy-based mostly products containing live microorganisms are the most vehicles of probiotics for humans. Dairy allergens are also preventing some consumers to consume milk-based probiotics but fruits and vegetables are free from milk allergens, disaccharides and cholesterol and then are appropriate substrates. The non-dairy beverages would be the ensuing food class wherever the healthy microorganism can create its mark. Potato juice is a medium for the production of probiotic beverages. We screened several microbes for potato probiotics and found the following potential microbes with probiotics attributes for potato probiotics beverages:

Table 4: Accession number

S. No.	Accession numbers	Microorganisms
1	NCDC 13	<i>Lactobacillus acidophilus</i>
2	NCDC 25	<i>Lactobacillus plantarum</i>
3	NCDC 214	<i>Lactobacillus fermentum</i>

Table 5: Effect of cultures on pH, Acidity, viable cell counts and reducing sugar

Cultures	After 72 hrs inoculation of LABs							
	pH		Acidity (%)		Viable cell counts (cfu/mL)		Reducing sugar contents (mg/100 mL)	
	Kufri Neelkanth	Kufri Chipsona -1	Kufri Neelkanth	Kufri Chipsona -1	Kufri Neelkanth	Kufri Chipsona -1	Kufri Neelkanth	Kufri Chipsona -1
<i>Lactobacillus acidophilus</i> NCDC 13	5.67 ± 0.01	5.16 ± 0.07	0.67 ± 0.01	0.87 ± 0.00	1.30 ± 0.3 × 10 ⁹	2.37 ± 0.3 × 10 ⁸	147 ± 0.08	189 ± 0.02
<i>Lactobacillus fermentum</i> NCDC 214	4.87 ± 0.03	4.53 ± 0.04	0.71 ± 0.00	0.75 ± 0.06	1.40 ± 0.3 × 10 ⁹	7.50 ± 0.3 × 10 ¹⁰	161 ± 0.00	191 ± 0.04
<i>Lactobacillus plantarum</i> NCDC 20	4.17 ± 0.05	4.36 ± 0.01	0.79 ± 0.3	0.85 ± 0.4	8.00 ± 0.3 × 10 ¹⁰	2.31 ± 0.3 × 10 ¹⁰	165 ± 0.01	197 ± 0.05
Mean ± SD (n=3)								

10. Genome-wide analysis of sucrose transporter genes in potato and their role in post harvest shelf-life and sensory attributes of potato

In order to see the genome-wide landscape of sucrose transporter genes in potato, the potato genome was analysed using PLAZA server. The analysis revealed presence of only one sucrose transporter gene (gene id: PGSC0003D MG4 00025610) in whole potato genome sequence database. The sucrose transporter gene PGSC0003DMG400025610 was found to be located on chromosome number 5. The size of the gene was found to be 1515 nucleotides which contained open Reading Frame (ORF) of 825 nucleotides (Fig.1). The gene structure analysis showed presence of 5 introns in the PGSC0003DMG400025610 sucrose transporter gene (Fig.2) The gene encoded a protein composed of 274 amino acids, and having theoretical isoelectric point of 5.25 and molecular weight of 28.99 kDa. In addition to potato genome database, looking into the NCBI GenBank showed several sucrose transporter genes of potato. Comparative analysis of secondary structure, signal peptide and transmembrane domains of these genes are presented in Table 1.

>PGSC0003DMG400025610ATGGGTCGTGTAGCAGAAAATAGTCCAAAGAATGAAGAACAGAGACCTGACAAGGATCAAGGTGATAGCTTCGCTGATAGCCCTGGAGCAGTTTTGGTCAATCTGTTGACCAGCTTACGTCATTTGCCTCCTGCAATGCATTCTGTTCTCATTGTCATGGCTCTGACTTGGTTGTCTGTTTCCCTTTTTCTTTTTTGACACGGATTGGATGGGAGAGAAGTCTATCATGGGGACCCGAAAGGA GAAGCAGATGAAGTAAATGCATATAACCAAGGT

GTCAGAGAAGGTGCATTTGGTTTGCTATTGAATTCTGTTGTCTTGGCGTTAGCTCCTTTCTTATTGAGCCAATGTGCAAGTGGATTGGTTCTAGACTTGTGTTGGCTGCGAGCAACTTCATTGTATTTGTCTGCATGGCCTGCACCGCTATCATTAGCGTGGTTTCTATCATGTGCACATACGGAGGGAGTCCAACATGTGATTGTGCTACTCGATCAACTCAAATTGCTGCTTTGGTTGTTTTCTCTCTTCTTGGCATTCTCTTGCTGTAACTTACAGTGTCCCTTTCTCTATCACAGCAGAGTTGACAGCTGACGCTGGTGGTGGTCAAGGGTTGGCAATAGGAGTCTGAATCTTGCAATTGTTGTACCTCAGATGGTTGTCTCGCTTGGTGCCGGTCCATGGGATGCTTTATTTGGTGGAGGAAACATACCGGCATTTGTCTTAGCATCTTTAGCTGCACTTGCTGCTGGAATTTTGTCTATGCTCAGACTACCAAATTTATCAAGTAATTTCAAATCAACTGGCTTCCATTTTGGTTGA

Fig. 1: Open Reading Frame Sequence (ORF; 825 nucleotides) of sucrose transporter gene PGSC0003DMG400025610

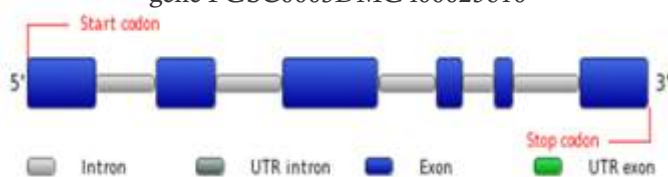


Fig. 2: Introns landscape (5 introns) of potato sucrose transporter gene PGSC0003DMG400025610

Table 1: Secondary structure, Signal peptide and Transmembrane content prediction of sucrose transporter genes of potato

S. No.	Genes	Secondary structure (%)			Signal peptide (%)	Transmembrane (%)
		Helix	Beta Sheet	Random Coil		
1	NM_001288141	65	0	34	-	54
2	X69165	52	6	42	-	52
3	AF237780	65	1	34	-	54
4	XR_368730	65	1	34	-	54
5	XR_368729	65	0	35	-	54
6	NM_001318624	52	6	43	-	52
7	NM_001288509	52	2	45	-	41
8	PGSC0003DMG400025610	64	1	35	-	49

DIVISION OF SOCIAL SCIENCES

PROGRAMME: TRANSFER OF POTATO TECHNOLOGIES TO STAKEHOLDERS AND ASSESSMENT OF THEIR IMPACTS

Analysis of constraints in potato production and the farmers' suggestions to overcome the constraints in Bihar

The study was attempted to analyse the constraints in potato cultivation and the farmers' suggestions to overcome the constraints, by interviewing 120 randomly selected potato growers of Bihar (60 each from Patna and Nalanda districts). The survey revealed that based on weighted mean score (WMS), the major constraints perceived by farmers in the study areas were lack of good quality seed (WMS=2.43), high cost of cultivation (2.43), low market price of the produce (2.42) and lack of suitable potato varieties (2.40). Other constraints were low profitability in potato cultivation, lack of knowledge about improved cultivation practices, storage and processing facilities, training, production inputs at right time, labour and high cost of quality seeds.

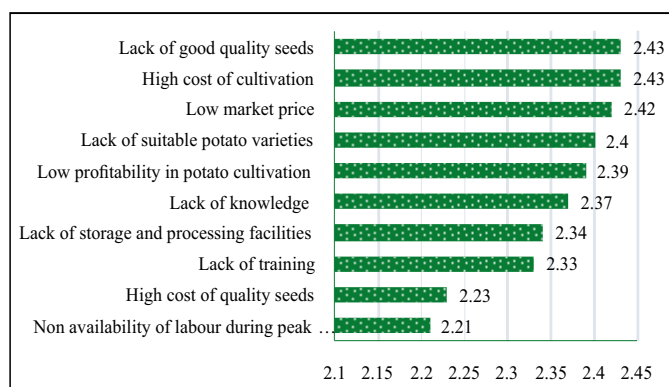


Fig. 1: Weighted mean score of the major constraints in potato production in Bihar

The major suggestions based on the responses of the farmers were training on potato production and processing, which were suggested by 42.5 percent of the respondents, controlling potato price fluctuation (41.57%), ensure availability of quality seeds of HYVs (41.67%), number of cold stores should be increased (25.83%), availability of processing units nearby (25.83) and availability of credit and subsidy facilities (20.00%).

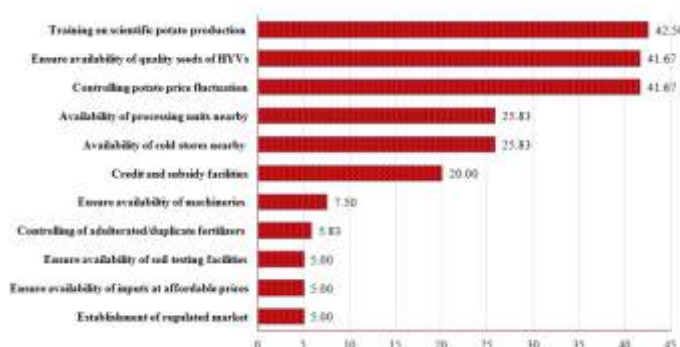


Fig. 2: Farmers' suggestions to overcome constraints in potato production in Bihar

Sources of potato seeds and major constraints in availing quality seeds of improved varieties in Bihar

The study was attempted to analyse sources of potato seeds and the major constraints in purchasing seed of improved varieties, by interviewing 120 randomly selected potato growers of Patna and Nalanda districts of Bihar. The analysis revealed that the most important seed source was seed traders/dealers, which was used by about 38.90 percent of farmers. These are mostly local traders and the farmers reported that most of the seeds procured from them were not of good quality. The second important seed sources were friends and relatives which were used by about twenty two percent of farmers. Other sources of seeds were seed growers and farm saved seeds.

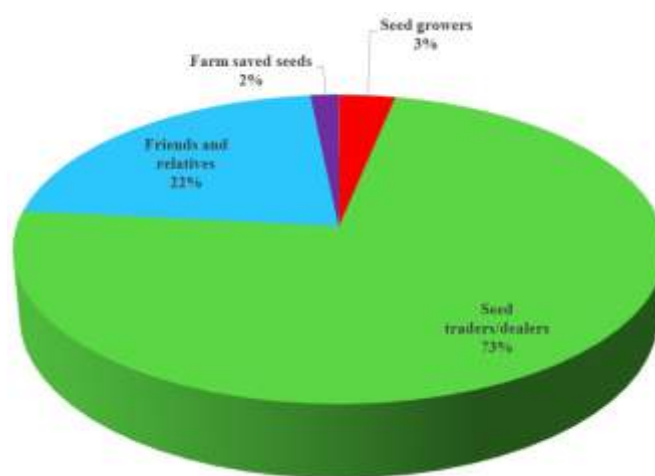


Fig. 3: Sources of potato seeds of sampled farmers in Bihar

The high cost of quality seeds with an overall weighted mean score (WMS) of 2.63 was ranked as the first major constraint in the study areas (Figure 4). Since the cost of potato is very high, poor farmers, especially the marginal and small farmers have to either use their self-retained seeds or poor-quality seeds from the local traders, leading to low productivity. The second constraint was lack of seed of required varieties (WMS=2.56), which was subsequently followed by lack of information about improved varieties (WMS=2.26), poor quality of available seeds (WMS=2.03) and lack and high cost of storage facilities (WMS=1.83).

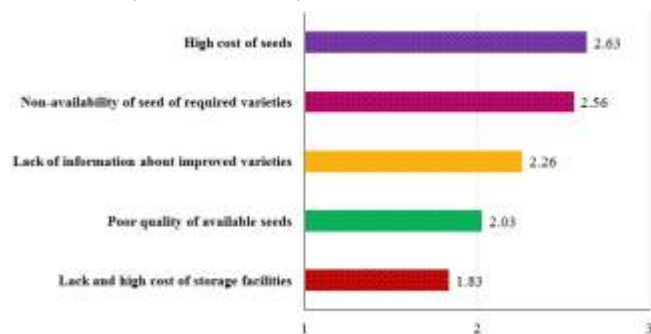


Fig. 4: Major constraints in procuring quality seeds of improved varieties in Bihar

Assessment of Seed Replacement Rate of potatoes in Bihar

The study for assessment of seed replacement rate (SRR) was conducted by 120 farmers of Patna and Nalanda districts of Bihar. The seed replacement rate model computes the percentage of the total area under the crop that can be covered with the quantity of seeds of improved varieties produced or available for the commencing agricultural year. It is calculated using the equation

Particulars	Patna	Nalanda	Overall
V=Seed of improved varieties used by the farmers (in quintal)	109.63	947.20	1056.83
A=Area under the potato crop (ha)	20.80	30.96	51.76
K=Seed rate per unit of area (quintal/ha)	23.59	31.58	27.65
SRR	22.34	96.88	73.84

TRANSFER OF TECHNOLOGIES EXTENSION ACTIVITIES AT ICAR-CPRI, SHIMLA

Twenty one days Winter School

CPRI organised twenty one days Winter School on “Innovations in Potato Improvement, Production and Utilization of Technologies for

Doubling Farmer's Income” during 18 January to 7th February, 2022 attended by 26 participants (13 physical and 13 virtual) representing 12 states and 11 disciplines. Training methodologies like lecture cum interactive discussions, practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants. The objective of the training was to enrich the knowledge and skill of the trainees regarding potato cultivation so as that they could deliver the same to the end users.



Officers training programme on potato shoot tip meristem culture

A six days training programme on “Potato Shoot Tip Meristem Culture” was organised during 1-6 April, 2022 for two officers of Assam government. The training was sponsored by APART (CIP), AAU Jorhat, Govt. of Assam. Training methodologies like lecture cum discussion, practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants. Most of the emphasis was on practical session as it was the requirement of the training.



Officers training programme on seed potato production through apical rooted cuttings

A six day training programme on “Seed Potato Production Through Apical Rooted Cuttings (ARC)” was organised during 25-30 April, 2022 for nine officers comprising of Assistant Professors and Technicians of Bihar government. The training was sponsored by Project Director, Centre for Advance Studies on Climate Change, RPCAU, Pusa Bihar. Training methodologies like lecture cum discussion, a number of practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants.



Awareness Programme on “Value addition in potato and other vegetables”

A one day training cum awareness programme on “Value addition in potato and other vegetables” under Atmnirbhar Bharat: One district One product (ODOP) programme was organised by ICAR-CPRI on 6th June at village Chhausha, Tehsil Kandaghat distt. Solan(HP). More than 200 farmers (men and women) from Chhausha and nearby panchayats participated in the programme. They were explained about the importance of value addition in vegetables and how they can work on the value addition of potato and other vegetables grown in their area by the experts from CPRI.



Officers Training Programme

A four day training on “Potato Value Chain: Seed, Production, Pest management, Post Harvest Technology and Value Addition” was organised for 20 ADOs from different districts of Assam during 14 - 17 June. The training was sponsored by Assam Rural Infrastructure and Agricultural Services Society (ARIAS), Govt. of Assam. Training methodologies like lecture cum discussion, practicals, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants.



Officers training programme on Potato Value Chain

A four day training programme on “Potato Value Chain: Seed Production, Pest Management, Post-Harvest Technology and Value Addition” was organised during 13-16 July for 17 officers of Bihar government. The training was sponsored by Bihar Rural Livelihood Promotion Society (JEEVIKA), Patna (Bihar). Training methodologies like lecture cum discussion, practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants.



One day training cum agricultural input distribution programme

A one day training programme on “*Fal, sabji evm aloo ki kheti ki unnat taknik par kisan prakshikshan evm krishi input vitran karyakram*” was organised on 11th October under SCSP sub-plan at Jathia Devi, Shimla for Schedule Cast farmers of that area. A total of 121 farmers participated in the programme. They were given lecture on various aspects of fruits, vegetables and potato cultivation. A pack of 5 kg NPK mixture and 400 ml Nutragen was distributed to all the participating farmer. Along with a *swacchta* drive was also undertaken on the same day in the village making them aware about the cleanliness.



PM Kisan Samman Sammelen cum one day training cum agricultural input distribution programme

Live broadcast of PM Kisan Samman Sammelen was held on 17th October. In this programme 50 farmers from Dehna Panchayat also participated along with the entire staff of the institute. A training programme on “*Fal, sabji evm aloo ki kheti ki unnat taknik par kisan prakshikshan evm krishi input vitran karyakram*” was also organised under SCSP sub-plan at the institute for Schedule Caste farmers of Dehna Panchayat. They were given lecture on various aspects of fruits, vegetables and potato cultivation. A pack of 5 kg NPK mixture and 400 ml Nutragen was distributed to all the participating farmer.



Farmers Training for Uttarakhand farmers

A 3 days training on “*Aloo mulya shrinkhla: aloo beej utpadan, keet evm rog prabandhan, faslottar prodyogiki aur mulyavardhan*” was organised during 24-26 November for 26 farmers from Uttarkashi (Uttarakhand) sponsored by Renuka Samiti, Uttarkashi (Uttarakhand). A good number of female farmers participated in this training. Training methodologies like lecture cum discussion, practical sessions, skill demonstration, field visit and video film show etc. were the modes for imparting the training to the participants.



Farmers Training for tribal farmers of Kinnaur district

A 3 days training on “*Himachal Pradesh ki oonchi pahadiyon me falo, sabjiyo aur aloo ka unnat utpadan aur sanrakshan taknik par kisan prakshikshan evm krishi input vitran karyakrm*” was organised during 27-29 November for 200+ tribal farmers of Kinnaur district at Sapni village of tehsil Sangla, block Kalpa (Kinnaur). They were given lecture on various aspects of fruits, vegetables and potato cultivation. Experts from KVK Rekongpeo also participated in the programme and delivered their input. A pack of 5 kg NPK mixture and 400 ml Nutragen was distributed to all the participating farmer.



Live Phone-in Programme at Doordarshan during 2022

Scientists from ICAR-CPRI, Shimla participated in the live phone-in programmes during the period. The details of the topic and the expert is as under:

Month	Topic	Name of the Expert
January	Potato varieties, sowing and fertiliser management for Mid-Hills of Himachal Pradesh	1. Dr. Vinod Kumar 2. Dr. Dalamu
March	Management of potato diseases and pests for Mid-Hills of Himachal Pradesh	1. Dr. Ravinder Kumar 2. Dr. Kailash Chandra Naga
April	Planting of seed potato in higher hills of Himachal Pradesh.	1. Dr. Vinod Kumar 2. Dr. Dalamu
May	Inter cultural operations and harvesting of potato in Himachal Pradesh	1. Dr. Ashwani Sharma 2. Dr. Jagdev Sharma
June	Post-harvest operation, storage & marketing in mid hills of Himachal Pradesh.	1. Dr. N K Pandey, 2. Dr. Brajesh Singh,
July	Intercultural operations in potato crop in higher hills of Himachal Pradesh	1. Dr. Ashwani Kumar Sharma 2. Dr. Vinod Kumar
August	Disease and Pest management in potato in higher hills of Himachal Pradesh	1. Dr. Ravinder Kumar 2. Dr. Rahul Tiwari
September	Potato harvesting and post-harvest operations in the high hills of Himachal Pradesh	1. Dr. Brajesh Singh 2. Dr. Milan Kumar Lal
October	Potato Varieties and their sowing for the plains of Himachal Pradesh	1. Dr. Dalamu 2. Dr. Vinod Kumar
November	Intercultural operations, harvesting and storage of potato in lower hills of Himachal Pradesh	1. Dr. Ashwani Kumar Sharma
December	Insect pest and disease management in potato	1. Dr. Ravinder Kumar

Activities of Agriculture Technology Information Centre (ATIC)

Sale and distribution of CPRI technical and extension bulletins: A total of 138 technical and extension bulletins were sold through ATIC. Moreover, nearly 3000 publications like CPRI profile, Crop Calendar and leaflets related to potato technologies were distributed free of cost to the institute visitors and during different exhibitions. Altogether revenue generated through sale of publications was of value Rs. 16,770/-.

Dissemination of knowledge to visitors: A total of 2186 persons visited in the institute during 2022. The visitors included 1468 School/B.Sc./M.Sc./Ph.D students from different states, 518 farmers and 200 teachers, extension workers/agri. or hort. Officers. The visitors were made aware about various activities and technologies of the institute through films, lectures, discussions, visit to important laboratories and institute's museum and farmers' museum in which the technologies were

displayed using posters, panels, live samples and models etc.

EXTENSION ACTIVITIES AT ICAR-CPRI RS, MODIPURAM

Frontline demonstration at farmer's field and KVK farm on varietal production technology:

In view to popularize the improved potato varieties and improved cultivation practices developed by institute for potato crop, we have conducted 11 field demonstrations on variety Kufri Lohit Kufri frysona, Kufri Ganga, Kufri Mohan-1, Kufri Neelkanth, Kufri Himalini, Kufri Sangam and Kufri Garima at 38 farmer fields i.e. Sant kabirnagar, Gorakhpur, Maharajganj, Bahraich, Meerut, Hapur, Aligarh, Bulandshahar, Hathrus in Uttar Pradesh and Muraina in Madhya Pradesh. In this year potato crop cafeteria also developed with 15-20 improved potato varieties at demonstration farm of KVK Sambhal, Bulandshar, JP Nagar, Bahraich and Lucknow districts of Uttar Pradesh for visit of farmers in mass from concern districts.

Frontline demonstration at farmer fields on improved potato varieties and seed production technology under SCSP: This year 350 quintals breeder seed of improved varieties like Kufri Pukhraj, Kufri Frysona, Kufri Surya and Kufri

Anand was distributed through Krishi Vigyan Kendra (KVK) of concerned districts to total 350 schedule caste farmers belong 18 districts of Uttar Pradesh and Haryana.

Details of Frontline demonstration at farmers field on improved potato varieties and seed production technology under SCSP during 2022

Sl. No.	District	Quantity of breeder seed distributed (q)	Number of farmers
1	Lucknow	20	20
2	Chitrakoot	20	20
3	Mahoba	20	20
4	Auraiya	20	20
5	Ajamgarh	20	20
6	Sonbhadra	20	20
7	Kausambi	20	20
8	Raebareilly	10	10
9	Jhanshi	20	20
10	Jalaun	20	20
11	Barabanki	20	20
12	Mirzapur	20	20
13	Unnao	20	20
14	Kanpur dehat	20	20
15	Lakhimpurkhiri	20	20
16	Sitapur	20	20
17	Hardoi	20	20
18	Yamunanagar (Haryana)	20	20
	Total	350	350

Training Programme Organized

Sl. No.	Title of training	Duration	Nos. of trainees	Beneficiaries	Sponsored Agency
1.	Kisan Bhagidari prathamika hamari karyakarm ke antergat kisan goshti-aloo ka khadya evam poshan suraksha main yogdan	28 April 2022	50	Farmers of districts Meerut, Hapur, Gautam Buddh Nagar, Shamli and Muzafarnagar districts of U.P.	ICAR-CPRI Shimla
2.	Urvark ka daksh evam santulit upyog	21 June 2022	60	Farmers of districts Meerut, Hapur, Gautam Buddh Nagar, Shamli and Muzafarnagar districts of U.P.	ICAR-CPRI Shimla
3.	Potato Production Techniques	October, 17, 2022	50	Farmers of districts Meerut, Hapur, Gautam Buddh Nagar, Shamli and Muzafarnagar districts of U.P.	ICAR-CPRI Shimla
4.	Potato Production Techniques	December, 9, 2022	100	Farmers of districts Meerut, Hapur, Gautam Buddh Nagar, Shamli and Muzafarnagar districts of U.P.	ICAR-CPRI Shimla

Sl. No.	Title of training	Duration	Nos. of trainees	Beneficiaries	Sponsored Agency
5.	Kisan samman divas	23 Decemb er, 2022	40	Farmers of districts Meerut, Hapur, and Muzafarnagar districts of U.P	ICAR-CPRI Shimla
6.	Seed Production Technology	22 - 23 August, 2022	10	Farmers of districts Aligarh, Mathura Eavah and Meerut	Farmer association, Aligarh
7.	Seed production and Breeding Techniques	5-6 January, 2023	17	Officers and field staff of M/S Jain irrigation system, Jalgaon (Maharashtra)	M/S Jain irrigation system, Jalgaon (Maharashtra)
8.	Aloo Divas evam kisan jagrukta karyakarm	15 Februar y 2023	220	Farmers of districts U.P.,Haryana, Punjab,Uttarakhand and Madhy Pradesh	ICAR-CPRI Shimla



Training programmes organised at ICAR-CPRI RS, Moodipuram

Participation and organization of exhibition and participation in exhibition, Aloo Divas and Krishi Pradarshini

Sl. No.	Title of exhibition	Duration	Nos. of trainees Beneficiaries
1	Participation in Fasl Kranti kisan Mela at JV College Bauraut district Baghpat	One days 2 November, 2022	200 Farmers belong to western districts of U.P.
2.	Participation in Krishi Exhibition at C.C.S University campus Meerut (U.P.)	One days 19 November, 2022	300 Farmers belong to western districts of U.P.
3	Participation in RISE IN UTTAR PRADESH Exhibition at HRIT Ghaziabad (U.P.)	Three days 22-24 November, 2022	600 Farmers stakeholders and students of NCR.
4.	Participation in Krishi Exhibition at ICAR- IIFSR Modipuram, on the occasion of national conference on Agro- ecology based Agri- Food Transformation systems	Three days 27-28 January, 2021	300 Farmers belong to western districts of U.P.
5.	Exhibition organized on the occasion of National potato day	15 February, 2023	220 farmers belong to UP, Haryana, Punjab, MP and Uttarakhand

Others Extension activities organized

Programmes/activities	Duration	Participation	Number of beneficiaries
Parthenium 17 th Awareness Week	16-22 August, 2021	Farmers & Staff Members	50
World soil day	December, 5, 2022	60 Farmers and students	100
Fit India freedom run 3.0	02-31 October, 2022	Staff members	64
Agri Startup evam kisan samelan	17 October, 2022	Farmers and Staff members	60
Phones attended at Kisan call centre	2022	300 queries of potato growers from various districts of U.P., M.P., Rajasthan, Gujrat, Punjab, Uttarakhand Delhi and Haryana states	500

Visits of farmers and students

1. Exposure visits of students: Total 137 UG students from various colleges and universities of U.P. Visited CPRI RS, Modipuram (UP).

2. Exposure visits of farmers: Total 128 farmers sponsored by various states under different schemes and personal visit from various districts of U.P., Uttarakhand, Punjab, M.P., and Haryana visited Central Potato Research Institute RS, Modipuram (UP)



Photos: Various extension activities at ICAR-CPRI RS, Modipuram (UP)

EXTENSION ACTIVITIES AT ICAR-CPRI RS, PATNA

Potato Breeder seed distribution among 153 number of SC farmers' under SCSP component: Breeder seed of two potato varieties namely Kufri Lalit and Kufri Neelkanth were distributed among 78 number of SC farmers to the tune of 39 quintals. The beneficiary farmers were from villages Bara, Gandhar, Sondih, Mauarkalan,

Nanauk, Kamalpur, Nawada, Bijubigha from Manpur block and villages Mastalipur and Vidhosharif from Gaya Sadar block of Gaya district. However, 38 quintals of potato breeder seed was distributed among 75 number of SC farmers in Nawada district. The beneficiary farmers were from village Mahuliyatand of Kauakol block and village Partokarhari of Akabarpur block of Nawada district.

Field exposure visit conducted for farmers of different areas of Bihar at ICAR-CPRI RS Patna during year 2022

Sl. No.	Date	Places	Number of beneficiary farmers
1	10.10.2022	Arrah & Shahpur	80
2	11.10.2022	Koilwar & Sandesh	80
3	12.10.2022	Udawanagar & Barhara	80
4	13.10.2022	Bihiya	40
5	24.11.2022	BAMETI Patna	40
6	16.12.2022	Nawada	98
		Total	418

EXTENSION ACTIVITIES AT ICAR-CPRI RS, JALANDHAR

Sl. No.	Title of the extension activities	Date and duration	No. of beneficiaries
1	Onsite training programs on Aeroponics technology at SD Biotech Bathinda	29 th November 2022	4 trainees
2	EDP on CPRI-Aeroponics technology for 3 officers from department of Agricultural Research and Education, Aizwal, Mizoram	16 th to 19 th November 2022	3 trainees
3	Awareness program for DAV College students at CPRI - ABI centre	17 th November 2022	30 students
4	Awareness program organized on Business opportunities in Hi-tech seed potato production at CPRI (RS) Jalandhar.	2 nd September 2022	38 trainees
5	Review workshop for aeroponic technology licensees organized at CPRI (RS) Jalandhar	15 th September 2022	20 trainees
6	Participation in 3 days Krishi Mela and Agri Exhibition in Morena, MP	11 th to 13 th November 2022	>1000 farmers
7	EDP on aeroponic technology organized for FPOs at CPRI (RS) Jalandhar	17 th September 2022	06 trainees
8	Training of incubatees from Dheeraj Farms on aeroponic technology for minituber production	10 th June 2022	06 trainees
9	Incubation program on aeroponic technology for minituber production	22 nd March 2022	05 trainees
10	Awareness program organized on Value addition in potato and aeroponic technology	11 th March 2022	43 participants
11	EDP organized for Big Fly Multitrade LLP on VEGFAST technology at CPRS Jalandhar	29 th April 2022	4 participants
12	Awareness program organized on Value addition in potato VEGFAST and aeroponic technology at CPRS Jalandhar technology for UG students of Sant Baba Bhag Singh University, Jalandhar	11 th May 2022	35 students
13	Awareness program organized on Value addition in potato VEGFAST and aeroponic technology at CPRS Jalandhar technology for UG students of CT Group of Institute, Jalandhar	12 th May 2022	47 students
14	Awareness program organized on Value addition in potato VEGFAST and aeroponic technology at CPRS Jalandhar technology for UG students of Saroop Rani College, Amritsar	23 rd April 2022	43 students
15	EDP organized on Agri-Entrepreneurship at CT College, Jalandhar.	22 nd April 2022	60 students
16	Training of incubatees from SD Biotech on aeroponic technology for minituber production	7 th and 25 th April, 2022	4 participants
17	Awareness program organized on Drone technology in Agriculture	6 th December 2022	48 participants
18	EDP on VEGFAST for SATH SAMAJIK GROUP	17 th January, 2022	50 participants
19	Training program organized on VEGFAST technology at CPRS, Jalandhar	19 th to 25 th January 2022	30 participants



Various extension activities at ICAR-CPRI RS, Jalandhar (Punjab)

EXTENSION ACTIVITIES AT ICAR-CPRI RS, GWALIOR

Activities	Date	Duration	Place
Participation in the exhibition and displayed potato varieties and advanced techniques of potato production.	11-13.11.2022	3 Days	Agri. Fair cum Exhibition, Ambedkar Stadium, Muraina
Organisation of Agri. Startup conclave and farmers conference, attended by 30 male and female farmers	17.10.2022	1 Day	ICAR-CPRIRS, Gwalior
Organisation of World Soil Day, attended by 51 farmers	05.12.2022	1 Day	ICAR-CPRIRS, Gwalior
Farmers visit: 89 farmers from different districts of the state were given information on the advanced techniques of potato production.	01.01.2022-31.12.2022	Round the year	ICAR-CPRIRS, Gwalior
Organisation of 2 cleanliness drives under Swachh Bharat Abhiyan at different locations of the station	02-31.10.2022 & 16-22.08.2022	29 Days & 7 Days	ICAR-CPRIRS, Gwalior
Debate competition for students of Agriculture University on 22-12-2022	22-12-2022	1 Day	ICAR-CPRIRS, Gwalior
Organising of yoga on the occasion of International Yoga Day.	21.06.2022	1 Day	ICAR-CPRIRS, Gwalior
International Women's Day celebrations were made by the members about the issues related to women.	08.03.2022	1 Day	ICAR-CPRIRS, Gwalior
17th Carrot Grass Awareness Week” programmes related to carrot grass eradication were organised at various places of the centre	16-22.08.2022	7 Days	ICAR-CPRIRS, Gwalior



Various extension activities at ICAR-CPRI RS, Gwalior (MP)

EXTENSION ACTIVITIES AT ICAR-CPRI RS, OOTY

Training Organized

1. Organized three days farmers training on "Potato Cultivation in Nilgiri Hills-New Problems and Way Forward" under SCSP component of the institute during 11th to 13th January 2022. The training has benefitted 90 farmers belonging to scheduled caste from different villages of the Nilgiri district of Tamil Nadu.
2. Organized one day workshop on "PM Kisan Samman Sammelan-2022" under SCSP component of the institute during 17th October 2022. The workshop has benefitted 50 farmers belonging to scheduled caste from the Nilgiri district of Tamil Nadu.
3. Scientists of the station also delivered lectures to 1718 students, farmers and other stakeholders during student and farmer visits to the station and during trainings organised by other organisations.

Participation in the Exhibitions

S. No.	Institution/Organization	Date	Beneficiaries	No. of participants
1.	124 th Flower show organized by Department of Horticulture and Plantation Crops, The Nilgiris, Tamil Nadu, India	20.05.2022 to 24.05.2022	>1 lakh farmers, Researchers, students, Govt. officials, etc.	>1,00,000
2.	Genetic Diversity Fair organized by Department of Horticulture and Plantation Crops, The Nilgiris, Tamil Nadu, India	29.12.2022	200 farmers	200

Frontline demonstrations (FLDs)

FLDs were conducted during summer season of 2022 in farmer's field at four locations of Nilgiri district viz., Koderi, Ulikal, Edakadu, and Berahatti villages for popularization of newly released ICAR-CPRI variety Kufri Sahyadri and Kufri Karan (with combined resistance to late blight and potato cyst nematode).

Other Extension Activities

- Imparted training to the Telangana State Horticultural Department officials on storage of potato cultivars after harvest on 10.02.2022.
- Organized a farmer's day under SCSP component of the institute during 7th July 2022. About 50 farmers belonging to scheduled caste from the Nilgiri district of Tamil Nadu were benefitted.

- Field Day: One field day was organized at Ulikal village on 04.08.2022 during the harvesting of the FLD trial and farmers of respective area were educated about the performance of the newly released hybrid and the advantages of growing the same.
- One villages Kenthorai was adopted under “Mera Gaon Mera Gaurav” and all the technical inputs related to potato production have been given during crop season.
- Organized a “Kisan Diwas” under SCSP

component of the institute during 23rd December 2022. About 50 farmers belonging to scheduled caste from the Nilgiri district of Tamil Nadu were benefited.

- Scientist, ICAR-CPRS, 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 2022.

EXTENSION ACTIVITIES AT ICAR-CPRI RS, SHILLONG

Training conducted

A total of 22 training were conducted during the

year 2022 covering 13 district (4 District-6 villages falls under aspirational District) and 6 states of NEH region. 960 beneficiaries were trained during the period report upon.

Sl. No	Title of the training	Place	Date	No of Days	No. of Beneficiaries
1	Advance in potato production technology	East Khasi Hills, Meghalaya	7 to 9 th Feb, 2022	3	60
2	Advance in potato production technology	West Jaintia Hills, Meghalaya	16 th to 18 th Feb, 2022	3	51
3	Improved Potato production technology	South Garo Hills, Meghalaya	01 st to 2 nd March, 2022	2	128
4	Improved Potato production technology	West Khasi Hills	04 th March 2022	1	54
5	Advance in potato seed production technology	East Khasi Hills, Meghalaya	22 to 24 th Feb, 2022	3	85
6	Improved Potato production technology	Ri-Bhoi District, Meghalaya	16 th March, 2022	1	53
7	Improved Potato production technology”	Peren, Nagaland	11 th Feb, 2022	1	20
8	Potato production technology	Lunglei, Mizoram	23 rd Feb, 2022	1	50
9	Potato production technology	Champhai, Mizoram	25 th March, 2022	1	40
10	Improved Potato production technology	Imphal West, Manipur	10 th March, 2022	1	40
11	Scientific management in Potato	Tirap, Arunachal	31 st Jan to 4 th Feb 2022	5	28
12	Scientific management in Potato	Tirap, Arunachal	5 th to 9 th Feb 2022	5	25
13	Scientific management in Potato	Tirap, Arunachal	10 th to 14 th Feb 2022	5	30
14	Scientific management in Potato	Tirap, Arunachal	15 th to 19 th 2022	5	31
15	Capacity Building programme cum input distribution	Sepahijala, Tripura	19th March, 2022	1	30

Sl. No	Title of the training	Place	Date	No of Days	No. of Beneficiaries
16	Cropping system of Potato with different types of vegetables	KVK, East Khasi hills.	6 th Sept, 2022	1	26
17	Online training on Potato Seed management	Aizawl Mizoram	29 th Sept, 2022	1	5
18	Agri Startup Conclave Kisan Sammelan	ICAR-CPRS, Shillong, East Khasi Hills	17 th , October, 2022	1	46
19	Quality seed production through apical rooted cuttings	Pyndenglitha, East Khasi Hills	20 th Oct, 2022	1	50
21	Advances in Potato Production Technology	East Garo Hills, Meghalaya	25 th Nov, 2022	1	40
22	Field day cum demonstration programme of ARC cuttings	Ri-Bhoi District, Meghalaya	1 st Dec, 2022	1	26



Training programmes organised in various states of North East India

Frontline Demonstrations

A total of 48 Front line demonstrations was conducted during 2022 covering 7 states of Northeast. 230 q Potato

Tuber Seed, 243 nos small farm tools/implements and 1,10,000 nos of Apical rooted cuttings were distributed to farmers/Beneficiaries.

Sl. No	Title	Place	No. of FLD
1	Improved Potato Cultivation with HYV Kufri Himalini and Kufri Girdhari	East Khasi Hills, Meghalaya	6
2	Improved Potato Cultivation methods with high yielding varieties (Kufri Joyti)	Imphal West, Manipur	3
3	Improved Potato Cultivation with HYV Kufri Himalini and Kufri Girdhari	West Jaintia Hills District, Meghalaya	3
4	Improved Potato Cultivation methods with high yielding varieties (Kufri Joyti)	Peren District, Nagaland	3
5	Improved Potato Cultivation methods with high yielding varieties (Kufri Jyoti and Kufri Megha)	Champhai District, Mizoram	3
6	Improved Potato Cultivation methods with high yielding varieties (Kufri Himalini)	West Tripura District, Tripura	3
7	Low-cost Potato Seed Production through ARC	East Khasi Hills, Meghalaya	3
8	Evaluation of processing varieties: Kufri Frysona and Kufri Chipsona 1	Nalbari and Baksa, Assam	10
9	Evaluation of Improved variety: Kufri Pukhraj	West Tripura	6
10	Improved Potato Cultivation	East Garo Hills, Meghalaya	3
11	Improved Potato Cultivation	Kangpokpi & West Imphal, Manipur	5

Spot lecture and Visitors

Sl. No	Date	Beneficiary	Institution /organization	No. of participants
1	16.03.22	Farmers	ATMA, Mawkynrew block, Meghalaya	30
2	06.04.22	Farmers	Exposure visit of stakeholder, Mizoram	7
3	23.04.2022	Students	College of Horticulture & Forestry, CAU, Pasighat, Arunachal Pradesh	50
4	10.08.22	Students	Kendriya Vidyalaya, Laitkor Peak, Air Force Station, Shillong	48
5	13.09.22	Students	College of Agriculture, Tripura.	22
6	29.09.22	Farmers	ATMA, Mawsynram Block - East Khasi Hills	30
7	29.09.22	Farmers	ATMA, Myllem Block- East Khasi Hills	65
8	6.12.22	Farmers	ATMA, Mawkynrew block, Meghalaya	30

Exhibitions / Kisan Mela

S. No	Title of the exhibition	Duration	Institution /organization	No. of participants
1.	Kisan Bhagidari Prathmikta Hamari" campaign organized under Azadi ka Amrit Mahotsav	26 to 30 th April, 2022	KVK, East Khasi Hills, Meghalaya	200 farmers of East Khasi Hills, Meghalaya
2.	Potato Conclave and Business Launch events	26 th – 27 th August, 2022	Directorate of Horticulture and Food Processing (DoH&FP), Govt. of Assam in collaboration with CIP	500 farmers of North East India
3	Kisan Mela	14 th and 15 th November, 2022	ICAR for NEH region Regional Center, Mizoram at Kolasib Mizoram	400 farmers of Kolasib district, Mizoram
4	World Soil day	5 th December, 2022	ICAR-CRPI, RS, Shillong collaborated with the KVK, East Khasi hills	150 farmers of East Khasi Hills, Meghalaya

Mobilization of Farmers to attend Agri-Startup Conclave and Kisan Sammelan” at ICAR-CPRI (RS) Shillong: A total of 45 numbers of Farmers were mobilized from 5 different villages of East Khasi District, Meghalaya, to attend the Agri-Startup Conclave and PM- Kisan Sammelan at Training Hall of ICAR-CPRI (RS) Shillong on

17.10.2022. The online broadcast programmed was witnessed. The gathering was also sensitized for the importance of quality seeds and methods of producing quality seeds was explained by scientist at the station. Farm inputs, viz, secature and rose-can were distributed to the farmers on the occasion.



Stall of CPRI RS, Shillong displaying Institute Technologies during exhibitions

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 108 documents were purchased, procured and added to library resources. The total collection at Shimla stands at 40252 documents comprised of 16707 books, 15780 back volume of journals, 2754 serials, 2271 annual reports, 586 theses, 251 standards, 51 maps/atlas, 1663 reprints and 198 CD's. The libraries at six regional stations and one campus at Modipuram are having their own library collection of 28052 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 CPRI Regional Stations

Regional Stations		Books	Back vols. of Journals	Other Documents (AR/Rpr/Bull)	Total	Current Journals subscribed (Indian)
1	CPRI RS, Modipuram	4733	6014	2562	13309	02
2	CPRI RS, Jalandhar	3366	1591	473	5430	02
3	CPRI RS, Patna	2118	1280	--	3398	02
4	CPRI RS, Gwalior	1221	4	81	1306	02
5	CPRI RS, Ooty	1688	580	565	2833	02
6	CPRI RS, Shillong	1561	-	171	1732	02
7	CPRI Unit, Kufri	144	-	-	144	--
	TOTAL	14831	9469	3852	28152	12

Periodicals and Serials Management

A total of A total of 121 current journals comprising of 16 foreign and 105 Indian have been subscribed at Shimla. Out of which 3 foreign and 20 Indian journals were subscribed on payment basis and rest 20 on exchange or gratis. In all 179 issues of such journals were received, marked and kept in library for use. Besides. 108 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, 8 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. 31 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 602 documents were circulated (borrowed and returned) for home studies and 967 readers consulted 6949 documents within the library. Besides, 7 outside scientists and research scholars of various research organizations consulted the library resources. 6 new members were enrolled and 7 old members withdrew their library membership due to their transfer or retirement. At present 96 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, 451 job requests were received for 97060 copies of photocopying and printing work of different scientific and administrative documents.

Documentation and Information Services

179 issues of journals were scanned for potato literature and 145 potato articles were found and recorded. Approximately, 108 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 thousands of pages were scanned for integrating into institute OPAC.

Resource Generation and utilization

The library has generated the revenue of Rs.2,11,411.00 which includes the amount of photocopying charges (Rs.2769.00), library discount on books (Rs.2,08,642.00) in addition to normal 10% GOC discount saved on purchase of library books and journals through CPRI Book store. A total of Rs. 7,23,493.00 was spent on purchase of library resources like books (Rs.3,99,869.00), and subscription of journals (Rs.3,23,628.00) at HQ library, Shimla.



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 82. पूजा मानकर, संजय रावल, नेम सिंह, सतीश कुमार लूथरा, विजय किशोर गुप्ता, मेही लाल, एवं एस सुभाष, बन्दना एवं मनोज कुमार 2022। कैसे पाएं आलू की अच्छी उपज। उन्नत कृषि (अक्टूबर- दिसम्बर, 2022) पेज 4-9
 83. पूजा मानकर, संजय रावल, नेम सिंह, सतीश कुमार लूथरा, विजय किशोर गुप्ता, मेहीलाल, सुभाष एस, बन्दना एवं मनोज कुमार। उत्तर प्रदेश के लिए आलू की उन्नत सस्य क्रियाएं, स्मारिका कन्नौज महोत्सव 2022, 49-51।
 84. संजय रावल, पूजा मानकर, संजीव शर्मा और मनोज कुमार, आलू निर्यात के बढ़ते आयाम। स्मारिका, कन्नौज महोत्सव 2022, 55-56
 85. सतीश कुमार लूथरा, वी के गुप्ता एवं बबीता चौधरी, 2022। आलू की अगेती फसल के लिए उपयुक्त नई किस्में, कृषक निदान वर्ष 5 अक्टूबर-दिसम्बर (1) 23-25
 86. सतीश कुमार लूथरा 2022 मैदानी क्षेत्रों के लिए आलू की नई किस्में, प्रेरणा पुंज (द्वितीय संस्करण) 28-31।
 87. शिव प्रताप सिंह और मुरलीधर ज सदावर्ती (21-22) कार्बनिक खेती एवं इसके उत्पाद की गुणवत्ता-विशेषकर आलू के संबंध में प्रयास, अंक 11:32-34

Patent granted/Applied

1. Patent on potato flakes energy bar. Published on 25th August, 2022. Potato pro. Source : Centre of food technology university of Allahabad (Patent No. 402984).
2. Patent on trough for production of plants (S type VEGFAST Trough) design (Reg. No. 340333-001)

3. Patent on trough for production of plants (Rectangular VEGFAST Trough) design (Reg. No. 340330-001)
4. Patent on vertical hydroponic system for production of plants design (Reg. No. 347610-001)

Germplasm registered

1. NUE/15-23 (INGR 22188), a nitrogen use efficient Potato germplasm. 2022. Developed by Tiwari JK, Kumar D, Dua VK, Kumar V, Rawal S, Buckseth T, Lal M, Singh RK, Dalamu, Luthra SK, Kumar M.

Sequence-database management:

1. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium solani* isolate OTY5 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence. (OM190520)
2. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM and Aggarwal R. 2022. *Fusarium verticillioides* isolate FJ8 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence (OM190523)
3. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium solani* isolate OTY9 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence;

and large subunit ribosomal RNA gene, partial sequence. (OM190521)

4. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium flocciferum* isolate HF2 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence. (OM194003)
5. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium verticillioides* isolate FJ9 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence. (OM190524)
6. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium flocciferum* isolate HF1 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence. (OM194002)
7. Tiwari RK, Lal MK, Kumar R, Naga KC, Kumar D, Chourasia KN, Bashyal BM, Aggarwal R. 2022. *Fusarium flocciferum* isolate HF3 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence. (OM194004)

INSTITUTE ACTIVITIES

Celebration of National Girl Child Day

National Girls Child Day was celebrated on 24th January, 2022 in which all the staff of CPRI joined in virtually. Dr. NK Pandey, Director (A) congratulated all on this occasion and guided all about the role of girl child in society in today's scenario. Dr. Arti Bairwa, head of the committee



formed for this programme, delivered a lecture on the evils spread in the society regarding girl child. She also told about the steps taken by the government about how to get rid of these evils, the various plans run by the government for the progress of girl child and how we can work for the upliftment of them. Other members of the committee Dr. Sumita Sharma and Smt. Poonam Sood also contributed to make this programme a success.

International Women's Day

International Women's Day was celebrated on 8th March, 2022 with the theme #BreakTheBias. Dr. Ruchi Sapahia, Asstt. Prof. of Law, HPNLU was the chief guest on the occasion. She deliberated a talk on the role of judiciary for bringing justice to



women also she discussed several cases where women were a party and how strongly they contested their case. She emphasised on the rights of women in the society and how to get them. Dr. NK Pandey, Director (A) talked about the theme i.e the gender biasness prevailing in the society and also how we need to think about the equality by giving equal opportunities and status to the women. Dr. Salej Sood, member of the committee deliberated a talk on role of women in the society through power point presentation. He also talked about the women who have held important posts nationally and internationally and managed them successfully.

World Health Day Celebration

World health day was celebrated at ICAR-CPRI on 8th April, 22. The day was presided over by Dr. Umesh Bharti, Padamshree Awardee. In his lecture Dr. Bharti focused on keeping the environment neat and healthy which in turn will keep us healthy as well. Along with him Sh. Abhay Kumar Sharma, Director, Art of Living



Programme (HP) was also present. He explained about the importance of yoga and meditation in our life. On this occasion, Dr. NK Pandey, Director, CPRI also addressed the staff. Dr. Som Dutt displayed some yoga asana which the staff of institute also followed.

27th Regional Committee Meeting-I

27th meeting of ICAR Regional Committee No.1 was held at ICAR-CPRI, Shimla on 22nd April, 2022. It was held in the dual mode physical as well as virtual. Dr. Ashok Kumar Singh, Director IARI, New Delhi was the chief guest at CPRI. Participants from the state of Uttrakhand,

Himachal Pradesh and union territory Jammu & Kashmir and Ladakh were present in the meeting.



All India Pension Adalat

An All India Pension Adalat was held at CPRI on 5th May. The so called adalat was attended by personnel from bank, pensioners of CPRI, Audit, Accounts and Establishment personnel of the institute. CPRI is the core institute for north hence DMR Solan and CITH Srinagar also joined in virtually along with all the CPRI Stations. All the matters and issues related to pension and pensioners were discussed at length and were resolved in this adalat.



Har Ghar Tiranga Programme

As per the instructions received from Ministry of Culture, Govt. of India and ICAR, the institute organised Har Ghar Tiranga Programme on 2nd June under Azadi Ka Amrit Mahotsav. The programme was held to encourage every citizen to hoist the national flag at their residence and to awaken patriotism in every citizen. The director deliberated the importance of the national flag and also the meaning of the tri colours and the ashoka chakra and also how it should be hoisted and taken care of.



Visit of KVK In-charges

More than 300 in-charges of KVKs from all over India visited CPRI as part of their educational excursion on 3rd June. The visitors came in small batches. They were shown the CPRI documentaries, museum, Aeroponics facility and the other laboratories. Some interactive lectures were also delivered explaining the role, mandate and methodology of working of CPRI to them during their visit.



Parliamentary Committee Visit

A Parliamentary Committee visited CPRI during 23-24 June under "Study visit of Parliamentary Committee on papers laid on the table (2022-23)"



chaired by MP Sh. Ritesh Pandey and accompanied by MP Sh. Raja Amreshwar Naik. The committee had other high level officers from ICAR. Long discussions were held as per the title of the visit and the visit ended on a positive note and praise of the institute.



Meeting with Dy. Director, Finance

A meeting of scientists and administrative staff with Sh. GP Sharma, Deputy Director, Finance, IARI was held on 24 June. The issues of availability of finance in procurement of scientific materials and equipment was discussed by the scientists and the difficulties coming in items purchased from GeM and the quality issues etc. were discussed with the administrative staff and the doubts were cleared on the spot for smooth running of the institute.



Organisation of Diwali Mela

After a gap of two years due to CORONA effect a Diwali Mela was organised on 19 October, 2022 just before Diwali for the staff and their families at the institute. A number of stalls comprising eatables by staff members and other local vendors, gift items, games for children and others were put up in this mela. Lucky seven, tombola and tug of war among different divisions were the

main attraction of this mela along with slow scooter race, musical chair for ladies and different kind of races for children were also a part of this mela. The winners of different events were given prizes by the chief guest along with lucky coupon draw at the end of the day long mela.



Organization of Fit India Freedom Run 3.0

Under Azadi ka Amrit Mahotsav CPRI organised Fit India Freedom Run 3.0 in the month of October. During this occasion a number of events were organised to test the fitness level of the staff and their family members. There was slow race for men and women of staff under different age groups volley ball matches of different categories, skipping for students, children of the staff, ladies and gents and yoga for all.



Vigilance Awareness Week 2022

Vigilance awareness week was observed at ICAR-CPRI, Shimla and its regional stations from 31st October to 6th November, 2022. On the first day i.e. 31st 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 3rd November an essay competition was organized, on 4th November a quiz competition was organized. All these competition had a common theme of corruption eradication and a vigil on offensive activities. On 7th November the week long observation came to an end with the concluding ceremony which was presided over by Sh. G. Sivakumar, DIG, 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. Devendra Kumar, Director also addressed the staff and conveyed that we shall practice ethical work and commit to good governance based on transparency and fairness. Dr. Ashwani Kumar Sharma, 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.

Rashtriya Kisan Diwas and 74th Foundation Day Celebration

On the occasion of *Rashtriya Kisan Diwas* on 23rd December, CPRI organised a kisan mela cum agri-exhibition at the institute. A number of other ICAR institutes like ICAR-NBPGR, Regional Station, Shimla, ICAR-IARI, Regional Station,



Shimla, ICAR-IIWBR, Regional Station, Shimla and some other private companies like IFFCO, General Aeronotics Pvt. Ltd., Bengaluru and Regional Horticulture Research and Training Station, Mashobra took part in this event by means of putting their stalls and displaying their technologies. CPRI also celebrated its 74th foundation day on this occasion. The programme was presided over by Dr. Rajeshwar Singh Chandel, Vice Chancellor, Dr Y.S. Parmar University of Horticulture and Forestry Nauni, Solan. Innovative and progressive farmers, best workers of all the categories of the institute and sports personnel of the institute were honoured during this programme. 250 farmers from Baghi and Dehna panchayat also participated in this programme. They were distributed electric spray pumps under SCSP sub-plan. It was a big event all together.

TRAINING AND CAPACITY BUILDING
Training and capacity building programmes attended by Scientific, Technical and Administrative staff of ICAR-CPRI, Shimla in 2022

Sl. No.	Name of Employee	Training Programme	Date and Organised by/ Venue
1.	Dr Vikas Mangal Scientist	Advanced Statistical Techniques for Data Analysis Using R	3-15 January 2022 at ICAR – IIRR, Hyderabad
2.	Smt. Tarvinder Kaur Kochhar, ACTO	Hands on Training on Transmission Electron Microscope (TME)	15-22 February 2022 at ICAR-NRRI, Cuttak
3.	Dr. Yogesh Gautam, PS	Artificial Intelligence in Agriculture	15th Feb. -7th Mar., 2022 at ICAR-IASRI, New Delhi
4.	Dr. Prince Kumar, Scientist	Winter School on “Horticultural Biodiversity Conservation for Livelihood and Nutritional Security in the Era of Anthropocene and Climate Change”	11-31 March, 2022 at ICAR-IIHR, Bengaluru
5.	Smt. Urmila Verma, Assistant	e-Procurement (WEP-11)	14 to 15 March, 2022 at ISTM, New Delhi
6.	Smt. Nirmala Chauhan, UDC	e-Procurement (WEP-11)	14 to 15 March, 2022 at ISTM, New Delhi
7.	Smt. Asha Thakur, STO	Extension strategies for scaling up of bio fortified crops	23-27 May, 2022 at ICAR – CTCRI
8.	Sh. Rakesh Kumar, STA	Extension strategies for scaling up of bio fortified crops	23-27 May, 2022 at ICAR – CTCRI
9.	Sh. Vijay Kumar, STA	Extension strategies for scaling up of bio fortified crops	23-27 May, 2022 at ICAR – CTCRI
10.	Dr. Pooja Mankar, Scientist	Application of Artificial Intelligence and cloud computing in agriculture	13-18 June, 2022 at ICAR-NAARM, Hyderabad
11.	Dr SK Luthra, PS	Cross to Cultivar: The Potato breeding programme	22 June, 2022 at Zamarte, Poland Plant Breeding and Acclimatization Institute, National Research Institute (IHAR), Poland, Zoom.
12.	Dr. Sundaresha S., Sr. Scientist	Genetically Engineered (GE) Plants: Biosafety Considerations, Policies, Challenges and Detection Strategies	19-25 July 2022 at ICAR-NBPGR, New Delhi
13.	Sh. Hans Raj, Assistant	MDP on Public Procurement(Basic)	25-30 July 2022 at AJNIFM, Faridabad
14.	Sh. Rajesh Chauhan, LDC	MDP on Public Procurement(Basic)	25-30 July 2022 at AJNIFM, Faridabad
15.	Dr. Ravinder Kumar, Sr. Scientist	Biosecurity and Biosafety: Policies, Diagnostics, Phytosanitary Treatments and Issues	2-11 August, 2022 at ICAR-NBPGR, New Delhi
16.	Dr. Ashwani Kumar Sharma, PS	Training Workshop for Vigilance officers of ICAR Institutes	24 -26 August, 2022 at ICAR-NAARM, Hyderabad
17.	Dr. Kailash Naga, Scientist	Introduction to Molecular Entomology	22-27 August, 2022 Agri Biotech, Hyderabad

18.	Sh. Vishwanath Bidaramali, STO	Drones for Precision Agriculture: Spraying and Hyperspectral Imaging	24 August to 13 September, 2022 at CAAST-CSAWM, Mahatma Phule Krishi Vidyapeeth, Rahuri
19.	Sh. Virender Kumar, Technician	Drones for Precision Agriculture: Spraying and Hyperspectral Imaging	24 August to 13 September, 2022 at CAAST-CSAWM, Mahatma Phule Krishi Vidyapeeth, Rahuri
20.	Dr Vikas Mangal Scientist	Cryopreservation	11-19 September, 2022 at International Potato Center (CIP), Lima (Peru).
21.	Sh. Lal Babu Dass, TA (Driver)	Automobile Maintenance, Road Safety and Behavioural Skills	26 September-01 October, 2022 at ICAR-CIAE, Bhopal
22.	Dr. Vinay Sagar, PS	NABL Accessor Training Course	NDRI, Karnal
23.	Dr. Aarti Bairwa, Scientist	NABL Accessor Training Course	NDRI, Karnal
24.	Dr Milan Kumar Lal, Scientist	Physiological and Molecular Mechanism/markers for Abiotic Stress Tolerance in Plants	26 Oct.- 4Nov. 2022 at Deptt. of Botany, University of Calicut, Kerala.
25.	Dr. Sushil Kumar, CTO	Emotional Intelligence at Workplace for Scientists/Technologists	31October- 4 November 2022 at the Centre for Organization Development, Madhapur, Hyderabad
26.	Sh. Avinish Kumar Atrey, ACTO	Emotional Intelligence at Workplace for Scientists/Technologists	31October- 4 November 2022 at the Centre for Organization Development, Madhapur, Hyderabad
27.	Dr. Kailash Naga, Scientist	CeRA National Workshop cum Awareness Programme	21 November , 2022 at CERA, New Delhi
28.	Smt. Madhu Bala, TO	CeRA National Workshop cum Awareness Programme	21 November , 2022 at CERA, New Delhi
29.	Sh. Roop Lal, TA (Driver)	Automobile Maintenance, Road Safety and Behavioral Skills	21 to 26 November, 2022 at ICAR-CIAE, Bhopal
30.	Sh. Udai Vir Singh, STO	Workshop for Technical Personnel	01-03 December, 2022 at ICAR-NDRI Karnal
31.	Sh. Ompal, STO	Workshop for Technical Personnel	01-03 December, 2022 at ICAR-NDRI Karnal
32.	Dr. Vineet Sharma, TO	Workshop for Technical Personnel	01-03 December, 2022 at ICAR-NDRI Karnal
33.	Dr. Yogesh Gautam , PS	Emotional and Social Intelligence at Workplace	13-15 December, 2022 at ICAR-IIWBR, Karnal

AWARDS AND HONOURS

Institute Best Worker Award 2022

S.No.	Name of the person	Category	Year
1.	Dr. Ravinder Kumar, CPRI, Shimla and Dr. Ratna Preeti Kaur, CPRI, RS, Jalandhar	Scientific	2022
2.	Sh. Arjun Kumar Sharma and Sh. Rakesh Srivastava, CPRI, RS, Patna	Technical	2022
3.	Smt. IC Dharmapaul, CPRI, RS, Ooty and Sh. Naresh Kumar, CPRI, RS, Jalandhar	Administrative	2022
4.	Sh. Kulwant Singh, CPRI, Shimla and Sh. Hira Singh, Kufri – Fagu Unit, Shimla	Supporting	2022

- Best oral Presentation:** Mhatre P.H., Ramya M., Gowsikasree S., Divya K.L., and Patil J. 2022. Compatibility of entomopathogenic nematode, *Steinernema cholasanense* with agrochemicals used in potato crop. In: 7th National Conference on Biological Control organized by SBA, Bengaluru and ICAR-NBAIR, Bengaluru, Karnataka during 15th to 17th December 2022.
- Dr. Ajay Kumar Thakur, Senior Scientist, ICAR-CPRI, Shimla conferred 'Fellow Award' by Society for Scientific Development in Agriculture & Technology (SSDAT), Meerut, UP (SSDAT Fellow-2022)
- Dr. Ajay Kumar Thakur, Senior Scientist, ICAR-CPRI, Shimla conferred 'Fellow Award' by Society for Plant Research (SPR), Greater Noida (SPR Fellow-2022)
- Dr Milan Kumar Lal was conferred the Best Thesis Award (Plant Physiology) from Society of Agroecological Sustainability, Odisha
- Dr Milan Kumar Lal was conferred the IARI PhD Merit Medal 2022 from ICAR-Indian Agricultural Research Institute, New Delhi
- Dr Milan Kumar Lal was conferred the R.D. Asana Gold Medal Award 2022 from Indian Society of Plant Physiology, New Delhi, India
- Dr. Priyank Hanuman Mhatre, Scientist (SS) received the “Young Scientist Award for the year 2022” during 4th National Conference on “Recent Advances in Applied Entomology and Environmental Sciences” organized by Dr. B. Vasantharaj David Foundation, Chennai on 1st October 2022.
- Dr. Pynbianglang Kharumnuid was awarded best paper presentation in online National Conference on “Effect of COVID-19 Pandemic on Agriculture and Constructive Strategies for Reformation” on 25th June, 2022 organized by the Society for Advancement of Agricultural Sciences (SAAS), Modipuram, Meerut, U.P.
- Dr. Ravinder Kumar, Senior Scientist (Plant Pathology), Division of Plant Protection, ICAR-CPRI, Shimla, Himachal Pradesh was awarded Certificate of Appreciation for the year 2022 in recognition of his meritorious services and efforts in compilation of institute ranking document of the Institute.
- Dr. Ravinder Kumar, Senior Scientist (Plant Pathology), Division of Plant Protection, ICAR-CPRI, Shimla, Himachal Pradesh was awarded Certificate of Appreciation for the year 2022 in recognition of his meritorious services and coordinating kisan melas organized by the Institute at different places of the country.
- Dr RP Kaur received Himadri Young Scientist Award 2019-20 awarded by The Indian Society for Horticulture Research and Development, Uttarakhand.
- Dr. Salej Sood received ITS grant of DST SERB for participation and presentation in 11th World Potato Congress, Dublin, Ireland from 30th May to 2nd June, 2022.
- Dr. Salej Sood was nominated member of the Research Advisory Group of Himalayan Forest Research Institute, Shimla, HP.

STAFF POSITION

Name of Scientific staff at ICAR-CPRI, Shimla & its Regional Stations as on 31.12.2022

1. Dr. Devendra Kumar, PS & Acting Director

Division of Crop Improvement & Seed Technology

2. Dr. Vinod Kumar, Principal Scientist & Acting Head
3. Dr. Vinay Bhardwaj, Principal Scientist
4. Dr. Salej Sood, Senior Scientist
5. Dr. (Mrs.) Tanuja Buckseth, Scientist
6. Sh. Hemant Balasaheb Kardile, Scientist
7. Dr. Ajay Kumar Thakur, Senior Scientist
8. Sh. Vikas Mangal, Scientist

Division of Crop Production

9. Dr. Vijay Kumar Dua, Principal Scientist & Acting Head
10. Dr. Jagdev Sharma, Principal Scientist
11. Dr. Anil Kumar Choudhary, Senior Scientist
12. Sh. Paresh Baldeorao Chaukhande, Scientist
13. Dr. Yogesh Gautam, Principal Scientist

Division of Social Sciences

14. Dr. Ravinder Kumar, Senior Scientist & Acting Head
15. Sh. Pynbianglang Kharumunid, Scientist

Division of Plant Protection

16. Dr. Sanjeev Sharma, Principal Scientist & Acting Head
17. Dr. Vinay Sagar, Principal Scientist
18. Dr. (Ms.) Aarti Bairwa, Senior Scientist
19. Dr. Kailash Chandra Naga, Scientist
20. Dr. Rahul Kumar Tiwari, Scientist
21. Sh. Chandan Maharana, Scientist

Division of CPB & PHT

22. Dr. Brajesh Singh, Principal Scientist & Acting Head
23. Dr. Som Dutt, Principal Scientist
24. Dr. Changan Sushil Sudhakar, Scientist
25. Dr. Dharmendra Kumar, Scientist
26. Dr. Milan Kumar Lal, Scientist

ICAR-CPRI Kufri-Fagu Unit

27. Dr. Ashwani Kumar Sharma, Principal Scientist & SIC
28. Dr. (Ms.) Dalamu, Senior Scientist

ICAR-CPRI Regional Station, Modipuram

29. Dr. Manoj Kumar, Principal Scientist & Acting Joint Director
30. Dr. Name Singh, Principal Scientist
31. Dr. SK Luthra, Principal Scientist
32. Dr. Vinay Singh, Principal Scientist
33. Dr. Anuj Bhatnagar, Principal Scientist
34. Dr. Sanjay Rawal, Principal Scientist
35. Dr. Dhruv Kumar, Principal Scientist
36. Dr. Vijai Kishore Gupta, Principal Scientist
37. Dr. (Mrs.) Babita Chaudhary, Principal Scientist
38. Dr. Mehi Lal, Senior Scientist
39. Dr. (Ms.) Bandna, Senior Scientist
40. Dr. (Mrs.) Pooja Praful Mankar, Scientist
41. Dr. Subhash. S, Scientist

ICAR-CPRI Regional Station, Jalandhar

42. Dr. Anil Sharma, Principal Scientist & Acting Head
43. Dr. Raj Kumar, Principal Scientist
44. Dr. (Ms) Ratna Preeti Kaur, Senior Scientist
45. Dr. Sunayan Saha, Senior Scientist
46. Er. Sukhwinder Singh, Scientist (SG)
47. Dr. Prince Kumar, Scientist
48. Dr. (Mrs.) Sugani Devi, Scientist
49. Er. Brajesh Nare, Scientist
50. Dr. Arvind Kumar Jaiswal, Scientist

ICAR-CPRI Regional Station, Gwalior

51. Dr. Subhash Katare, Principal Scientist & SIC
52. Dr. Murlidhar J. Sadawarti, Senior Scientist

ICAR-CPRI Regional Station, Shillong

53. Dr. Ngursangzuala Sailo, Senior Scientist & SIC
54. Dr. (Mrs.) Clarissa Challam, Scientist
55. Dr. (Mrs.) P Janani, Scientist
56. Dr. (Mrs.) Yvonne Angel Lyngdoh, Scientist

ICAR-CPRI Regional Station, Muthorai (Ooty)

57. Dr. Mhatre Priyank Hanuman, Scientist & SIC
58. Ms. Divya K. Lekshmanan, Scientist

ICAR-CPRI Regional Station, Patna

59. Dr. Raj Kumar Singh, Principal Scientist & SIC
60. Dr. Shiv Pratap Singh, Principal Scientist
61. Dr. (Mrs.) Sarala Yadav, Senior Scientist

Name of Technical staff at ICAR-CPRI, Shimla & its Regional Stations as on 31.12.2022

ICAR-CPRI, Shimla

1. Mrs. Tarvinder Kochhar, ACTO
2. Mr. Dharminder Verma, ACTO
3. Dr. Kapil Kumar Sharma, ACTO
4. Mr. Rajdeep Bux, ACTO
5. Mr. Kana Singh Chauhan, ACTO
6. Mr. Parvesh Jassal, ACTO
7. Mr. Kameshwar Sen, ACTO
8. Mr. Avinish Kumar Atrey, ACTO
9. Mr. Chander Mohan Singh Bist, ACTO
10. Mr. Santosh Kumar, ACTO
11. Dr. Sumita Sharma, ACTO
12. Mr. Vinod Kumar, ACTO
13. Mrs. Shruti Gupta, STO
14. Mr. Tilak Raj, STO
15. Mr. Rakesh Kumar Patyal, STO
16. Mrs. Asha Thakur, STO
17. Mr. Dharminder Kumar Gupta, STO
18. Mr. Dharam Prakash Gautam, TO
19. Mr. Sheesh Ram Thakur, TO
20. Mr. Sushil Singh, TO (Driver)
21. Mr. Naresh Kumar Sharma, TO
22. Mr. Naresh Chand, TO
23. Mr. Rajinder Kumar, TO
24. Mrs. Madhu Bala, TO
25. Mr. Hari Kishore, TO
26. Mr. Ram Singh, TO
27. Mrs. Manjeet Syal, TO
28. Mr. Roop Lal, STA (Driver)
29. Mr. Ravinder Kumar, STA
30. Mr. Naresh Kumar, STA
31. Mr. Ranjesh Bhardwaj, STA
32. Mr. Deep Ram, STA
33. Mr. Ashok Kumar, STA (Driver)
34. Mr. Rakesh Kumar, STA
35. Mr. Jagdish Chand, TA (Welder)
36. Mr. Jagdish Chand, ST (T-I-3) (Carpenter)
37. Mr. Dev Raj, ST
38. Mr. Parmesh Dutt, ST
39. Mr. Neem Chand, ST
40. Mr. Laiq Ram, ST
41. Mr. Surinder Pal, ST
42. Mr. Mansha Ram, ST
43. Mr. Arjun Dass, ST
44. Mr. Vivek Kumar, Technician
45. Mr. Rahul, Technician
46. Mr. Sanjay Kumar, Technician
47. Mr. Rakesh Kumar, Technician

48. Mrs. Sonam, Technician
49. Ms. Vandana Parmar, Technician
50. Ms. Vineeta Sharma, Technician
51. Mr. Kulwant Singh, Technician

ICAR-CPRI Kufri –Fagu Unit

52. Mr. Kedar Singh, TO
53. Mr. Ajit Singh, STO
54. Mr. Ram Jivan, STO
55. Mr. Mohan Lal, ST

ICAR-CPRI Regional Station, Modipuram

56. Mr. Mahipal Singh Bharti, CTO
57. Mr. Harvir Singh, CTO
58. Dr. Ashok Kumar, CTO
59. Mr. Krishan Pal Singh, CTO
60. Mr. Ompal, ACTO
61. Mrs. Kusum Singh, ACTO
62. Mr. Harvir Singh, ACTO
63. Mr. Murari Lal, ACTO
64. Mr. Subhash Chand, ACTO
65. Dr. Vineet Sharma, ACTO
66. Mr. Avinash Chaudhary, ACTO
67. Mr. Dinesh Singh, ACTO
68. Dr. Sanat Kumar, ACTO
69. Mr. Pushpendra Kumar, STO
70. Mr. Udai Vir Singh, STO
71. Mr. Ved Singh, STO
72. Mr. Harvinder Singh, STO
73. Mr. Vishvanath Bindermali, STO
74. Mr. Manish Maan, STO
75. Mr. Mahesh Pal Singh, TO (Driver)
76. Mr. Sayed Danish Abbas Rizvi, STA
77. Mr. Vipin Kumar, TA (Driver)
78. Mr. Madan Pal, ST
79. Mr. Satpal Singh, ST
80. Mr. Siddharth Saroha, Technician
81. Mr. Rohit Verma, Technician
82. Mr. Ajay Kumar, Technician

ICAR-CPRI Regional Station, Jalandhar

83. Mr. Munna Lal, CTO
84. Mr. Jaswinder Singh, CTO
85. Mr. Yogesh Kumar Gupta, ACTO
86. Mr. Akhilesh Kumar Singh, ACTO
87. Mr. Parveen Kumar, TO
88. Mr. Narinder Mayer, TO
89. Mr. Kulwinder Singh, TO
90. Mr. Pardeep Kumar Upadhaya, TO
91. Mr. Anil Kumar Chandel, STA
92. Mr. Som Dutt Randev, STA

93. Mr. Vijay Kumar, STA
94. Mr. Pawan Kumar, ST
95. Mr. Virender Kumar, Technician

ICAR-CPRI Regional Station, Gwalior

96. Dr. Yogendra Pal Singh, ACTO
97. Dr. Sanjay Kumar Sharma, ACTO
98. Mr. Shyam Kumar Gupta, ACTO
99. Mr. Rajender Kumar Samadhiya, STO
100. Mr. Surendar Singh, TO
101. Mr. Radha Kishan, STA (Driver)
102. Mr. Nihal Singh, STA (Driver)
103. Mrs. Nisha Verma, TA (Hindi Translator)
104. Mr. Tara Chand, ST
105. Mr. Sanjeev Kumar Meena, Technician
106. Mr. Vinod Kumar Meena, Technician

ICAR-CPRI Regional Station, Patna

107. Mr. Arjun Kumar Sharma, ACTO
108. Mr. Rakesh Srivastava, TO
109. Mr. Anil Kumar, TO
110. Mr. Alekh Narain, TO
111. Mr. Narendra Kumar, TO
112. Mr. Lal Babu Das, STA Driver
113. Mr. Sunil Kumar Singh, ST
114. Mr. Rishav Kumar, Technician
115. Mr. Pratish Kumar Patel, Technician
116. Mr. Sumit Kumar, Technician
117. Mr. Akhilesh Singh, Technician

ICAR-CPRI Regional Station, Shillong

118. Mr. Sabarius Nongrum, ST
119. Mr. Anubhav Kumar, TT

ICAR-CPRI Regional Station, Muthurai

120. Mr. R Lakshmanan, STA
121. Mr. B. Suresh, ST

Name of Admn. staff at ICAR-CPRI, Shimla & its Regional Stations as on 31.12.2022

ICAR-CPRI, Shimla

1. Sh. Alok Kumar, CAO
2. Sh. Raj Kumar, SFAO
3. Ms. Sunita, DD (Language)
4. Sh. Chander Prakash, FAO
5. Sh. Joginder Singh Thakur, AO
6. Smt. Poonam Sood, AAO
7. Smt. Meena Verma, AAO
8. Smt. Babli Bhawani, AAO
9. Sh. Surjit Singh, PPS
10. Sh. Gurjeet Singh, PS

11. Smt. Shashi Bala Thakur, PS
12. Sh. Suresh Kumar, PS
13. Sh. Krishan Lal, Assistant
14. Ms. Rita Walia, Assistant
15. Sh. Amar Chand, Assistant
16. Mrs. Urmila Verma, Assistant
17. Mrs. Sunita Thakur, Assistant
18. Sh. Om Parkash, Assistant
19. Mrs. Shyam Lata Beakta, Assistant
20. Smt. Chandni Baghta, Assistant
21. Sh. Deep Ram, Assistant
22. Sh. Pawan Kumar, Assistant
23. Sh. Sachin Kanwar, Assistant
24. Sh. Hans Raj, Assistant
25. Sh. Girish Thakur, PA
26. Mrs. Nirmala Chauhan, UDC
27. Sh. Kamal Chand Verma, UDC
28. Sh. Ashwani Gupta, UDC
29. Sh. Tej Singh, UDC
30. Mrs. Geeta Devi, UDC
31. Mrs. Sonia Chauhan, UDC
32. Mrs. Punam Jyoti, UDC
33. Sh. Mohinder Singh, UDC
34. Sh. Narender Paul, UDC
35. Sh. Raghubir Singh, UDC
36. Sh. Gokal Ram, UDC
37. Sh. Rakesh Negi, UDC
38. Sh. Ashish Kalyan, UDC
39. Sh. Kundan Lal, LDC
40. Sh. Nand Lal, LDC
41. Smt. Kiran, LDC

ICAR-CPRI Regional Station, Jalandhar

42. Ms. Prawartika Das, AAO
43. Sh. Sukhpal Sharma, Assistant
44. Mrs. Sandhya Kapila, Assistant
45. Sh. Rakesh, Assistant
46. Sh. Suresh Kumar Verma, PA
47. Mrs. Daishey Tuli, UDC
48. Sh. Daljit Singh, UDC
49. Sh. Naresh Kumar, UDC

ICAR-CPRI Regional Station, Modipuram

50. Sh. Sandeep, AAO
51. Sh. Rajesh Kumar, PS
52. Smt. Sneha Lata, UDC
53. Smt. Seema Verma, UDC
54. Sh. Ashok Kumar, UDC
55. Sh. Suraj Singh, LDC
56. Sh. Pradyuman K. Saraswat, UDC
57. Sh. Tejbir Singh, LDC

ICAR-CPRI Regional Station, Patna

- 58. Sh. Jagbir Singh, AAO
- 59. Sh. RK Gupta, UDC
- 60. Sh. Pawan Kumar, Steno Gr-III
- 61. Sh. Rajesh Chauhan, LDC

ICAR-CPRI Regional Station, Gwalior

- 62. Sh. Sanjib Kumar, AAO
- 63. Sh. Sunil Kumar, LDC

ICAR-CPRI Regional Station, Ooty

- 64. Smt. IC Dharmapaul, AAO

ICAR-CPRI Regional Station, Shillong

Nil

Name of Skilled Support Staff ICAR-CPRI, Shimla & its Regional Stations as on 31.12.2022**ICAR-CPRI, Shimla**

- 1. Sh. Subhash Chand, SSS
- 2. Sh. Rajinder Kumar, SSS
- 3. Sh. Sanjeevan Kumar, SSS
- 4. Sh. Narender Kumar, SSS
- 5. Smt. Kajal, SSS
- 6. Sh. PadamDev, SSS
- 7. Sh. Roshan Lal, SSS
- 8. Smt. Manjit, SSS
- 9. Sh. Amar Nath, SSS
- 10. Sh. Rajinder Singh, SSS
- 11. Sh. Padam Chand, SSS
- 12. Sh. Ashok Kumar, SSS

ICAR-CPRI Kufri-Fagu Unit

- 13. Sh. Hira Singh, SSS
- 14. Sh. Saran, SSS
- 15. Sh. Roop Singh, SSS
- 16. Sh. Jia Lal, SSS
- 17. Sh. Hira Singh, SSS

ICAR-CPRI Regional Station, Modipuram

- 18. Sh. Jagtey, SSS
- 19. Sh. Som Pal, SSS
- 20. Sh. Mani Ram, SSS
- 21. Sh. Rajpal, SSS
- 22. Sh. Rajbir Singh, SSS
- 23. Sh. Raj Kumar, SSS
- 24. Sh. Sudesh Pal, SSS
- 25. Sh. Gyanendra Kumar, SSS
- 26. Sh. Ramphal, SSS
- 27. Sh. Mukesh, SSS

- 28. Sh. Murari, SSS
- 29. Sh. Rajpal Singh, SSS

ICAR-CPRI Regional Station, Jalandhar

- 30. Mrs. Passo, SSS
- 31. Smt. Rashpal Devi, SSS
- 32. Sh. Ram Lubhaya, SSS
- 33. Sh. Paramjit Singh, SSS
- 34. Sh. Ram Sarup, SSS
- 35. Sh. Jagan Nath, SSS

ICAR-CPRI Regional Station, Patna

- 36. Sh. Teka Rai, SSS
- 37. Sh. Jagat Kumar, SSS

ICAR-CPRI Regional Station, Gwalior

- 38. Sh. Niranjan Singh, SSS
- 39. Sh. Ram Singh, SSS
- 40. Sh. Jagdish, SSS
- 41. Sh. Shyam Singh, SSS
- 42. Sh. Parkash Tomar, SSS
- 43. Sh. Virendra Singh, SSS
- 44. Sh. Ranbir Singh, SSS
- 45. Sh. Kallu, SSS
- 46. Sh. Ashok Kumar, SSS
- 47. Smt. Vimla Devi, SSS
- 48. Sh. Jaswant Singh, SSS
- 49. Sh. Kedar, SSS
- 50. Sh. Punjab Singh, SSS
- 51. Sh. Ram Parkash, SSS
- 52. Sh. Bharat Singh, SSS
- 53. Sh. Mannu Singh, SSS
- 54. Sh. Lala Ram, SSS
- 55. Sh. Tilak Singh, SSS
- 56. Sh. Net Ram, SSS
- 57. Sh. Mangal, SSS
- 58. Sh. Jandel Singh, SSS
- 59. Sh. Bhagirath, SSS
- 60. Sh. Ramdin, SSS
- 61. Sh. Sikander Singh, SSS

ICAR-CPRI Regional Station, Shillong

- 62. Smt. Theibet Thawmuit, SSS

ICAR-CPRI Regional Station, Muthurai

Nil

SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2022

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	00	05	07	04	03	30	23	07	42	27	15
2.	CPRIRS, Jalandhar	01	00	01	01	01	00	10	08	02	12	09	03
3.	CPRIRS, Modipuram	01	00	01	04	04	00	10	10	00	15	14	01
4.	CPRIRS, Gwalior	00	00	00	03	01	02	03	01	02	06	02	04
5.	CPRIRS, Patna	00	00	00	01	00	01	04	03	01	05	03	02
6.	CPRIRS, Ooty	00	00	00	00	00	00	03	02	01	03	02	01
7.	CPRIRS, Shillong	00	00	00	00	00	00	04	04	00	04	04	00
	TOTAL	07	00	07	16	10	06	64	51	13	87	61	26

*Excluding RMP

SANCTIONED, FILLED & VACANT POSITION OF SCIENTIFIC STAFF (DISCIPLINE-WISE) OF CPRI & ITS REGIONAL STATIONS AS ON 31.12.2022 (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	2	3	7	4	3
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	2	1	3	2	1
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	1	1	8	7	1	10	8	2
15.	PL. PATHOLOGY	-	-	-	-	-	-	2	2	-	7	4	3	9	6	3
16.	PL. PHYSIOLOGY	-	-	-	-	-	-	1	1	-	5	4	1	6	5	1
17.	SOIL SCIENCE SOIL CHEM./ FERT. MICRO	-	-	-	-	-	-	1	1	-	2	1	1	3	2	1
18.	SEED SCIENCE AND	-	-	-	-	-	-	1	1	-	3	2	1	4	3	1

S-sanctioned, F-filled, V- vacant

Scientific Category

New Joining

- Dr. (Mrs.) Yvonne Angel Lyngdoh, Scientist (Vegetable Science) joined at ICAR-Central Potato Research Institute, Regional Station, Shillong on 06.10.2022 (FN).

Transfers (Inter-institute)

- Dr. Jagesh Kumar Tiwari, Senior Scientist (Vegetable Science), ICAR-Central Potato Research Institute, Shimla relieved on 02.04.2022 (AN) to join at ICAR-Indian Institute of Vegetable Research, Varanasi.

2. Dr. Bapi Das, Scientist (Vegetable Science)), ICAR-Central Potato Research Institute, Regional Station, Shillong relieved on

18.08.2022 (AN) to join at ICAR-NEH, RS, West Tripura.

Promotions

Sl.No.	Name of Scientist	Level on promotion	Date of promotion
Promoted vide ICAR-DRMR, Bharatpur Office Order dated 26.09.2022.			
1.	Dr. Ajay Kumar Thakur	Level-13A of 7 th CPC (Pre-revised Pay Band Rs. 37,400 – 67,000 + RGP Rs.9,000)	07.01.2020
Promoted vide this office order dated 15.07.2022:-			
2.	Dr. Baswaraj Raigond	Level-13A of 7 th CPC (Pre-revised Pay Band Rs. 37,400 – 67,000 + RGP Rs.9,000)	04.11.2021
3.	Dr. Salej Sood	Level-13A of 7 th CPC (Pre-revised Pay Band Rs. 37,400 – 67,000 + RGP Rs.9,000)	14.05.2022
4.	Dr. Sushil Sudhakar Changan	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	05.07.2021
5.	Dr. (Mrs.) Bandana	Level-13A of 7 th CPC (Pre-revised Pay Band Rs.37,400 – 67,000 + RGP Rs.9,000)	11.05.2022
6.	Dr. (Ms.) Aarti Bairwa	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	01.01.2022
7.	Dr. Sunayan Saha	Level-12 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.8,000)	27.04.2020
8.	Sh. Hemant B. Kardile	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	01.07.2019
9.	Dr. Kailash Chandra Naga	Level-11 of 7 th CPC (Pre-revised Pay Band Rs. 15,600 – 39,100 + RGP Rs.7,000)	05.07.2021

Probation / Confirmation

Sl. No.	Name of Scientists	Date of appointment	Date on which probation was completed	Date of confirmation
1.	Dr. Subhash S., Scientist (Ag. Entomology), ICAR-CPRI, Shimla	02.07.2018	01.07.2020	02.07.2020
2.	Sh. Chandan Maharana, Scientist (Plant Pathology), ICAR-CPRI, Shimla	07.01.2020	06.01.2022	07.01.2022

Retirement

1. Dr. NK Pandey, Principal Scientist & Director (Acting), ICAR-Central Potato Research Institute, Shimla retired from Council's service w.e.f. 31.07.2022 (AN).
2. Dr. Shambhu Kumar, Principal Scientist, ICAR-Central Potato Research Institute, Regional Station, Patna retired from Council's service w.e.f. 31.10.2022 (AN).

Death

1. Dr. E.P. Venkatasalam, Principal Scientist, ICAR-Central Potato Research Institute, Regional Station, Ooty expired on 15.02.2022
2. Dr. Sundaresha S., Senior Scientist, ICAR-Central Potato Research Institute, Shimla expired on 19.09.2022

SANCTIONED FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.12.2022

Functional Group	Hqrs.		Shillong		Jalandhar		Modipuram		Gwalior		Patna		Ooty		Kufri		Total		
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	V
Field Farm Technician (FFT)																			
Cat. I Jr. Tech. Asstt. / Sr. Field Asstt./ Field Asstt.	29	31	5	2	8	7	13	8	4	4	12	9	4	2	8	4	83	67	16
Cat. II Sr. Tech. Asstt. (T-4) Tech. Asstt. (T-3)	9	6	-	-	4	3	13	09	2	1	3	1	-	-	-	-	31	20	11
Cat. III Farm Supdt. T-6	-	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	2	2	0
Lab. Technician-																			
Cat. I Computer (T-2)	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	3	3	0
Projector Operator, T-2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0
Cat. II Lab. Tech. (T-4)/ Lab. Tech. (T-3)	3	2	-	-	1	-	1	1	1	2	-	-	-	-	-	-	6	5	1
Cat. III Computer programmer T-6	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	0
Lib. Information / Documentation																			
Cat. II Lib. Asstt. (T-3)	1	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	3	2	1
Asstt. Librarian (T-5)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1
Documentalist, T-3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1
Tech. Asstt. (Stat.) (T-3)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	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	V
Photography																			
Cat. I Photographer /	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	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	1	0
Sr. Mechanic (T-2)	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	2	2	0
Fitter (T-1)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0	1
Welder	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0
Mechanic cum Electrician	1	1	-	-	2	-	1	-	-	-	-	-	-	-	-	-	4	1	3
Operator Electrical	1	1	-	-	-	1	1	-	-	-	1	-	-	-	-	-	3	2	1
Driver	3	2	2	-	2	-	2	2	2	-	2	1	-	-	-	-	13	5	8
Tractor Driver	1	1	1	-	1	-	4	-	3	2	1	-	1	-	-	-	12	3	9
Cat. II Foreman (T-4)	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1	1
Asstt. Foreman (T-3)	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	0
Overseer (Civil) T-3	1	-	-	-	-	-	-	01	-	-	-	-	-	-	-	-	1	1	0
Cat. III Instrument Engineer, T-7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1
Total	61	51	08	02	22	13	42	27	13	11	19	11	05	02	08	04	178	121	57

SANCTIONED, FILLED AND VACANT POSITION OF TECHNICAL CATEGORY AS ON 31.12.2022

Category	Sanctioned	Filled	Vacant
Category-I	125	86	39
Category-II	49	32	17
Category-III	04	03	01
Total	178	121	57

Appointment

1. Sh. Manish Maan, Senior Technical Officer (Lab Tech Group in Category-III) joined at CPRI, Shimla on 24.06.2022
2. Sh. Vishvanath Bindermali, Senior Technical Officer (FFT Group in Category-III) joined at CPRI RS, Modipuram on 30.06.2022

Promotions

1. Smt. Madhu Bala, Senior Technical Assistant, CPRI, Shimla promoted to Technical Officer from 12.06.2021
2. Smt. Manjeet Syal, Senior Technical Assistant, CPRI, Shimla promoted to Technical Officer from 04.06.2021
3. Smt. Jitender Kaur Arora, Senior Technical Assistant, CPRI, Shimla promoted to Technical Officer from 10.06.2020
4. Sh. Ram Singh, Senior Technical Assistant, CPRI, Shimla promoted to Technical Officer from 07.05.2021
5. Sh. Hari Kishor, Senior Technical Assistant, CPRI, Shimla promoted to Technical Officer from 04.06.2021
6. Sh. Kulwant Singh, SSS, CPRI, Shimla promoted to Technician from 01.04.2022 (33.33% Deptt. Promotion quota)
7. Sh. Ram Dass Rai, Retd. Senior Technician(Driver), CPRS Shillong promoted to Technical Assistant (Driver) from 10.06.2017
8. Sh. Nihal Singh, T-I-3(Driver), CPRS, Gwalior promoted to Technical Assistant from 27.05.2012 and Senior Technical Assistant from 27.05.2017
9. Sh. Mahesh Pal Singh, T-I-3(Driver), CPRIRS, Modipuram placed in Technical Assistant in Cat. II on 29.06.2006, Promoted to Senior Technical Assistant from 29.06.2011 and Technical Officer from 29.06.2016

10. Sh. Narayan Singh, Retd. T-I-3(Driver), CPRIRS, Modipuram placed in Technical Assistant in Cat. II on 29.06.2006, Promoted to Senior Technical Assistant from 29.06.2011 and Technical Officer from 29.06.2016
11. Sh. UP Paudal, Retd. T-I-3, CPRIRS, Modipuram placed in Technical Assistant in Cat. II on 27.08.2010 and promoted to Senior Technical Assistant from 27.08.2015 and Technical Officer from 28.08.2020
12. Sh. Radha Krishan, T-I-3, CPRS, Gwalior promoted to Technical Assistant in 7.11.2013 and promoted to Senior Technical Assistant from 7.11.2018
13. Sh. Ravindra Sharma, Retd. Technical Officer, CPRS Patna promoted to Senior Technical Officer from 01.01.2012
14. Sh. Rajendra Kumar Sharma, Retd. Technical Officer, CPRIRS, Modipuram promoted to Senior Technical Officer from 1.1.2010
15. Sh. Rakesh Kumar Patyal, Technical Officer, CPRI, Shimla promoted to Senior Technical Officer from 22.02.2020
16. Sh. Dharminder Kumar Gupta, Technical Officer, CPRI, Shimla promoted to Senior Technical Officer from 06.06.2021
17. Smt. Asha Thakur, Technical Officer, CPRI, Shimla promoted to Senior Technical Officer from 04.06.2021
18. Sh. Pushpender Kumar, Technical Officer, CPRIRS, Modipuram promoted to Senior Technical Officer from 11.02.2021
19. Sh. Vinod Kumar, Senior Technical Officer, CPRI, Shimla promote to Assistant Chief Technical Officer from 14.7.2021
20. Dr.(Mrs.) Sumita Sharma, Senior Technical Officer, CPRI, Shimla promoted to Assistant Chief Technical

Officer from 28.05.2020

21. Sh. Shyam Kumar Gupta, Senior Technical Officer, CPRS, Gwalior promoted to Assistant Chief Technical Officer from 15.06.2021
22. Sh. Jaswinder Singh, Assistant Chief Technical Officer, CPRS, Jalandhar promoted to Chief Technical Officer from 29.10.2021

Transfer/ Inter-Institutional Transfer

1. Smt. Jitender Kaur Arora, Senior Technical Assistant, CPRI, Shimla transferred to ICAR-IISWC, Chandigarh on 11.03.2022.
2. Sh. Pavan Kumar Malik, Technical Officer, CPRIRS, Modipuram transferred to ICAR-IARI, New Delhi on 31.03.2022.

3. Sh. Shushil Kumar, Chief Technical Officer, CPRI, Shimla transferred to ICAR-DMR, Solan on 16.12.2022.
4. Sh. Vivek Kumar, Technician, AKMU Section to Social Science Division on 14.03.2022
5. Sh. Sumit Kumar, Technician, CPRS, Shillong to CPRS Patna on 17.05.2022
6. Sh. Manish Maan, Senior Technical Officer, CPRI, Shimla to CPRIRS, Modipuram on 17.11.2022

Retirements

1. Sh. Ram Daiyal, Senior Technician, CPRI, Shimla retired on 30.04.2022
2. Sh. Yogesh, Chief Technical Officer, CPRI, Shimla retired on 30.06.2022

Administrative Staff Sanctioned / Filled/Vacant Position as on 31.12.2022 at CPRI, Shimla

Group	Shimla			Shillong			Jalandhar			Modipuram			Gwalior			Patna			Ooty			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
CAO	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Dy. Director Comptroller	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
SF&AO	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1
AO	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1
F&AO	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
AAO	4	3	1	0	0	0	1	1	0	1	1	0	1	1	0	1	1	0	0	1	-1	8	8	0
AF&AO	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
DD (OL)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
PPS	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
PS	3	3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	4	4	0
PA	2	1	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	4	2	2
Asstt.	16	12	4	1	0	1	2	3	-1	2	0	2	1	0	1	1	0	1	1	0	1	24	15	9
UDC	6	13	-7	0	0	0	1	3	-2	1	4	-3	0	0	0	1	1	0	0	0	0	9	21	-12
LDC	4	3	1	1	0	1	1	0	1	1	2	-1	1	1	0	0	1	-1	1	0	1	9	7	2
Steno.G-III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0	0	0	1	-1
Total	44	41	4	2	0	2	6	8	-2	6	8	-2	3	2	1	4	3	1	2	1	1	67	64	3

Appointment/New Joining

1. Sh. Alok Kumar, CAO, CPRI, Shimla joined on 31.03.2022
2. Sh Surjit Singh, PPS, CPRI, Shimla joined on 01.09.2022
3. Ms. Sunita, DD (Language), CPRI, Shimla joined on 21.11.2022

Administrative Staff. Promotions

1. Sh. Joginder Singh Thakur, AAO, CPRI, Shimla promoted to the post of Administrative Officer w.e.f. 20.05.2022
2. Sh. Suresh Kumar, Personal Assistant, CPRI, Shimla promoted to the post of Private Secretary w.e.f. 09.11.2022

Granted financial up-gradation under MACP Scheme

1. Smt. M Rani, Ex Assistant, CPRI (RS), Ooty, granted 3rd MACP w.e.f. 23.01.2021 in Pay Matrix Level 7.
2. Smt. Urmila Verma, Assistant, CPRI, Shimla, granted 3rd MACP w.e.f. 20.07.2022 in Pay Matrix Level 7.
3. Smt. Sunita Thakur, Assistant, CPRI, Shimla granted 3rd MACP w.e.f. 30.04.2022 in Pay Matrix Level 7.
4. Sh. Om Prakash, Assistant, CPRI, Shimla granted 3rd MACP w.e.f. 16.06.2022 in Pay Matrix Level 7.
5. Sh. Naresh Kumar, UDC, CPRIRS, Jalandhar, granted 3rd MACP w.e.f. 27.12.2020 in Pay Matrix Level 5.

Transfers on selection basis

1. Sh. Pankaj Kumar, CAO, CPRI Shimla, relieved w.e.f. 08.04.2022 (AN) and Joined as Director at Animal Science Division at ICAR New Delhi.
2. Sh. Ram Chand, Private Secretary, CPRI, Shimla, relieved w.e.f. 04.11.2022 (A/N) to join as Principal Private Secretary at CIPHT, Ludhiana.

Retirement

1. Sh. Chanda Ram, AAO, CPRI, Shimla Retired on 28.02.2022
2. Sh. Surinder Singh, Assistant, CPRI RS, Gwalior Retired on 30.06.2022

Sanctioned Filled & Vacant Position of Skilled Support Staff as on 31.12.2022

Name	Sanctioned	Filled	Vacant
Shimla/Kufri	30	17	13
Modipuram	21	12	09
Jalandhar	14	06	08
Gwalior	26	24	02
Patna	07	02	05
Shillong	04	01	03
Ooty	03	-	03
Total:	105	62	43

Promotion

1. Sh. Kulwant Singh, SSS, CPRI, Shimla promoted to the post of Technician (T-1) w.e.f. 01.04.2022

Grant of MACP benefit

1. Sh. Rajinder Kumar, SSS, CPRI, Shimla granted 3rd MACP w.e.f. 30.11.2020
2. Smt. Vimla Devi, SSS, CPRS, Gwalior granted 2nd MACP w.e.f. 17.04.2021
3. Smt. Muni Devi, SSS, CPRI-Kufri-Fagu-Unit granted 2nd MACP w.e.f. 02.08.2021
4. Sh. Raj Kumar, SSS, CPRIRS, Modipuram granted 1st MACP w.e.f. 13.12.2021
5. Sh. Sudesh Pal Singh, SSS, CPRIRS, Modipuram granted 1st MACP w.e.f. 13.12.2021
6. Sh. Ram Sarup, SSS, CPRS, Jalandhar granted 2nd MACP w.e.f. 16.01.2022
7. Sh. Kulwant Singh, SSS, CPRI, Shimla granted 3rd MACP w.e.f. 14.02.2022

Retirements

1. Sh. Bishun Rai, SSS, CPRIRS, Patna retired on 31.01.2022
2. Sh. Sukhwinder Dass, SSS, CPRIRS, Jalandhar retired on 28.02.2022
3. Sh. Tapan Burman, SSS, CPRIRS, Patna retired on 31.03.2022
4. Sh. Amirudin, SSS, CPRIRS, Modipuram retired on 30.04.2022
5. Sh. Parashu Ram, SSS, CPRIRS, Gwalior retired on 31.07.2022
6. Sh. Kanhiya Prasad, SSS, CPRI, Shimla retired on 31.08.2022
7. Sh. Babu Ram, SSS, CPRI, Shimla retired on 31.12.2022
8. Sh. Kali Charan, SSS, CPRIRS, Gwalior retired on 31.12.2022

Death

1. Sh. Ram Kishun Ram, SSS, CPRIRS, Patna expired on 01.11.2022

INSTITUTE BUDGET (2022-23)

ANNEXURE 'A'

INDIAN COUNCIL OF AGRICULTURAL RESEARCH ANNUAL ACCOUNT 2022-23 ABSTRACT OF 'OTHER RECEIPTS' FOR THE YEAR 2022-23

(Amount in Rs.)

S. No.	HEAD OF ACCOUNT	AMOUNT
1	Sale of farm produce	8051948
2	Sale of fish & poultry	
3	Sale of land	
4	Sale of building	
5	Sale of vehicle, other machine tools	748025
6	Sale of livestock	
7	Sale of publication and advertisement	
8	Licence fee	1169159
9	Interest earned on loans & advances	441794
10	Leave salary and pension contribution	
11	Receipts from schemes	
12	Analytical and testing fee	
13	Pre-Shipment fee	
14	Application fee from candidates	
15	Diploma Charges	
16	Receipts from services rendered	
17	Unspent balance of Grants of previous years	
18	Interest earned on short term deposits	2719017
19	Income generated from Internal Resource Generation Schemes	3107433
	a) Training	
	b) Consultancy	
	c) Contract Research	
	d) Sale of technology	
	e) Other (institutional charges)	
20	Net profit in Revolving funds	49795896
21	Recoveries of Loans & Advances	420600
22	Miscellaneous Receipts	3757601
	TOTAL : OTHER RECEIPTS	70211473.00

INDIAN COUNCIL OF AGRICULTURAL RESEARCH ANNUAL ACCOUNT 2022-23

Details of Institute Govt. Grant Expenditure for the year 2022-23

(Amount in Rupees)

S. No.	Head	Allocation Govt. Grant 2021-22	Allocation Internal Resource + Additional amount provided by HQ out of Council's share(2021-22)	TOTAL ALLOCATION 2021-22	Expenditure (Govt. Grant) 2021-22				Expenditure (Revenue Generation) 2021-22	TOTAL EXPENDITURE 2021-22
1	2	3	4	5 (3 + 4)	6				7	8 (6 + 7)
					NEH	TSP	SCSP	Other than NEH & TSP		
1	Works									
	A. Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B. Building									
	i. Office building	2300000.00	0.00	2300000.00	0.00	0.00	0.00	845202.00	0.00	845202.00
	ii. Residential building	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	iii. Minor Works	0.00	0.00	0.00	4600.00	0.00	0.00	1255803.00	0.00	1260403.00
2	Equipments	10900000.00	0.00	10900000.00	3054789.00	99582.00	99582.00	8312247.00	0.00	11566200.00
3	Information Technology	1000000.00	0.00	1000000.00	88303.00	0.00	0.00	872824.00	0.00	961127.00
4	Library Books and Journals	800000.00	0.00	800000.00	0.00	0.00	0.00	723493.00	0.00	723493.00
5	Vehicles & Vessels	1400000.00	0.00	1400000.00	0.00	0.00	0.00	1280548.00	0.00	1280548.00
6	Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Furniture & fixtures	600000.00	0.00	600000.00	52298.00	0.00	0.00	304202.00	0.00	356500.00
8	Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total – CAPITAL (Grants for creation of Capital Assets)	17000000.00	0.00	17000000.00	3199990.00	99582.00	99582.00	13594319.00	0.00	16993473.00
1	Establishment Expenses(Salaries)									0.00
	i. Establishment Charges	422487000.00	0.00	422487000.00	0.00	0.00	0.00	422486755.00	0.00	422486755.00
	ii. Wages	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	iii. Overtime Allowance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total – Establishment Expenses (Grant in Aid - Salaries)	422487000.00	0.00	422487000.00	0.00	0.00	0.00	422486755.00	0.00	422486755.00

1	Pension & Other Retirement Benefits	326374000.00	0.00	326374000.00	0.00	0.00	0.00	0.00	326373992.00	0.00	326373992.00
2	T.A.										0.00
	A. Domestic TA / Transfer TA	3000000.00	0.00	3000000.00	0.00	0.00	0.00	0.00	3040231.00	0.00	3040231.00
	B. Foreign TA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total - Traveling Allowance	3000000.00	0.00	3000000.00	0.00	0.00	0.00	0.00	3040231.00	0.00	3040231.00
3	Research & Operational Expenses										0.00
	A. Research Expenses	10900000.00	0.00	10900000.00	9781422.00	432110.00	1387048.00	2973473.00	0.00	0.00	14574053.00
	B. Operational Expenses	7500000.00	0.00	7500000.00	203572.00	0.00	0.00	1666505.00	0.00	0.00	1870077.00
	Total - Research & Operational Expenses	18400000.00	0.00	18400000.00	9984994.00	432110.00	1387048.00	4639978.00	0.00	0.00	16444130.00
4	Administrative Expenses										0.00
	A. Infrastructure	25500000.00	0.00	25500000.00	206740.00	0.00	4505.00	15298868.00	0.00	0.00	15510113.00
	B. Communication	500000.00	0.00	500000.00	92037.00	0.00	17000.00	548132.00	0.00	0.00	657169.00
	C.Repair & Maintenance			0.00	0.00	0.00	0.00				0.00
	i. Equipments, Vehicles & Others	3000000.00	0.00	3000000.00	1553027.00	0.00	0.00	2048160.00	0.00	0.00	3601187.00
	ii. Office building	2000000.00	0.00	2000000.00	554700.00	0.00	0.00	2378853.00	0.00	0.00	2933553.00
	iii. Residential building	2000000.00	0.00	2000000.00	0.00	0.00	0.00	1003330.00	0.00	0.00	1003330.00
	iv. Minor Works	500000.00	0.00	500000.00	0.00	0.00	0.00	107070.00	0.00	0.00	107070.00
	D. Others (excluding TA)	25600000.00	0.00	25600000.00	7468789.00	66527.00	1500744.00	29373392.00	0.00	0.00	38409452.00
	Total - Administrative Expenses	59100000.00	0.00	59100000.00	9875293.00	66527.00	1522249.00	50757805.00	0.00	0.00	62221874.00
5	Miscellaneous Expenses										0.00
	A. HRD	400000.00	0.00	400000.00	139280.00	0.00	90623.00	61420.00	0.00	0.00	291323.00
	B. Other Items (Fellowships, Scholarships etc.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C. Publicity & Exhibitions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D. Guest House - Maintenance	100000.00	0.00	100000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E. Other Miscellaneous	1000000.00	0.00	1000000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total - Miscellaneous Expenses	1500000.00	0.00	1500000.00	139280.00	0.00	90623.00	61420.00	0.00	0.00	291323.00
	Total --Grants in Aid - General	408374000.00	0.00	408374000.00	19999567.00	498637.00	2999920.00	384873426.00	0.00	0.00	408371550.00
	Grand Total (Capital + Establishment+General)	847861000.00	0.00	847861000.00	23199557.00	598219.00	3099502.00	820954500.00	0.00	0.00	847851778.00
6	Loans and Advances	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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